Orana
Farm-scale Natural Capital Account

2022

LA TROBE UNIVERSITY | Research Centre for Future Landscapes

Integrated Futures

In partnership with

Arthur Rylah Institute for environmental research · BCG · Bush Heritage Australia · Landcare Australia · Australian Government National Landcare Program · Odonata Foundation · Sensand · TAFI · Trust for Nature

Published December 2023.

This account has been prepared by the core Farm-scale Natural Capital Accounting project team of Danny O'Brien, Rachel Lawrence, Imogen Semmler and Sue Ogilvy (Integrated Futures), Angela Hawdon (Bush Heritage Australia) and James Radford, Fred Rainsford, Alex Maisey and Grace Sutton (La Trobe University). This account has been prepared for research purposes, including the development of natural capital measurement and accounting methods. It contains the Natural Capital Accounts and an explanation of how the accounts have been developed.

Please cite as: O'Brien, D., Hawdon, A., Lawrence, R., Maisey, A., Ogilvy, S., Rainsford, F., Semmler, I., Sutton, G. and Radford, J. (2023). Orana Farm-scale Natural Capital Account 2022. La Trobe University and Integrated Futures.

Disclaimer

This report has been prepared for the purposes of demonstrating how natural capital information may be compiled and presented to farmers. It does not constitute financial or investment advice and should not be relied on for this purpose. To the extent permitted by law La Trobe University accepts no responsibility for any loss, claim or liability incurred by any party in connection with this report.

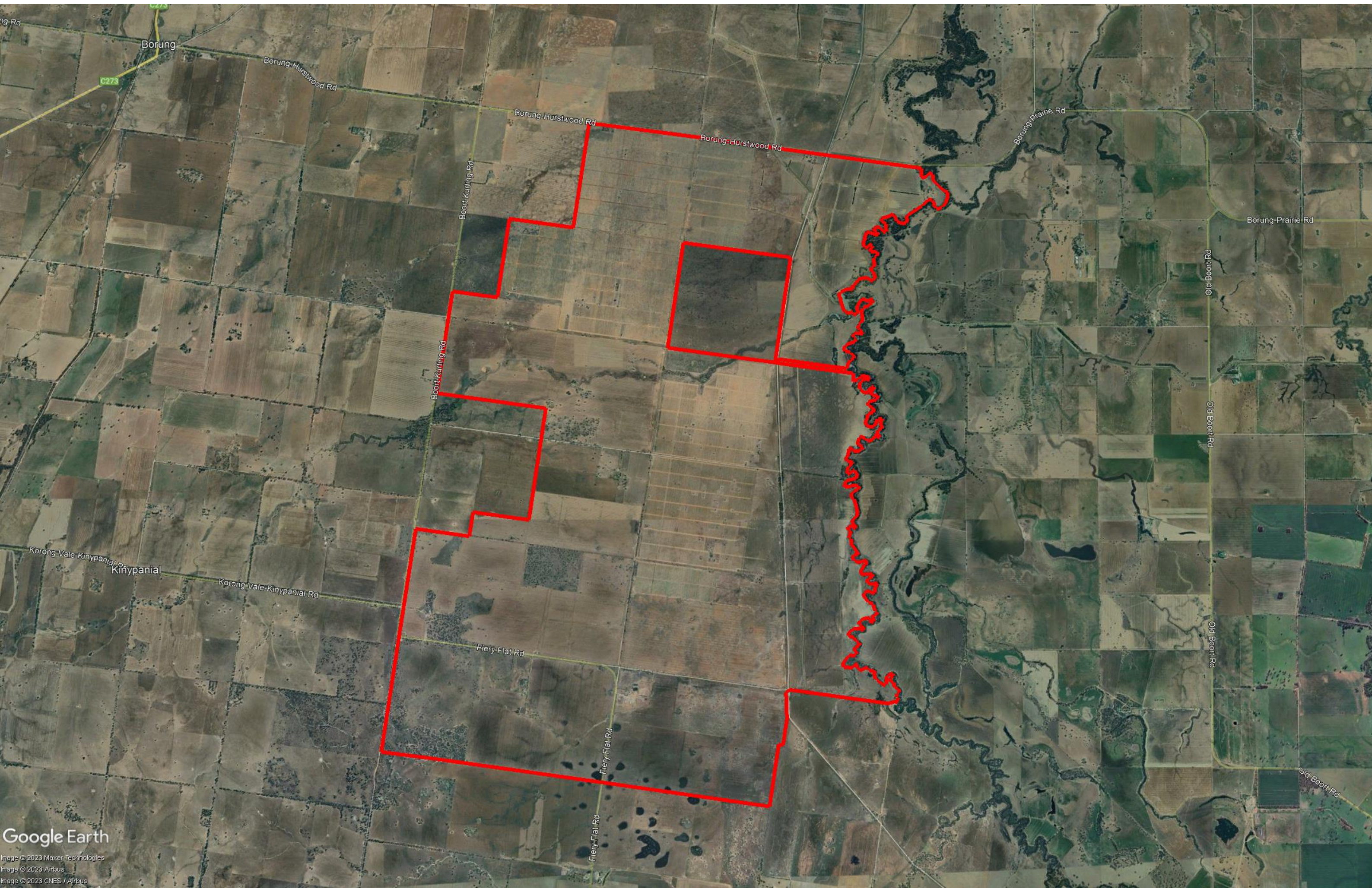
Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment, and community. We pay our respects to the Traditional Custodians of the lands on which we live and work, their culture, and their Elders past and present.

The Farm-scale Natural Capital Accounting project funded by the Australian Government's Smart Farming Partnership program with co-investment from La Trobe University and Odonata Foundation.

Cover photo image credit: Jim Radford

Contents

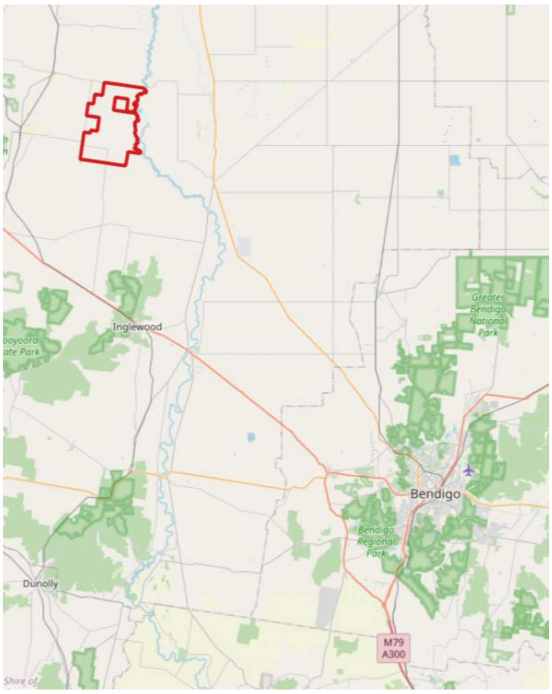


Borung
Borung-Hurstwood Rd
Borung-Hurstwood Rd
Borung-Hurstwood Rd
Boort-Kurting Rd
Boort-Kurting Rd
Borung-Prairie Rd
Borung-Prairie Rd
Old Boort Rd
Korong Vale-Kinypanial Rd
Kinypanial
Korong Vale-Kinypanial Rd
Fiery Flat Rd
Fiery Flat Rd
Google Earth

Orana Overview

Orana is a 5,251 ha property situated on Dja Dja Wurrung lands in central Victoria and straddles the Victorian Riverina and Victorian Midlands bioregions. Orana is a mixed farming enterprise, growing sheep meat on 363 ha of pasture, a variety of cereals, canola and legumes on 2,668 ha of dryland and 671 ha of irrigated cropping, and 1,219 ha of perennial horticulture (olives). Orana is managed using regenerative farming principles for sustainable economic, environmental, conservation and social benefits. It follows the Odonata Foundation's 7Cs of corridors, climate, creatures, culture, community, capital appreciation and cashflow.

Orana has 2.1% tree cover and contains remnants of Plains Grassland, Plains Woodland, Herb-rich Woodland, Grassy Woodland, Riverine Grassy Woodland, Wetland, and Lignum Swamp. During the natural values surveys conducted for this project, 71 species of native birds and 76 species of native plants were detected on the property, including three threatened bird species and two threatened plant species. We chose the Brown Treecreeper (Vulnerable both nationally and in Victoria yet relatively common on Orana) as the emblematic species for Orana.



Location of Orana
Map Credit: Google Maps

Orana emblem: Brown Treecreeper
Photo Credit: Alex Maisey

Natural Capital Accounting

Natural capital refers to all biotic (living) and abiotic (non-living) natural resources that are present in a particular area. Natural capital is made up of *assets* (sometimes called *stocks*) that are physical entities that can be described in terms of their extent (length, area or volume) and condition (quality of the asset). Natural capital assets includes both *environmental assets*, which are the individual components of the biophysical environment (e.g., minerals, water, soil), and *ecosystem assets*, which are areas of a specific ecosystem type.

***Natural capital** is the foundation of all farming systems. Soil and water support crops and pastures, vegetation provides food and shelter for livestock and regulate the micro-climate for crops, and native animals (e.g., insects, reptiles, birds) provide services such as pollination, pest control and waste decomposition.*

***Natural capital accounts** are a statement of the natural capital assets present in a defined area at a given point in time, and the ecosystem services generated by those assets. Natural capital accounts are defined in biophysical terms and are compiled according to a set of standards, and are quantifiable, verifiable, and repeatable.*

On a farm, natural capital includes both naturally occurring ecosystems and ecosystems that have been established and maintained by humans. Examples include areas of native vegetation (remnant and replanted), grasslands (native and exotic pastures), croplands and wetlands. These each have a defined spatial extent and can be assigned a condition state based on various attributes.

Natural capital assets combine to produce *ecosystem services* that have value to society (e.g., food and fibre, climate regulation, water purification, minerals, timber, energy) (Figure 1). It is important to note that asset type or condition is not determined by primary land use, and that the same asset can provide a range of ecosystem services (e.g., grazing, conservation, carbon, water production).

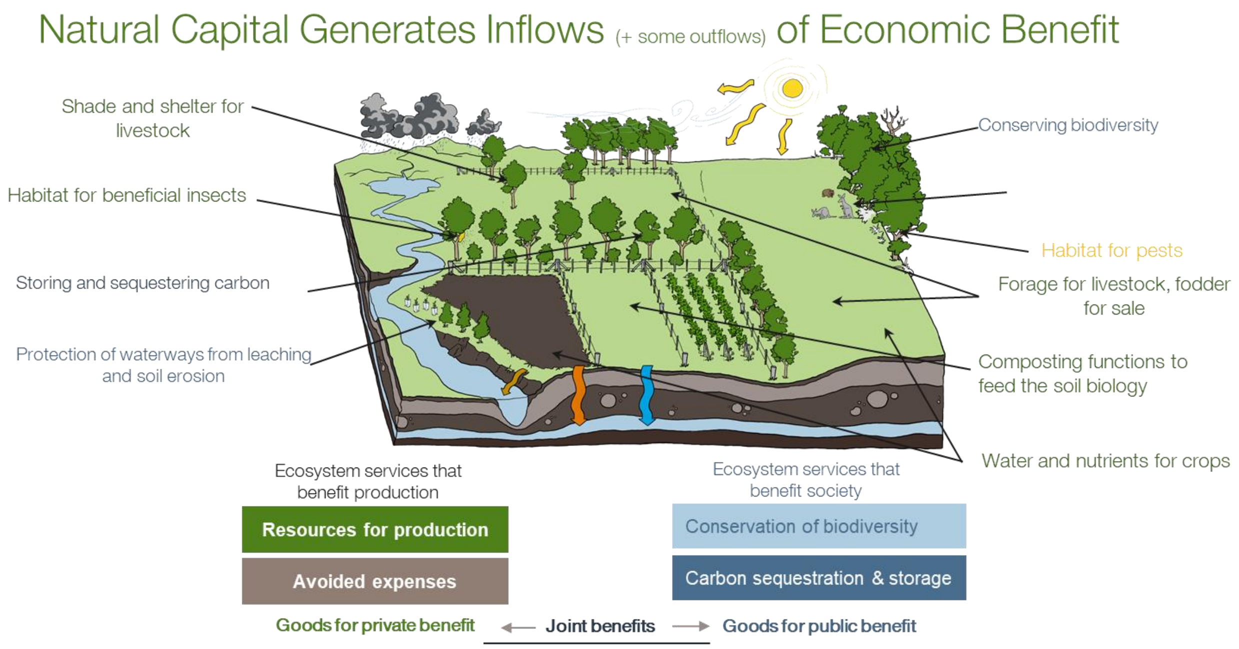


Figure 1. Ecosystem services generated by natural capital assets on a farm.

Navigating your Natural Capital Account

This report contains the natural capital accounts for Orana for the 2022 calendar year. The natural capital and environmental performance of Orana has been quantified using a combination of satellite imagery analysis, on-ground field observations and farmer-supplied data. It is based on farm operations data pertaining to 2019-2022 and on-ground rapid assessments of ecosystem state and condition conducted in October 2021 (see Appendix 1). Soil carbon data covers 2017 to 2022. Bird surveys for the natural values program were conducted in Spring 2021 and Autumn 2022. Plant surveys for the natural values program were conducted in Spring 2021.

To generate natural capital accounts, the ecological condition of the natural capital assets on a farm needs to be quantified in a robust and repeatable way. To do this, we used state and transition models to describe and quantify the natural capital assets present. State and transition models have been used extensively to describe condition states and the processes that maintain states or drive shifts between states. We developed a series of generic, but high-resolution, state and transition models to describe all areas of a farm in terms of the departure from a 'reference' (or best-on-offer) condition state (see Appendix 2). Our state and transition models expand on traditional ecosystem state and transition models by incorporating all production areas, including pastures, annual crops and perennial crops, and re-planted areas. We developed state and transition models for woodlands, forests, grasslands and shrublands, and applied the relevant state and transition model depending on the pre-1750 vegetation type present at a site (therefore, a farm may have more than one state and transition model).

The accounts are an objective assessment of the natural capital assets on a farm, and the ecosystem services that flow from those assets, for a given point in time. The extent and condition of the assets present will be affected by current management but also by historical land-use management and current landscape context. These legacy effects and landscape context will impose constraints on the current condition of natural capital assets, particularly in terms of ecological condition and biodiversity metrics. Accordingly, interpretation of the accounts must be considered in the context of the surrounding landscape and past land-uses. For example, in heavily cleared or intensively-managed landscapes, the regional species pool will necessarily limit the total number of native species that could be expected to occur on a particular farm, irrespective of contemporary on-farm management. However, current management is also important, and incremental improvements are possible in all landscapes with careful management of natural capital. The accounts are designed to capture such improvements in the natural capital asset base.

Similarly, it is important to differentiate between factors that are under the control of the land manager (e.g., current management practices) and those that are beyond their control (e.g., climate, surrounding landscape context, fire) and how these factors influence the extent and condition of natural capital assets, respectively. For example, the impact of a bushfire, flood or drought, should not necessarily result in a decline in the natural capital asset base if the integrity (condition) of the assets is maintained. Again, the accounts are designed to be robust to such variations caused by factors beyond the control of the land manager.

This data has been compiled, analysed, and is presented in this report in a series of accounting tables and associated maps and figures. This report contains the following sections:

Accounts of Natural Capital Assets

1. Register of ecological (natural capital) assets – provides information about the different types of natural capital assets that comprise the farm. Includes a map and area-based asset account of ecosystem condition based on a customised, whole of farm state-and-transition model.

2. Biodiversity assets – provides information on the areas of better and lower predicted quality habitat for biodiversity, based on models of bird and plant diversity. Includes maps and area-based asset account of habitat for birds (broken down into all birds, woodland birds and grassland birds) and native plants (again with sub-sets for native grasses, herbs and all ground covers).

Ecosystem Service Accounts

1. Ecosystem services – provides information on the areas of better and lower predicted quality habitat for pollinators (insects), decomposers (invertebrates), and predators (invertebrates). Includes maps and data-based asset account of decomposition, pollination and pest control services.

2. Soil condition – provides information on ground cover and soil organic carbon (provided by Downforce Technologies).

3. Forage production (for livestock properties) – provides information about how many hectares of the property are in each pasture classification, representing differing provisioning services for livestock. Includes a map and area-based asset account of grazing assets based on composition, cover and resilience of pastures.

4. Shade and shelter - provides information on production areas receiving shade and shelter (wind protection), including maps and area-based asset account of shade and shelter.

Environmental Performance

1. Greenhouse gas emissions (GHG) position – provides estimates of whole of farm GHG emissions and carbon sequestration. Categorised by Scope 1, 2 and 3 for whole of farm and per farming sector on a farm (wool, sheep meat, beef, crop etc).

2. Resource-use intensity – provides information about the resources used and pollution generated by the farms operations per unit of product, estimated per farming sector on a farm.

The report is accompanied by:

- A document describing the state and transition model(s) (STM) that have been used to classify the different types of ecosystems present on Orana. See Appendix 2.

- A document describing the grazing classification framework. See Appendix 4.

- A link and login to the Sensand platform where you will find the digital copy of your farm-scale natural capital account. This includes an interactive user interface to examine your accounts and examine the results of individual rapid ecological assessments, plant surveys and bird surveys at point locations.

- A link and login to the Downforce Technologies portal where you can view the results of your soil organic carbon assessments from 2017 to 2022.

- A list of all bird species, plant species and invertebrate species detected on Orana during the natural values surveys.

How can Natural Capital Accounts help farm businesses?

We hope these accounts will assist Orana to set and achieve its financial, environmental, and social goals and to help communicate their environmental performance to their stakeholders. Natural capital accounts enable farmers to record and explain (account for) any changes to a farm's natural capital.

When combined with production data, natural capital accounts can help farm businesses to:

- determine where improvements can be made to farm management to increase environment health and profitability;
- show how natural capital supports agricultural production, and therefore, farm profitability;
- uncover opportunities to improve farm productivity and profitability through better management of natural capital;
- demonstrate the public benefit of maintaining and improving natural capital; and
- communicate your farm's environmental performance to a range of stakeholders (e.g. buyers, lenders, insurers).

Supporting Farm Management Decisions

Natural capital accounts provide a direct 'line of sight' from natural capital assets to benefits for production. The accounts can assist farmers to see *where* on their farm they improve farm productivity and profitability through better management of natural capital.

- Identify where to plant trees to maximise production outcomes from shade and shelter.
- Use forage condition at paddock level to optimize stock management for best production outcomes.
- Identify where to plant native shrubs and trees to increase pollination or pest control services.
- Identify areas vulnerable to soil loss and erosion due to low or variable ground cover.

Support Negotiations with the Supply Chain

Natural capital accounts provide farm-scale data in a format that provides an overview of farm sustainability. Farmers can use their accounts for evidence-based sustainability reporting to buyers (collect once, share many) who need to disclose their climate and nature risks and impacts.

- May be used for reporting requirements under certification schemes.
- May be used for market access disclosures, such as GHG emissions, deforestation or *nature positive*.
- May be used to negotiate direct-buyer contracts, premiums pricing, brand access and security of sale

Support Negotiations with Financial Stakeholders

Financial stakeholders (banks, insurers, investors) are increasingly concerned with climate and natural capital risk and reporting requirements. Natural capital accounts can communicate a farm's environmental performance to a range of financial stakeholders (collect once, share many). Repeat accounts will show change over time and evidence of sustainable management, reducing vulnerability to climate and nature-related risk and decreasing credit risk for banks and investors.

- Farmers have received lower interest rates on their loans from banks based on early natural capital accounts.
- Banks are developing Green leading products to farms that can evidence lower risk with outcome measures like natural capital account data.
- Farming for the Future has partnered with Australian Sustainable Finance Initiative to work through how finance sector can use this information for reporting, and how they might support farmers to collect this information. (not sure whether to include this?)

Support Ecosystem Service Market Access

Natural capital accounts demonstrate the public benefit of maintaining and improving on-farm natural capital, which may open new income streams, such as habitat credits and stewardship payments. All our measures and indicators align with the *Climateworks* Natural Capital Measurement Catalogue and are coherent with the Taskforce on Nature-related Financial Disclosure requirements. Our intention is to become an *Accounting for Nature* approved method paving the way for trading in biodiversity credit markets.

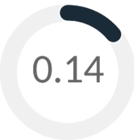
- May be used to reward farmers for habitat management or biodiversity outcomes under stewardship or habitat credit schemes.
- May be used to access premium pricing (co-benefits) on carbon projects.
- May be used to negotiate direct agreements with companies to fulfil their ESG requirements.

Our vision is that:

- farmers that build natural capital are financially rewarded through exclusive market access, price premiums, favourable financial terms, and payment for public benefits such as biodiversity habitat and carbon sequestration, and that:
- natural capital accounts are the tool through which sustainable farm practices that build natural capital are verified and validated, meaning that:
- natural capital accounting becomes standard practice for running profitable farming enterprises, and that:
- natural capital accounts are good for farm business and pay for themselves.

Natural Capital Dashboard: Orana

Ecological Condition Score

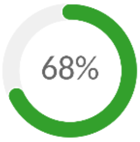


Riparian Buffer Score

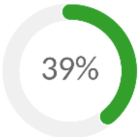
Proximity Score

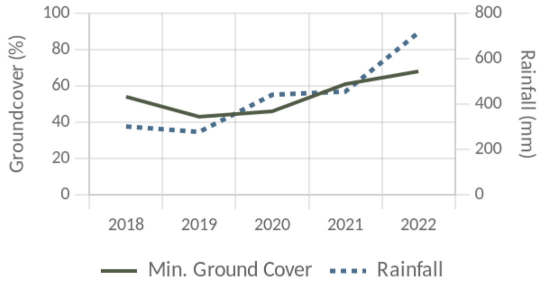
Soil Protection Metrics

Mean minimum groundcover for 2022 (5-year mean: **55** %)



Proportion of farm with minimum groundcover above 70% for 2022 (5-year mean: **18** %)



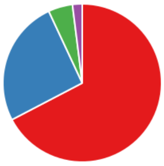


Biodiversity Metrics

Total # bird species:	74
# woodland bird species:	24
# grassland bird species:	5
# waterbird species:	7
Total # plant species:	145
# native plant species:	76
# native shrub species:	8
# native tree species:	6

Habitat quality for woodland birds

Habitat quality for native plants



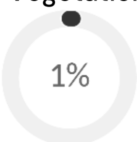
Threatened species recorded:

Plant	Buloke (CE)
Plant	Rytidosperma monticola (E)
Bird	Brown Treecreeper (V)
Bird	Southern Whiteface (V)
Bird	Diamond Firetail (V)

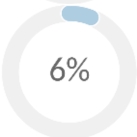
Ecosystem Service Metrics

Shade and Shelter from Woody Vegetation

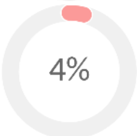
% of farm receiving shade



% of farm receiving shelter from cold winds

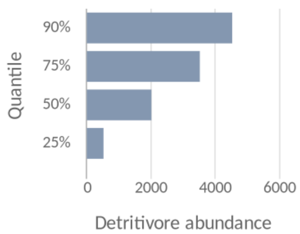


% of farm receiving shelter from hot winds

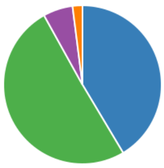


Invertebrate Habitat

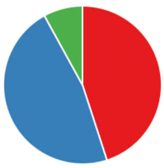
Detritivores



Pollinators



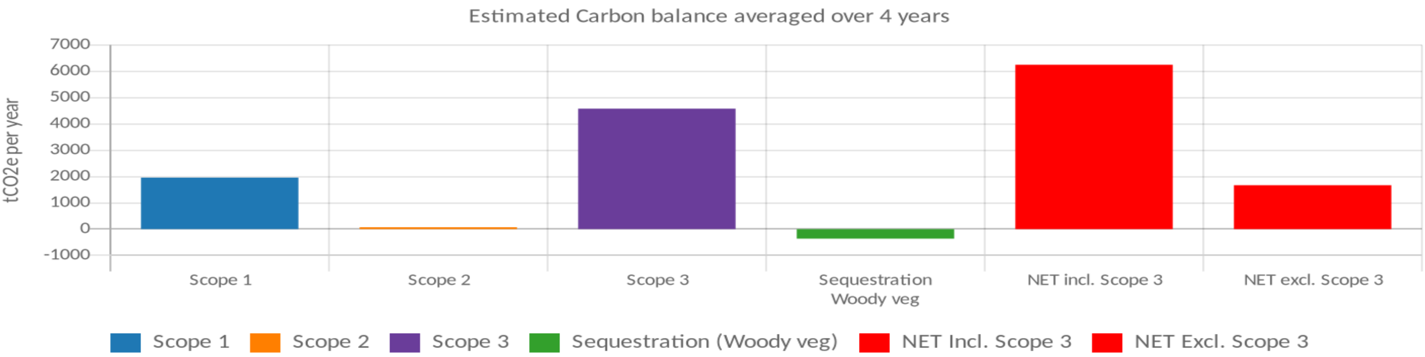
Predators



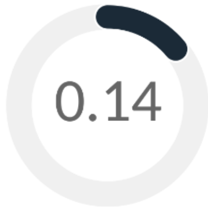
Colour key for biodiversity and invertebrate habitat quality pie charts

- Poor
- Moderate
- Good
- Very Good
- Outstanding

Emissions and Sequestration Estimates



Natural Capital: Type & Condition Extent



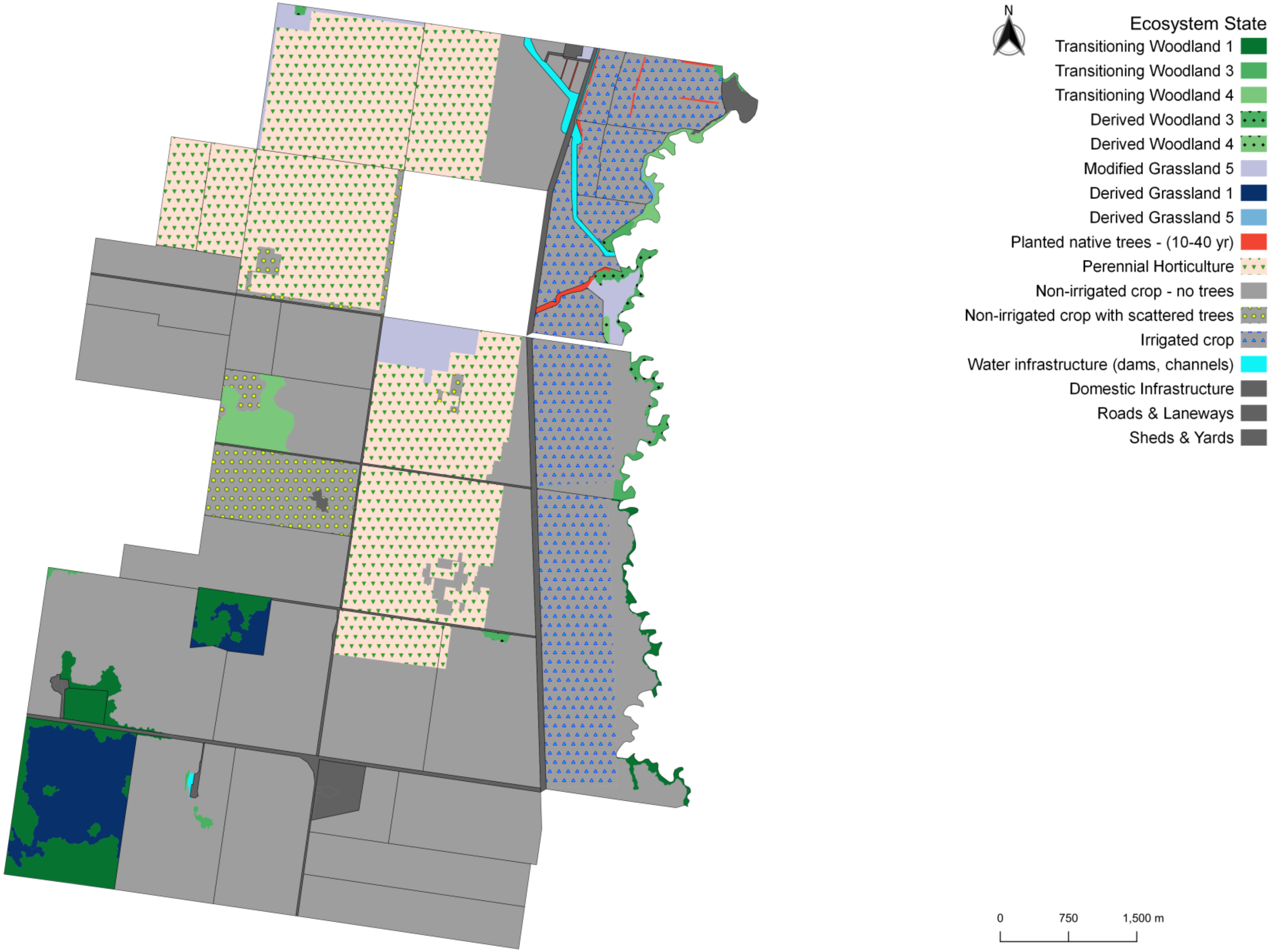
This section provides a summary of the natural capital assets on Orana. It provides information about the extent (area) of each of the different ecosystem types (Column 1) and their constituent ecosystem states from the relevant state and transition model (Column 2) present on Orana. This table also shows the 'ecological condition weighting' applied to each ecosystem state (see Appendix 3), as an indication of its ecological condition relative to the 'reference' state (which has a weighting of 1.0). We used an area-weighed sum of the ecological condition of each ecosystem state to generate a whole of farm ecological condition score (see Appendix 3). For Orana, this value is 0.14.

The Farm-scale Natural Capital Accounting team has performed analysis of spatial imagery and used field observations to classify each paddock (or sub-paddock) on Orana according to the ecosystem state it represents (see Appendix 1). These findings have been consolidated into a summary that contains information about both the extent and condition of each ecosystem type on Orana. This can be used to estimate the ecosystem services generated by the natural capital on Orana for your farm business, your family, your community, and the wider public benefit.

Table 1. Ecosystem Type and State on Orana by extent (ha) as @ 18/10/2021

Ecosystem Type	Ecosystem State	Area (ha)	Ecological Condition Weighting	Proportion of farm
Horticulture	Perennial Horticulture	1219.2	0.10	23 %
Woodland	Derived Woodland 3 - little regeneration - mostly exotic ground layer	26.1	0.30	0 %
Woodland	Derived Woodland 4 - no regeneration - exotic ground layer	2.0	0.20	0 %
Woodland	Transitioning Woodland 1 - some historical clearing - regeneration - ground layer with high native diversity	154.9	0.90	3 %
Woodland	Transitioning Woodland 3 - little regeneration - mostly exotic ground layer	14.6	0.60	0 %
Woodland	Transitioning Woodland 4 - no regeneration - exotic ground layer	56.8	0.40	1 %
Grassland	Derived Grassland 1 - diverse native ground layer	157.0	0.50	3 %
Grassland	Derived Grassland 5 - perennial exotic ground layer	1.8	0.10	0 %
Grassland	Modified Grassland 5 - perennial exotic ground layer	86.0	0.10	2 %
Cropland	Non-irrigated crop with scattered trees	170.7	0.20	3 %
Cropland	Non-irrigated crop - no trees	2497.0	0.10	48 %
Cropland	Irrigated crop	671.1	0.10	13 %
Planted vegetation	Planted native trees - maturing (10-40 years)	10.2	0.40	0 %
Infrastructure	Domestic Infrastructure	25.4	0.00	0 %
Infrastructure	Roads & Laneways	135.3	0.00	3 %
Infrastructure	Sheds & Yards	2.1	0.00	0 %
Infrastructure	Water infrastructure (dams, channels)	20.9	0.00	0 %
Total		**5,250.9**	**0.14**	**100%**

Ecosystem State Map(s)



Map 1. Ecosystem States on Orana

Riparian Condition

The riparian zone is the area between the waterline of a waterway and the top of the bank or the transition to upland vegetation. The width of the riparian zone varies with the morphology of the waterway and the topography of the landscape but is generally between 10-30 metres, but in landscapes with low relief it can extend for hundreds of metres. Riparian vegetation is important in agricultural landscapes because it provides refuge and habitat for native fauna and flora, filters surface water flows improving water quality and regulating flows, and captures carbon for sequestration and storage (because riparian areas are in more productive areas, they often capture and store more carbon than surrounding areas). Riparian areas are usually linear, potentially increasing structural connectivity on farms and in landscapes. Therefore, the extent to which riparian areas retain native vegetation (or are replanted) is a useful indicator for multiple values (e.g., habitat, water quality, connectivity, flow regulation).

The riparian buffer score is the proportion of the riparian zone that has tree canopy cover. For the purposes of generating this score, riparian areas are classified as mapped (named) creeks, streams and rivers on a farm, or areas that are clearly identifiable as riparian from remote sensing or aerial imagery. The riparian buffer score is calculated as the total area of riparian canopy cover divided by the total area of riparian zone, where the riparian zone is defined as a 50m buffer either side of major waterways (rivers) and 30m either side of minor waterways (creeks). It is a continuous variable from 0 (no canopy cover in the riparian zone) to 1 (complete canopy cover in the riparian zone). Canopy cover includes native and exotic, and remnant and replanted woody vegetation. Where the farm boundary coincides with a waterway, only the riparian zone on the farm is included in the calculation. Where the waterway runs through a natural grassland, we would not expect the riparian zone to have canopy cover. This will result in an underestimate of the true riparian condition. For Orana, the riparian buffer score is 0.21.

Map 2. Map of canopy cover distribution and riparian areas for Orana

Biodiversity Accounts

This section provides summary accounts of the biodiversity values of Orana, focusing on birds and plants. It provides information about the number of species of birds and plants found on the farm as well as the extent and quality of habitat on the farm for each type of organism. The measures of bird and plant diversity give an indication of the value of the farm for biodiversity conservation and the maps indicate where on the farm biodiversity values are higher or lower for different groups.

The maps show the predicted species richness (i.e., number of species) per hectare of birds and per 0.05 ha for plants across the farm. They are derived from statistical models that used ecosystem state, topography, the size of the habitat patch and counts of species at sites to predict bird and plant species richness across the farm. The models were based on data collected from 1155 sites for birds and 1090 sites for plants on farms across south-eastern Australia. Darker tones indicate areas of higher species richness, which is an indication of the relative quality of the habitat for each group of organisms. Values can be viewed as a species density per area, or the number of species that would be expected using a similar protocol (4 x 10 min x 1 ha bird surveys, 500 m^2 plant survey) at each site.

Birds

We generated models, predictions and maps of habitat quality for three groups of birds. 1) All bird species. This group includes any bird, no matter what type. 2) Woodland birds. Woodland birds rely on relatively intact patches of woodlands for their daily foraging, nesting and roosting requirements. This is a group of birds that is declining in occurrence and abundance across Australia and is of conservation significance. 3) Grassland birds. These birds tend to avoid areas with trees and rely on grasslands, pastures, and crops. Grassland birds include quails, pipits, and larks.

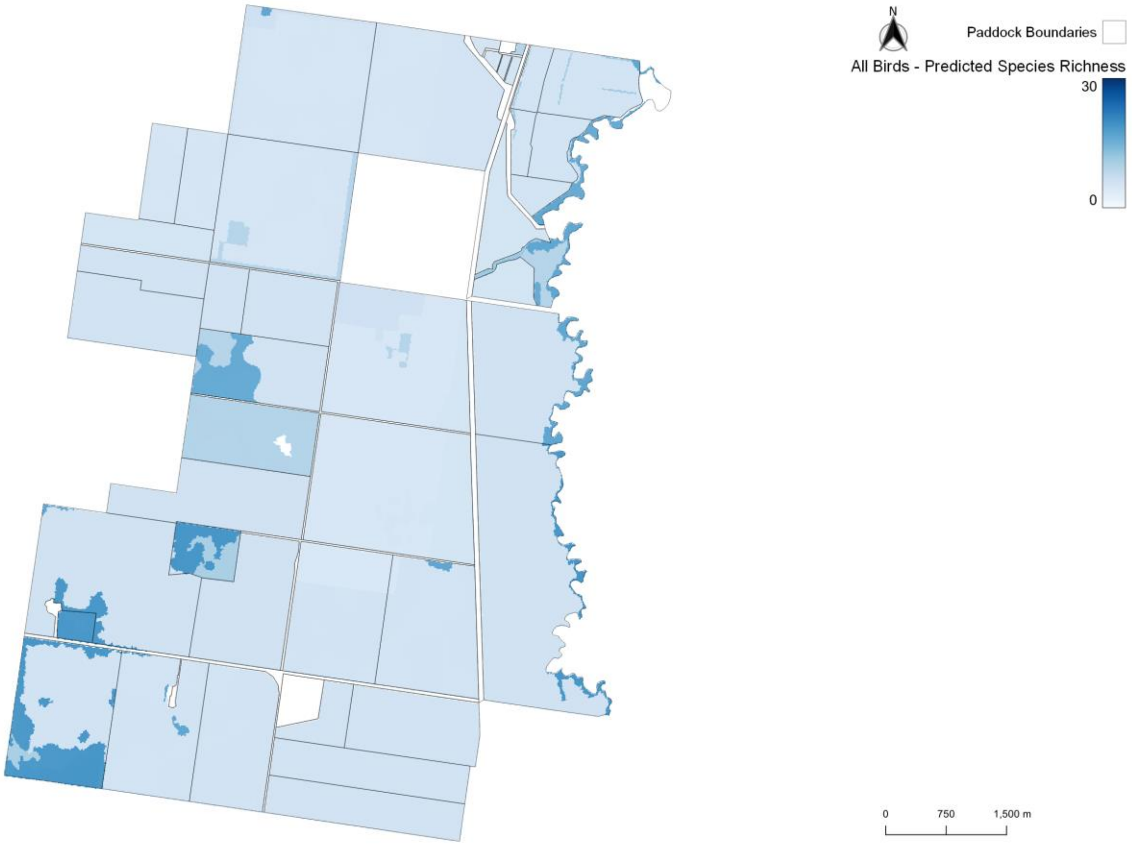
The following table provides measures (in hectares and percentage of the farm) of the amount of habitat on Orana considered to be of 'poor', 'moderate', 'good', 'very good', or 'outstanding' quality for birds. The habitat quality classes were determined for each group of bird from empirical data collected from farms located across south-eastern Australia and are based on the number of species that would be expected to use a 1 ha site.

For birds, the following thresholds were applied:

- All bird species. 0-6 species per ha = poor, 7-10 = moderate, 11-15 = good, 16-21 = very good, >21 = outstanding.
- Woodland birds. 0 species per ha = poor, 0-1 = moderate, 2-5 = good, 6-11 = very good, >11 = outstanding.
- Grassland birds. 0 species per ha = poor, 1 = good, >1 = outstanding.

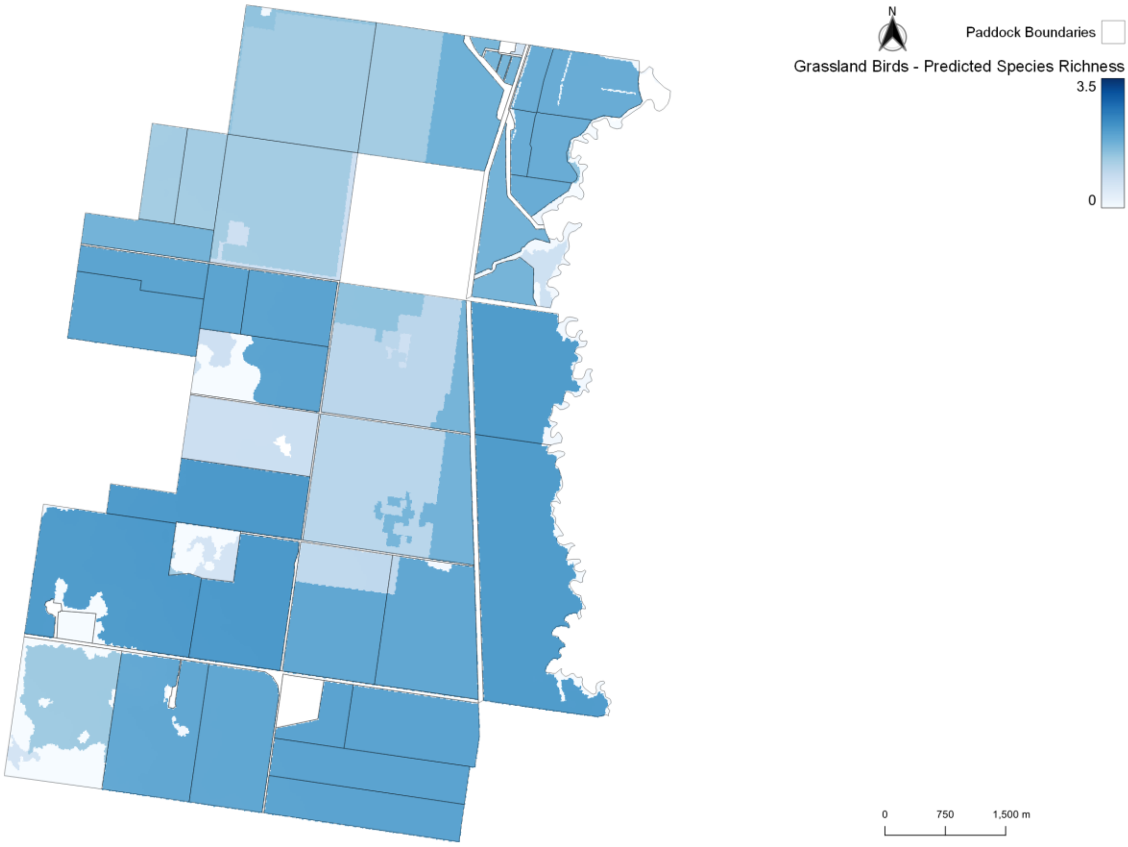
Table 2. Habitat quality for birds on Orana

Bird group	Metric	Habitat quality				
		Poor	Moderate	Good	Very good	Outstanding
All birds	Area (ha)	4589.4	212.2	14.5	251.1	0.0
	% of farm	90.6%	4.2%	0.3%	5.0%	0.0%
Woodland birds	Area (ha)	4584.8	190.8	136.6	155.0	0.0
	% of farm	90.5%	3.8%	2.7%	3.1%	0.0%
Grassland birds	Area (ha)	279.2	N/A	1630.7	N/A	3157.4
	% of farm	5.5%	N/A	32.2%	N/A	62.3%



Map 3. Predicted species richness for all birds on Orana

Map 4. Predicted species richness for woodland birds on Orana



Map 5. Predicted species richness for grassland birds on Orana

Plants

We generated models, predictions and maps of habitat quality for four groups of plants. 1) All plant species. This group includes both native and exotic plant species. 2) All native plant species. This group includes only those species considered native to Australia, regardless of life form. 3) Native ground layer. These species are native to Australia and include grasses, forbs, sedges and rushes. 4) Native shrubs. Native shrubs may be woody or non-woody but generally have a branched form and grow higher than about 1 m.

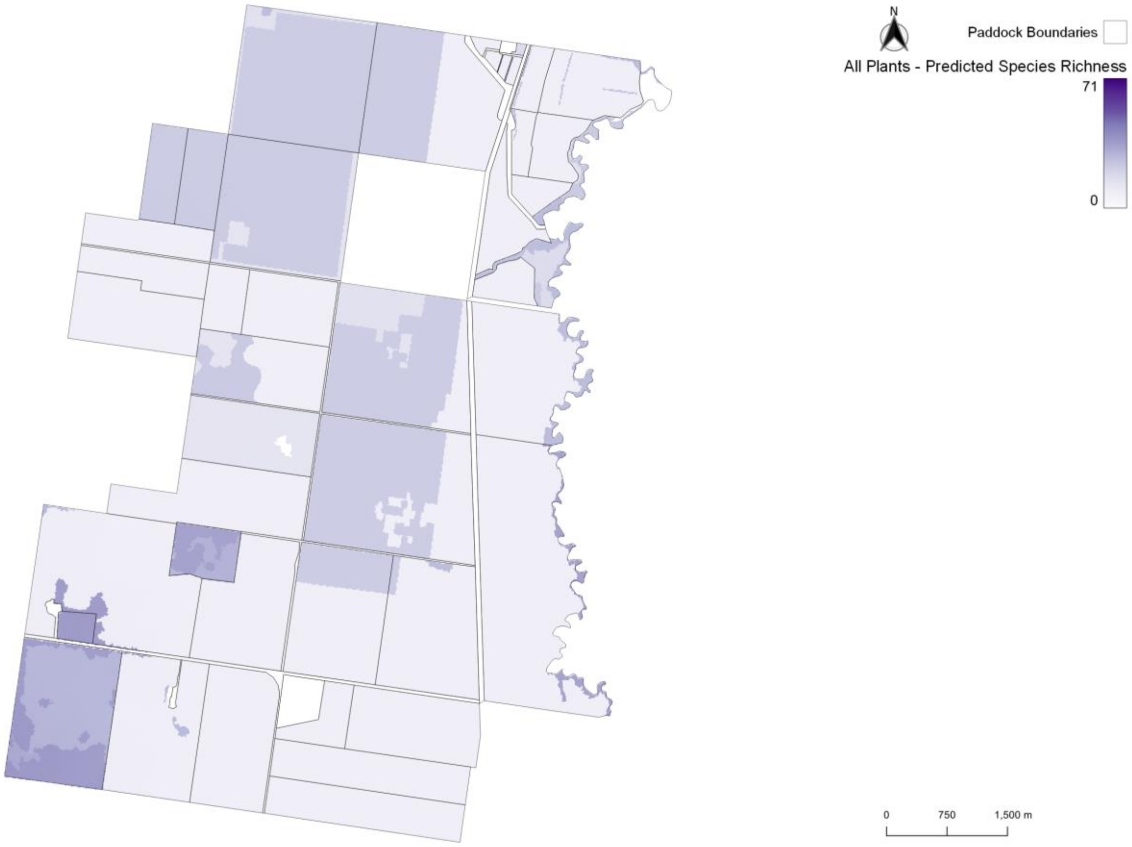
The following table provides measures (in hectares and percentage of the farm) of the amount of habitat on Orana considered to be of 'poor', 'moderate', 'good', 'very good', or 'outstanding' quality for groups of plants. The habitat quality classes were determined for each group of plant from empirical data collected from farms located across south-eastern Australia and are based on the number of species that would be expected to be found in a 500 m^2 (0.05 ha) plot.

For plants, these thresholds were applied:

- All plant species. 0-18 species/0.05 ha = poor, 19-27 = moderate, 28-38 = good, 39-49 = very good, >49 = outstanding.
- All native plant species. 0-4 species/0.05 ha = poor, 5-11 = moderate, 12-21 = good, 22-32 = very good, >32 = outstanding.
- Native ground layer. 0-4 species/0.05 ha = poor, 5-11 = moderate, 12-21 = good, 22-31 = very good, >31 = outstanding.
- Native shrubs. 0 species/0.05 ha = poor, 1-2 = good, 2-4 = very good, >4 = outstanding

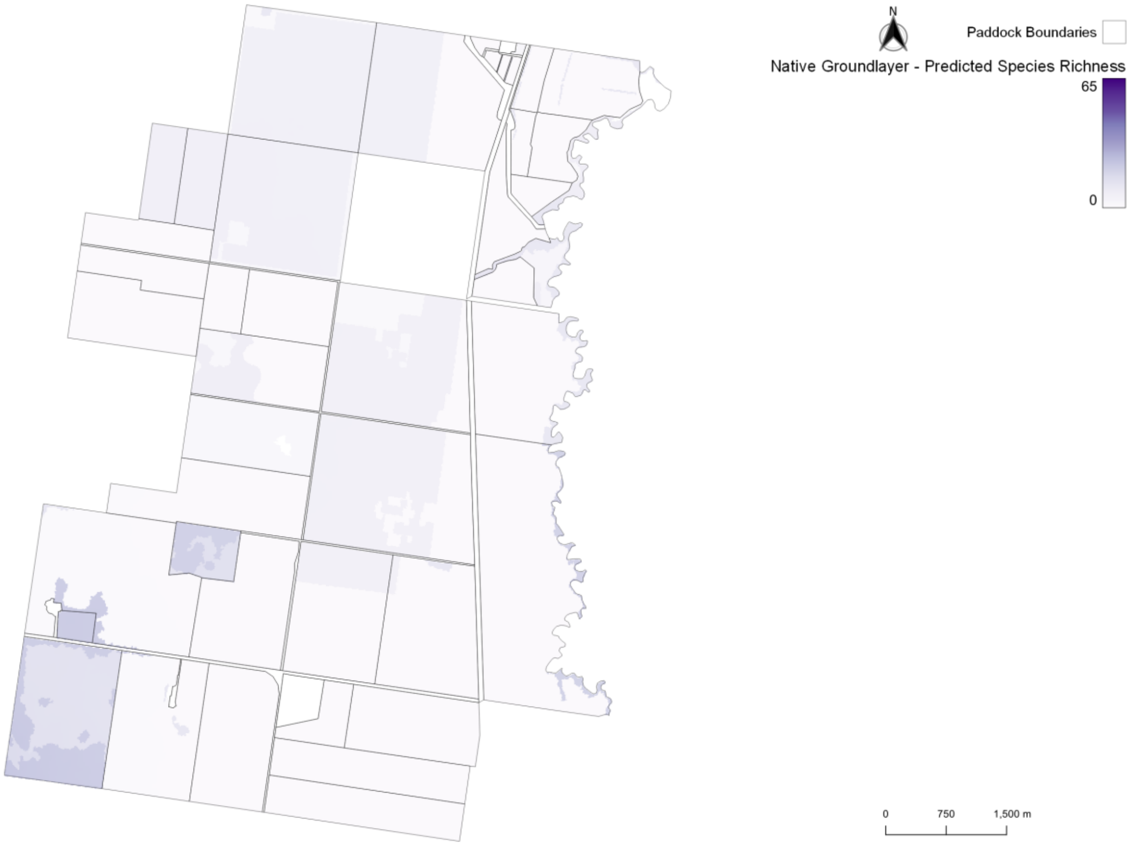
Table 3. Habitat quality for plants on Orana

Plant group	Metric	Habitat quality				
		Poor	Moderate	Good	Very good	Outstanding
All plants	Area (ha)	3432.3	1305.3	329.7	0.0	0.0
	% of farm	67.7%	25.8%	6.5%	0.0%	0.0%
All native plants	Area (ha)	3432.3	1310.6	239.7	84.7	0.0
	% of farm	67.7%	25.9%	4.7%	1.7%	0.0%
Native ground layer	Area (ha)	3432.3	1313.0	300.8	21.2	0.0
	% of farm	67.7%	25.9%	5.9%	0.4%	0.0%
Native shrubs	Area (ha)	3490.3	N/A	1423.4	153.6	0.0
	% of farm	68.9%	N/A	28.1%	3.0%	0.0%



Map 6. Predicted species richness for all plants on Orana

Map 7. Predicted species richness for all native plants on Orana



Map 8. Predicted species richness for native ground layer on Orana

Map 9. Predicted species richness for native shrubs on Orana

Ecosystem Service Accounts

Ecosystem services that support agriculture, such as pollination, pest suppression and the regulation of soils, forage pastures and microclimate, underpin farm productivity, reduce costs and increase yields. These services represent significant economic value yet are difficult to quantify due to the complexity of the ecosystems and interactions between species that provide them. The extent of these services varies depending on the function, form and structure of the ecosystems that provide them. For example, the abundance and activity of predatory invertebrates can reduce the amount of pesticides required to keep pests at an acceptably low level, therefore avoiding costs. In other examples, the height and structure of vegetation and its configuration (i.e. shelter belt vs. patch) determines the value of shade and shelter provided to livestock.

In this section of the accounts, several of the most important ecosystem services have been defined, measured and mapped across Orana. Areas of horticulture (e.g., vineyards, olive groves) were excluded from maps of arthropod services, as these were not sampled for arthropods.

Services supplied by invertebrates

Arthropods are a diverse group of invertebrate animals that include insects, spiders, springtails and mites. These communities are extraordinarily diverse, with many hundreds if not thousands of species, representing millions of individuals, likely to be present on any farm. Arthropods provide essential ecosystems services relating to decomposition, pollination, pest suppression and disease control and can indirectly regulate the provision of other services such as shade and shelter, through predatory or competitive control of pests (e.g., caterpillar outbreaks in shelterbelts). Broadly, the more species present, the more 'redundancy' can be expected in the system, and therefore lower risks to agriculture from environmental shocks (e.g., drought, severe weather, disease).

Invertebrate samples were collected from 650 sites located on 38 farms across south-eastern Australia to generate spatially-explicit models of predicted diversity or abundance of different arthropod groups, using remotely-sensed variables (e.g., topography, vegetation type, rainfall) to map predicted ecosystem services across farms.

Decomposers

Many arthropod invertebrates feed on detritus (i.e., are decomposers). This process breaks down coarse litter as the first stage of decomposition and re-mineralisation of plant matter. These "detritivore" communities live predominantly in the litter and soil across all ecosystems that occur on a farm, including wetlands, woodlands, pastures and crops.

Statistical models were developed to understand and predict detritivore abundance across farms, with particular interest in the benefits of adjacent revegetation and remnant vegetation in facilitating decomposer community into production areas.

Annual rainfall had a very pronounced influence on invertebrate abundance. This was a positive relationship, with more detritivores predicted to be present with increasing rainfall. The red point on the graph in Figure 2 places Orana on the rainfall-detritivore abundance curve, providing an indication of the predicted average abundance of detritivores across the farm, holding all other variables at their mean.

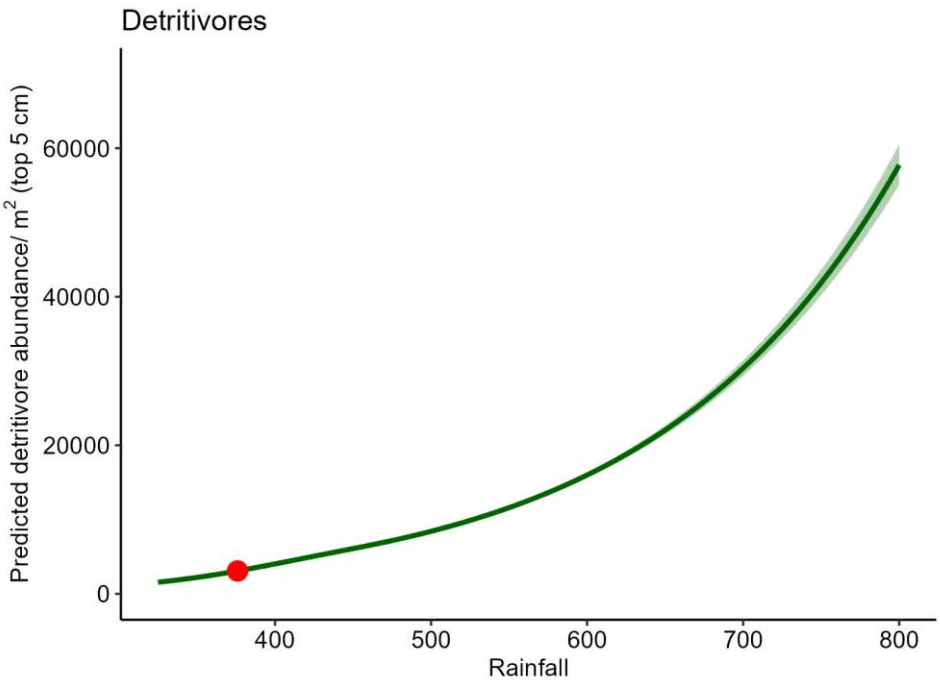
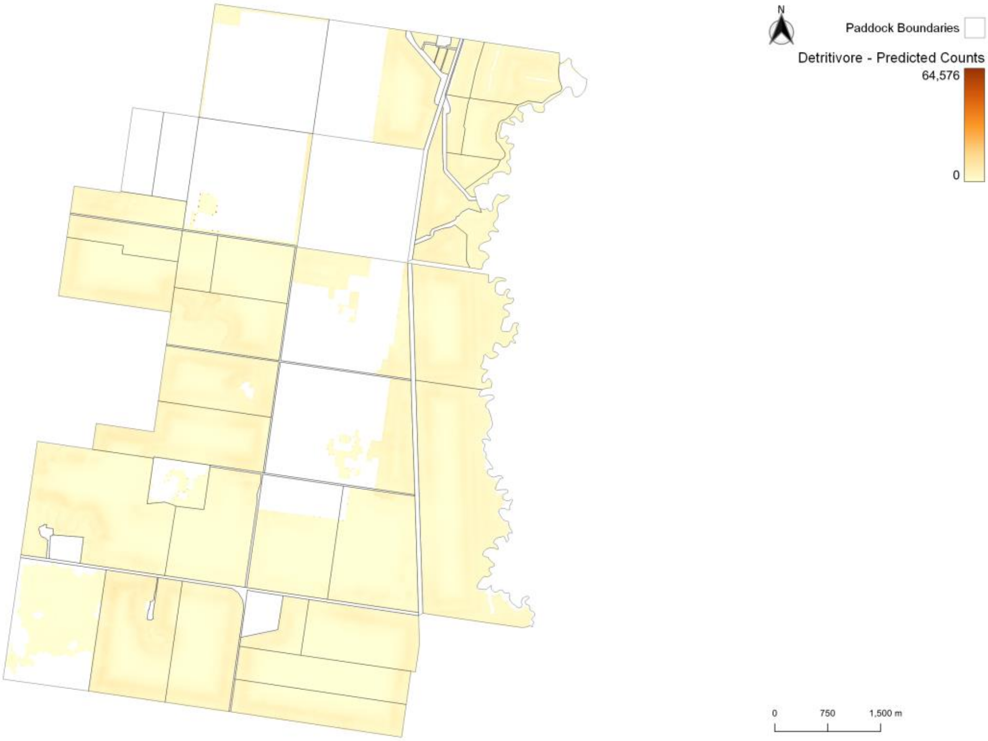


Figure 2. Predicted abundance of arthropod detritivores (number per m^2) in relation to mean annual rainfall. The red dot indicates the predicted average abundance of detritivores/m^2 for Orana, with a predicted abundance of 3,084 detritivores/m^2, holding all other variables at their mean value.

Other variables that were important in the model were fractional groundcover, topography, ecosystem state, distance to trees and distance to ecotype edge. This model was used to predict detritivore abundance across Orana. The predicted detritivore abundance has been grouped into quantiles so that change can be measured through time against this baseline (Table 4). The highest quantile threshold provides a measure of the number of detritivores predicted at the 90th percentile (i.e. the best 10% of the farm is predicted to have greater than 4,522 detritivores per m^2). If habitat suitability for detritivores were to improve over time, the predicted abundance at these quantile thresholds would increase in future assessments (or conversely, if habitat suitability for detritivores were to decline, abundance values would decrease).

Table 4. Quantile thresholds for detritivore abundance on Orana

Quantile	Predicted Abundance
90%	4,522
75%	3,516
50%	2,010
25%	520



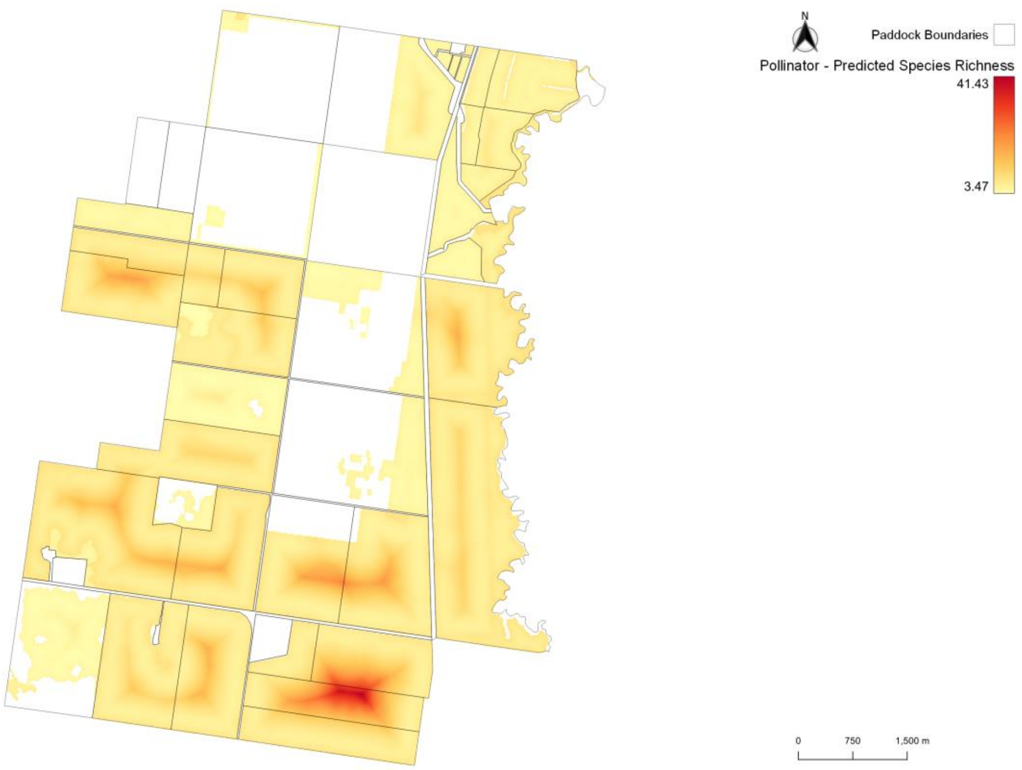
Map 10. Predicted counts of detritivores on Orana

Pollinators

Many groups of arthropods pollinate plants while feeding on the pollen or nectar of both native and introduced plants. Bees are well-recognised and highly efficient pollinators, but flies (particularly hoverflies; order Diptera), beetles (order Coleoptera), and wasps (order Hymenoptera) are also potential pollinators. With the recent introduction of Varroa mite (*Varroa destructor) to Australia,* other potential pollinator groups may become more important into the future.

To incorporate the services of pollinators in the accounts, the richness (number of species) of pollinator arthropods have been modelled across the farm based upon ecological and landscape features such as topography, broad vegetation structure and composition, as well as fine-scale habitat features such as litter cover and access to bare soil.

This model was used to predict pollinator abundance across Orana and has been grouped into quantiles so that change can be measured through time against this baseline. Orana contained 1,856 ha (50.4%) of good quality habitat, 229 ha (6.2%) of very good quality habitat and 99 ha (2.7%) of outstanding quality habitat for pollinators (**Table** 5).

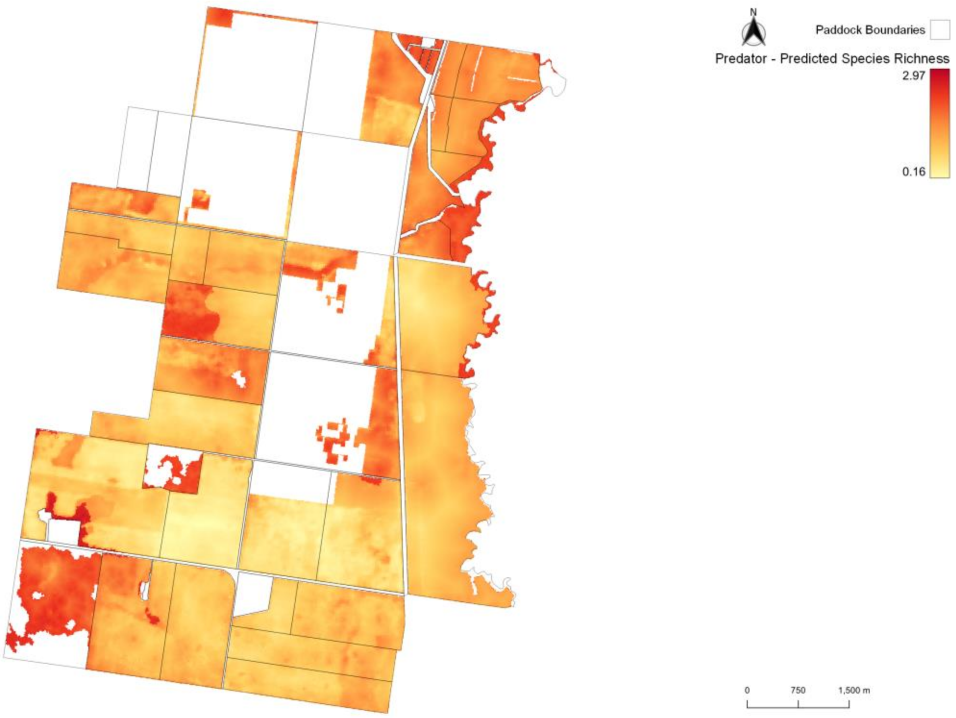


Map 11. Predicted species richness for pollinators for Orana

Pest Predation

Many arthropods are predators or parasitoids of agricultural pests. Spiders (order Araneae), lacewings (order Neuroptera) and mantids (order Mantodea) depredate on a wide variety of pests, while parasitoid wasps (e.g., family Ichneumonidae and family Bracionidae) target aphids and caterpillars. These beneficial arthropods reduce the costs to farmers by reducing crop and pasture damage and through avoided pesticide costs.

A model was developed to predict beneficial predator abundance across Orana and has been grouped into quantiles so that change can be measured through time against this baseline. Orana contained 282 ha (7.7%) of good quality habitat, 0 ha (0.0%) of very good quality habitat and 0 ha (0.0%) of outstanding quality habitat for arthropod predators (**Table** 5).



Map 12. Predicted species density of predators for Orana

For invertebrate groups, these thresholds were applied to habitat quality quantiles:

- Pollinators: 0-4 species/ 50m transect = poor, 5-7 = moderate, 8-12 = good, 12-17 = very good, >17 = outstanding.
- Predators: 0-1 species/ 50m transect = poor, 2 = moderate, 3 = good, 4 = very good, >4 = outstanding.

Table 5. Habitat quality for different invertebrate groups on Orana

Invertebrate group	Metric	Habitat quality				
		Poor	Moderate	Good	Very good	Outstanding
Pollinators	Area (ha)	0.1	1498.3	1856.1	228.8	99.4
	% of farm	<0.1%	40.7%	50.4%	6.2%	2.7%
Predators	Area (ha)	1658.1	1745.4	282.2	0.0	0.0
	% of farm	45.0%	47.4%	7.7%	0.0%	0.0%

Soil Regulation Services

The physical, chemical, and biological properties of soil determine its capacity to store and supply soil-water, substrate and nutrients for multiple natural capital assets: native ecosystems, planted vegetation and particularly, intensive land-use systems, including crops and pastures. However, there is no universally accepted definition of soil quality or soil health (i.e., a desirable value or range for specified soil attributes) nor how soil quality can be quantified in a way that is predictive of the type and amount of ecosystem services soil will generate. Indeed, soil quality / soil health will be strongly influenced by the intended land use (e.g., to support native vegetation, pastures, crops of different sorts) such that low values of an attribute (e.g., soil P) may be desirable for one use (e.g., native grasslands) but undesirable for another (e.g., cropping) and vice-versa. Until a unified definition of soil health emerges coupled with cost-effective methods to measure key attributes of soil health at spatial and temporal scales that reflect farm management practices, we have used ground cover as a surrogate for soil condition.

In addition to the on-site ecological assessments, condition information such as groundcover changes over time can be assessed using satellite imagery. Annual groundcover products from the Landsat satellites have been used to generate the groundcover statistics (Table 6). The Landsat satellite maps the property approximately every 6 days and generates data at a resolution of 30 m x 30 m.

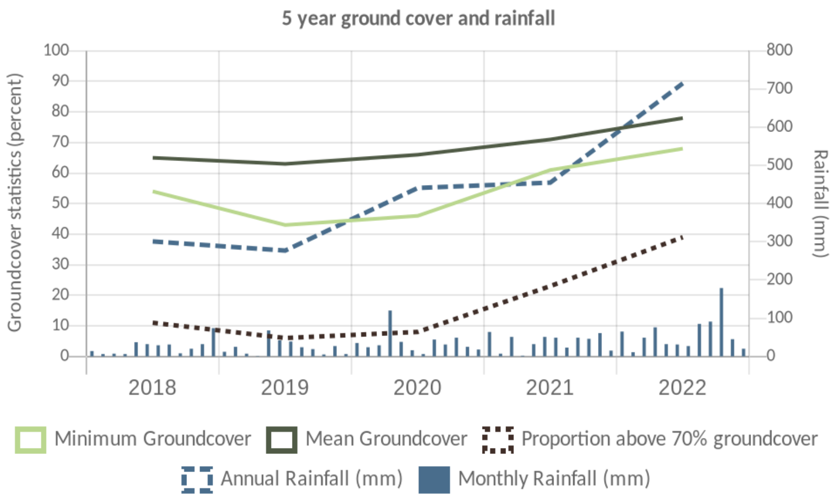


Figure 3. Ground cover vs rainfall on Orana (2018-2022)

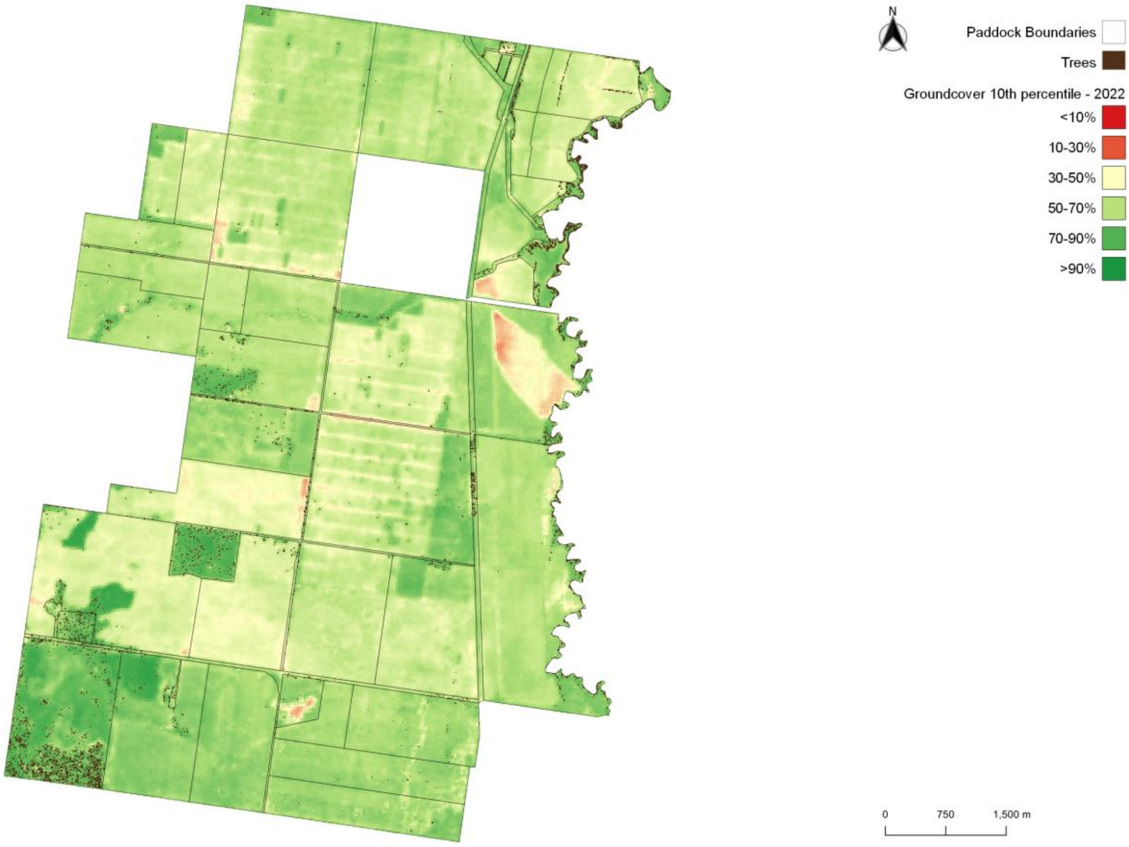
The estimates of minimum groundcover are a good proxy for soil regulation services such as the protection from erosion (wind and rain). The proportion of the property maintained at or above a threshold of 70% has been analysed for the latest year as well as providing a 5-year average.

Rainfall is a key factor in the ability to retain groundcover. The various groundcover metrics have been plotted against rainfall.

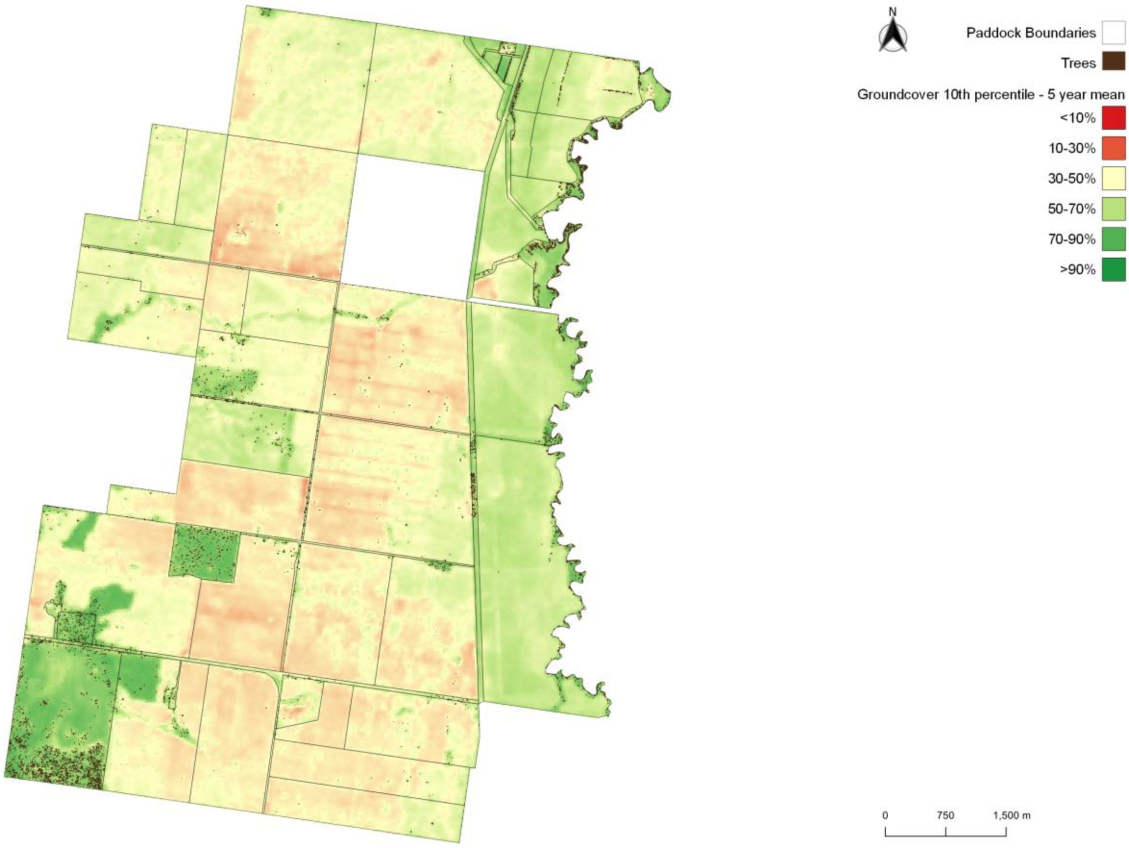
Table 6. Ground cover statistics for Orana for 2022 and 5-year mean (2018-2022)

Description	Metric for 2022	5-year mean (2018-2022)
Mean minimum groundcover	68 %	55 %
Percentage of farm with minimum groundcover above 70%	39 %	18 %
Mean modelled rainfall	716 mm	438 mm

The maps in the following pages present a spatial and temporal view of the groundcover data and provide a level of detail that would assist Orana to manage their exposure to erosion events. The minimum groundcover metric has been calculated using the Annual Fractional Cover Percentile product available from Digital Earth Australia. The 10th percentile groundcover (GC10) metric value for a 30x30m pixel represents the groundcover percentage for that pixel seen in the lowest (barest) 10 percent of satellite images for the latest year as well as averaged across 5 years. The areas of the property covered with trees have been masked from the measurements.



Map 13. Minimum (10th percentile) ground cover for 2022 for Orana



Map 14. 5-year mean minimum (10th percentile) ground cover for Orana

Forage Production Services

Forage Condition is a measure of the capacity of the farm to dependably produce quality forage for livestock. It is estimated using the proportion and diversity of perennial, palatable, persistent, and productive forage plants (including native and exotic plants) on the land used for grazing.
The ecologist who visited your farm inspected a representative sample of your paddocks to assess pasture composition. They used this information to classify each paddock into one of four grazing classification categories:

- **A:** Paddocks with a high degree of cover of a diverse mix of pasture species that are regarded as perennial, palatable, productive (and persistent) (3P species). Annual grasses and forbs may be present as gap fillers.
- **B:** Paddocks that have a moderate to high cover of 3P species but generally with lower diversity. Annual grasses and forbs may be present along with perennial grasses of lower palatability or productivity.
- **C:** Paddocks with sparse perennial cover. 3P species are at very low abundance and perennials present are persistent but of lower productivity and/or palatability. May have a diverse mix of annual pasture species (may be sown pastures). Weedy or no value species likely to be present.
- **D:** Paddocks that are dominated by annual species, either sown or naturalised. Almost no perennial pasture species present. Pastures include swards with plants with no or very low forage value and may have significant amounts of bare ground.

The labels A B C and D are not intended to imply a value judgement and should not be considered as a ranking. The classifications are used to represent the physical characteristics of the pasture. We recognise that different managers have different preferences for pasture type, species, and diversity.

Paddocks that weren't visited but had similar ground cover (evaluated using remote sensing) and management characteristics (from your farm records) to visited paddocks were assigned the same forage classification. The forage condition indicator is a weighted average of forage condition over the whole farm.

Pasture composition varies substantially with seasonal conditions and can be affected by timing of grazing. The pasture condition classifications, the timing of observations and the observation protocols used for assessing pasture composition in this research are designed to take these things into account.

Table 7. Orana - Grazing classification and extent (ha) by Ecosystem Type and State as @ 18/10/2021

Ecosystem Type	Ecosystem State	Grazing Classification			
		A	B	C	D
Horticulture	Perennial Horticulture	0	0	0	0
Woodland	Derived Woodland 3 - little regeneration - mostly exotic ground layer	0	0	14	12
Woodland	Derived Woodland 4 - no regeneration - exotic ground layer	0	0	0	2
Woodland	Transitioning Woodland 1 - some historical clearing - regeneration - ground layer with high native diversity	18	28	109	0

Woodland	Transitioning Woodland 3 - little regeneration - mostly exotic ground layer	0	0	7	8
Woodland	Transitioning Woodland 4 - no regeneration - exotic ground layer	0	0	43	13
Grassland	Derived Grassland 1 - diverse native ground layer	22	0	135	0
Grassland	Derived Grassland 5 - perennial exotic ground layer	0	2	0	0
Grassland	Modified Grassland 5 - perennial exotic ground layer	0	86	0	0
Cropland	Non-irrigated crop with scattered trees	0	0	0	0
Cropland	Non-irrigated crop - no trees	0	0	0	0
Cropland	Irrigated crop	0	0	0	0
Planted vegetation	Planted native trees - maturing (10-40 years)	0	0	0	0
Infrastructure	Domestic Infrastructure	0	0	0	0
Infrastructure	Roads & Laneways	0	0	0	0
Infrastructure	Sheds & Yards	0	0	0	0
Infrastructure	Water infrastructure (dams, channels)	0	0	0	0
Total		**40**	**116**	**308**	**35**

Map 15. Grazing classification for Orana

Shade and Shelter services

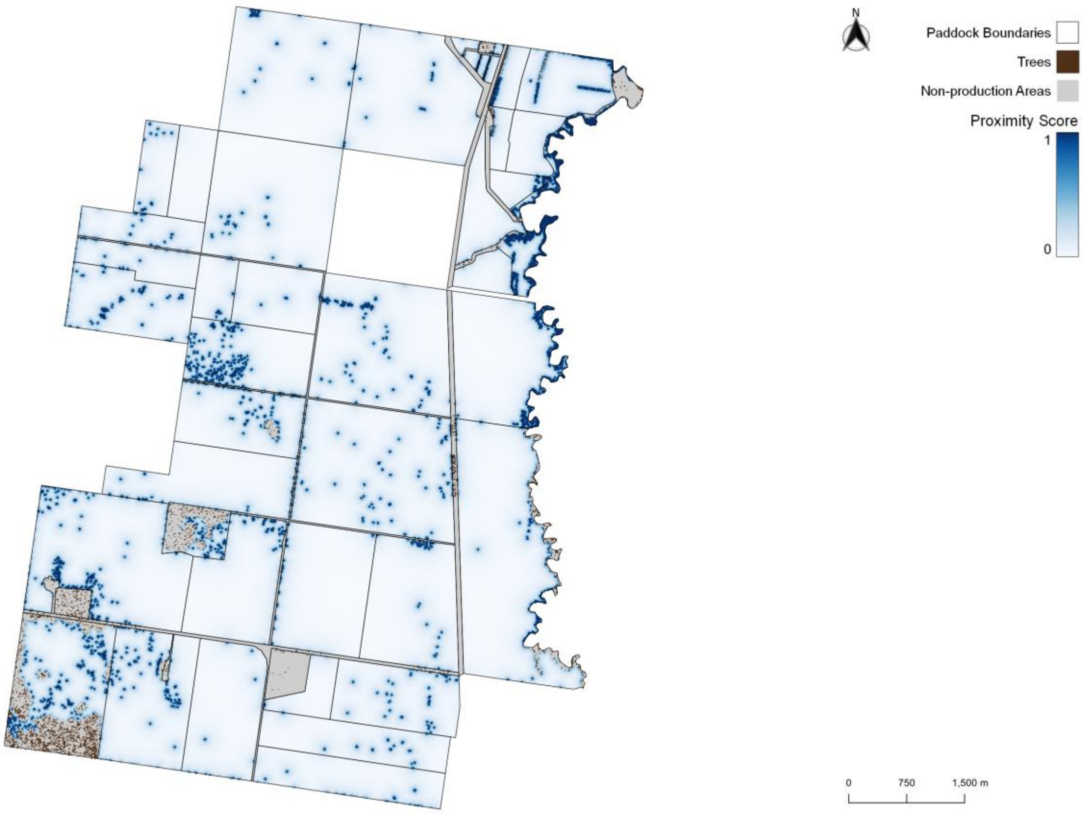
This section details summary accounts of the shade and shelter values on the farm. It provides information about a farms' overall spread of trees (proximity) and the amount of shade and shelter services in relation to production areas. Our research has shown that the woody vegetation on a farm has an important role to play in providing ecosystem services that contribute to production. The contribution can be in the form of shade and shelter for livestock and crops, as well as providing less obvious services such as hosting invertebrates that can provide pollination and pest-suppression services.

The contribution being provided has been assessed in several ways – firstly by looking at the relationship between the wooded vegetation and the production areas (proximity) – and then through the analysis of the shade and shelter services that are provided.

Proximity

Proximity is the degree to which production areas are close to wooded vegetation (including native and exotic trees, planted and remnant vegetation). The closer production areas are to wooded vegetation, the more likely they are to receive benefits from shade and shelter for crops and livestock, as well as beneficial animals such as pollinators and predators of pests.

A Proximity score for the whole farm has been derived using methods described in Appendix 5. The overall Proximity result is an average of all locations on Orana (Map 16). Proximity approaches 1 when all production areas that are within 10m of wooded vegetation. Proximity values of 0.5 indicate production areas are 20m from wooded vegetation; values of 0.2 are 50m from wooded vegetation; values of 0.1 are 100m from wooded vegetation, and values approaching 0 are further away from wooded vegetation. Non-production areas (grey) are excluded from Proximity calculations. For Orana, the Proximity score is 0.12.



Map 16. Proximity score for Orana

Shade

Woody vegetation provides protection from extreme temperatures and is associated with improved crop and livestock productivity. The Shade Index (ShdI) is a measure of the amount of shade provisioned to the production areas by trees for a single point in time (15:00 on the summer solstice). Summer solstice at 15:00 was determined as the time at which production areas would receive the maximum ecosystem service benefit. The value presented is an indicator of the proportion of shade throughout the day (i.e., a farm with a high shade index at 3pm is likely to have an overall higher value irrespective of time of day than a farm with lower shade value at 3pm). As shade may be provided to production areas by trees on and off the farm, data are presented for both accordingly. Refer to Appendix 6 for the detailed calculation method for shade.

Table 8. Extent (ha) and proportion of production areas receiving shade at 3pm on summer solstice from trees on-farm and off-farm on Orana

Shade Type	Production areas (ha)	Proportion of production areas	Grazing areas (ha)	Proportion of grazing areas	Cropping areas (ha)	Proportion of cropping areas
On farm	54.3	1.1%	41.5	2.6%	54.3	1.6%
Off farm	0.0	0.0%	0.0	0.0%	0.0	0.0%

Map 17. Shade ecosystem service for Orana

Shelter

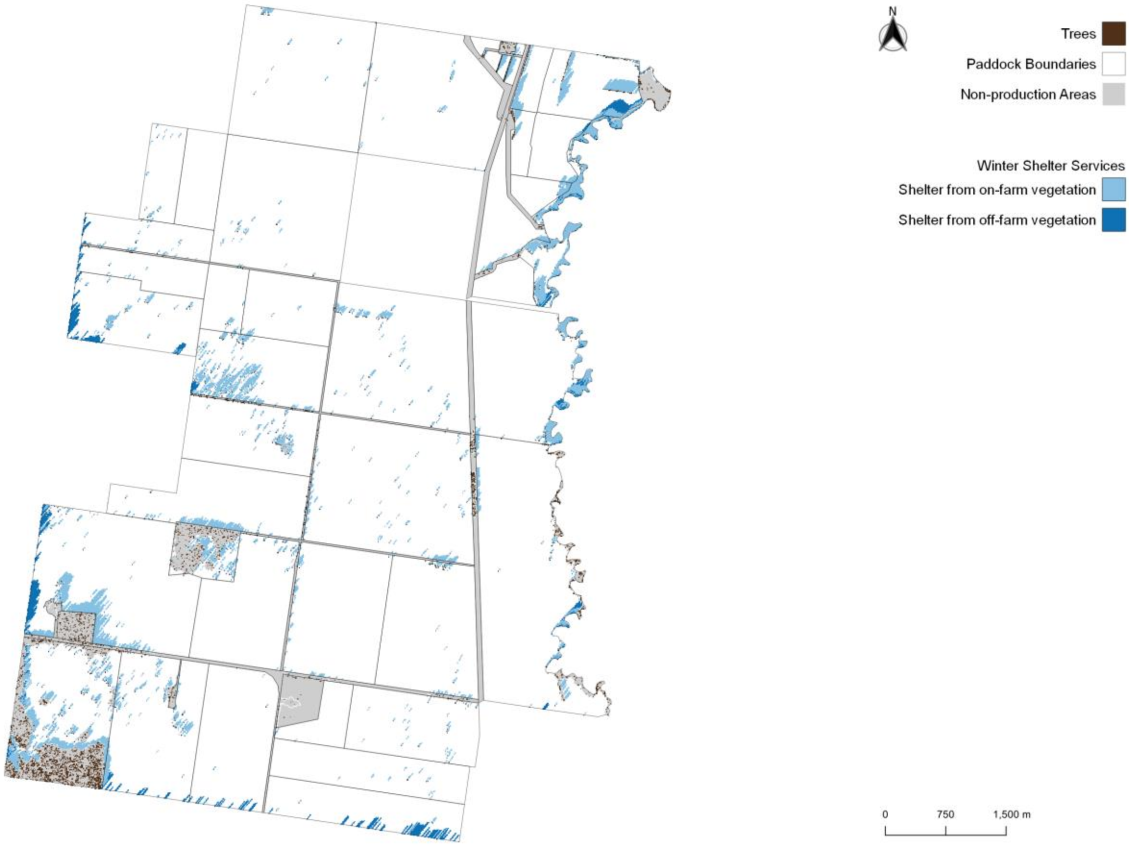
Amelioration of wind chill, frost and cold is important on livestock properties with survival and lambing success positively correlated with shelter in cold and wet conditions. In cropping enterprises, shelter reduces wind speed, loss of soil moisture and is most beneficial in hot and dry climates. These ecosystem services are also relevant for pasture productivity and yields on livestock enterprises. Shelterbelts are known to protect up to 20 times the height of the canopy while scattered trees and patches of contiguous canopy should have a lower protection factor. The parameters of this model are informed by results from the CSIRO *Perennial Prosperity* project, which is seeking to quantify the benefits of farm forestry for agricultural production. The Shelter Index (Shel) is a measure of the amount of shelter provisioned to the production areas by trees and is calculated for summer (NW winds) and winter conditions (SW winds).

Refer to Appendix 6 for the detailed calculation method for shelter services.

Table 9. Extent (ha) and proportion of production areas receiving shelter (summer/winter) from trees on-farm and off-farm on Orana

Shelter Type	Production areas (ha)	Proportion of production areas	Grazing areas (ha)	Proportion of grazing areas	Cropping areas (ha)	Proportion of cropping areas
Summer on farm	168.7	3.4%	97.9	6.2%	71.5	2.1%
Summer off farm	51.5	1.0%	13.6	0.9%	37.9	1.1%
Winter on farm	223.6	4.5%	123.4	7.8%	101.1	3.0%
Winter off farm	45.1	0.9%	8.6	0.5%	36.5	1.1%

Map 18. Shelter ecosystem service from summer hot winds for Orana



Map 19. Shelter ecosystem service from winter cold winds for Orana

Environmental Performance Indicators

Increasingly, businesses in the agricultural supply chain are asking for information about farm performance on key environmental issues such as pollution generation and efficiency of resource-use. This report aims to provide this information and to estimate the farm's dependence on non-renewable inputs. This section provides a summary of the environmental performance[1] of selected elements of the farm business:

Net GHG emissions | Scope 1, 2, select Scope 3, and carbon sequestration

This chart shows the average annual emissions and sequestrations for the farm. Quantities above the zero line are emissions in tonnes of carbon equivalent (tCO2-e). Quantities below the line are carbon sequestration (also in tCO2-e). All these movements are combined into the 'net' bars on the right to show the net total emissions for your farm. See next page for more detail.

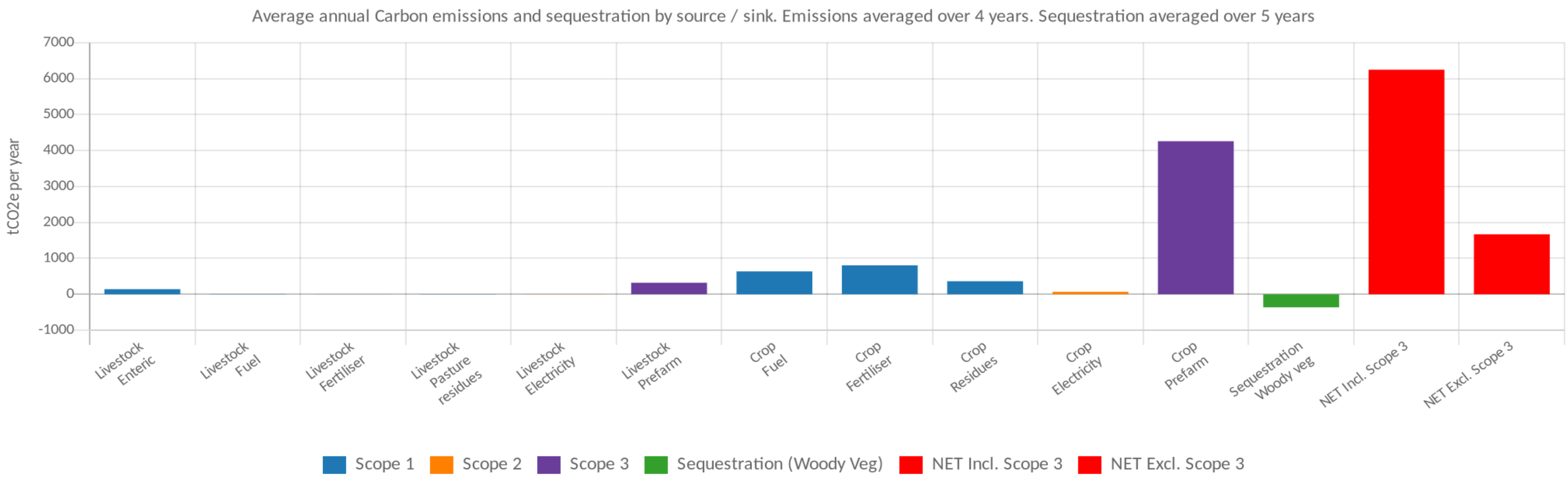


Figure 4. Average annual carbon emissions and sequestration by source/sink for Orana

[1] Environmental performance reporting refers to the reports of the consumption and use of resources such as water and fertiliser and the generation of pollution including waste to landfill, GHG emissions, and other emissions (e.g., soil, manure and plant residues to water and air).

Table 10. Definitions and source of data used in calculation of annual emissions and sequestration

Emissions Scope	Description
Scope 1	Emissions generated directly from on-farm operations. For example, livestock emissions as well as fuel and input use.
Scope 2	Electricity purchased from the grid and consumed on farm. Renewable energy generated and consumed on site is zero-carbon.
Scope 3	Emissions generated by off-farm suppliers in producing and transporting select inputs used on your farm. The inputs included are; sheep and cattle purchases, synthetic fertiliser, superphosphate, urea, feed (grain, hay/silage, lucerne). Also included are off-farm emissions from electricity use (e.g., transmission losses) and upstream fuel consumption (e.g., extraction of fossil fuels).
Carbon sequestration in woody vegetation[2]	Modelled tonnes of carbon sequestered on farm. This is an estimate of carbon sequestered in woody vegetation only over the time period of 2018 to 2022. This has been modelled using FLINTpro™ using the National Forest and Sparse Woody Vegetation dataset as the primary input.

The table below shows the average whole of farm Scope 1, 2, and selected Scope 3 emissions, and carbon sequestration in woody vegetation. This is also classified into geospheric and biospheric sources which have different influences on the global carbon cycle.

Geospheric emissions come from the use of fossil fuels. That is, fuel sourced from geological storages that have built up over millions of years. These emissions represent the longer-term carbon cycle.

Biospheric emissions: come from the use of biological sources (i.e., livestock, as well as clearing and oxidation of vegetation). These emissions represent the shorter-term carbon cycle.

Orana emits more carbon than it sequesters and is a net carbon emitter with respect to on-farm operations for the reporting period (2019-2022).

Orana has an average annual net total emissions of 6,248 tCO_2-e including Scope 3 (off-farm) emissions and 1,668 tCO_2-e excluding Scope 3 (off-farm) emissions. The largest emission source derives from pre-farm inputs (Scope 3) associated with crop production (Table 11).

We have excluded soil carbon sequestration from the net emissions calculations given the volatile nature of the soil carbon sequestration rates. Refer to Figure 6 for details of the estimated carbon stocks in the top 30cm of soil over the reporting period.

[2] Sequestration in the woody vegetation has been modelled using FLINTPro™ and represents carbon stock changes in woody vegetation, including stocks in remnant vegetation. The methods used do not take into account the concept of additionality or any carbon sold by the land holder. As such, these figures cannot be used for the purposes of trading carbon or to make formal claims of carbon neutrality. Each industry scheme will have specific requirements for calculation and compliance, and they may vary from the methods used here.

Table 11. Average annual greenhouse gas emissions and sequestration for Orana

Location of emissions	Scope	GHG Emissions	4-year average[3] annual emissions (tCO2-e)		
			Geospheric Source	Biospheric Source	Total
Livestock production			19.27	459.34	478.61
On-farm	1	Enteric/manure/urine/leaching and atmospheric deposition	0.00	141.29	141.29
	1	Energy (fuel consumption),	5.85	0.00	5.85
	2	Energy (electricity consumption)	3.92	0.00	3.92
	1	Fertiliser application	2.01	0.04	2.04
	1	Pasture/fodder crop residues (oxidisation)	0.00	5.07	5.07
Off-farm	3	Pre-farm (production and transport of select inputs and upstream energy emissions)	7.49	312.94	320.43
Crop production			2,464.86	3,666.96	6,131.82
On-farm	1	Energy (fuel consumption)	636.20	0.00	636.20
	2	Energy (electricity consumption)	68.70	0.00	68.70
	1	Fertiliser application	761.67	43.70	805.37
	1	Crop residues (oxidisation)	0.00	362.64	362.64
Off-farm	3	Pre-farm (production and transport of select inputs and upstream energy emissions)	998.29	3,260.63	4,258.92
		Total Emissions	2,484.13	4,126.30	6,610.44
		On-farm | Scope 1 (Direct) total	1,405.73	552.73	1,958.47
		On-farm | Scope 2 (Indirect) total	72.62	0.00	72.62
		Off-farm | Scope 3 (Indirect) total	1,005.78	3,573.57	4,579.35
		Carbon sequestered in woody vegetation[4]			(362.7)
		Net total emissions (excluding scope 3)			1,668.4
		Net total emissions (including scope 3)			6,247.7

[3] Farm emissions tend to vary significantly season to season due to production variations, so we use up to a five-year average (depending on data availability) to reflect usual business activity. For example, Scope 3 input emissions are calculated using purchases rather than when inputs are actually used. Averaging spreads out these bulk purchases for increased data accuracy.
[4] Sequestration in woody vegetation has been modelled using FLINTPro™ and represents carbon stock changes in woody vegetation, including stocks in remnant vegetation. The methods used do not take into account the concept of additionality or any carbon already sold by the land holder. As such, these figures cannot be used for the purposes of trading carbon or to make formal claims of carbon neutrality. Each industry scheme will have specific requirements for calculation and compliance, and they may vary from the methods used here.

Carbon stocks and sequestration in woody vegetation

This graph shows estimated carbon stocks and sequestration in the woody vegetation across your whole farm. Carbon stocks refer to the amount of carbon stored on your farm (estimated using woody vegetation – forests[5] and plantings only), whereas carbon sequestration is the ecosystem service that draws down and stores carbon (i.e., into carbon stocks). This data uses satellite imagery and regional modelling rather than actual on farm carbon tests. It covers the past, present, and future (dotted lines). The blue line estimates above ground carbon from living woody vegetation. The green line estimates below ground woody vegetation (the carbon stored in roots - this is different to soil carbon which is not calculated). The orange line shows dead woody vegetation (e.g. fallen logs and branches), and the red line shows wood harvested and used in wood products (construction, furniture, paper). These four lines are added together to represent the total carbon stored in woody vegetation (purple line). Carbon sequestration is represented by the movement in the purple line between periods. Refer to Appendix 7 for the detailed calculation method for the carbon stocks in woody vegetation.

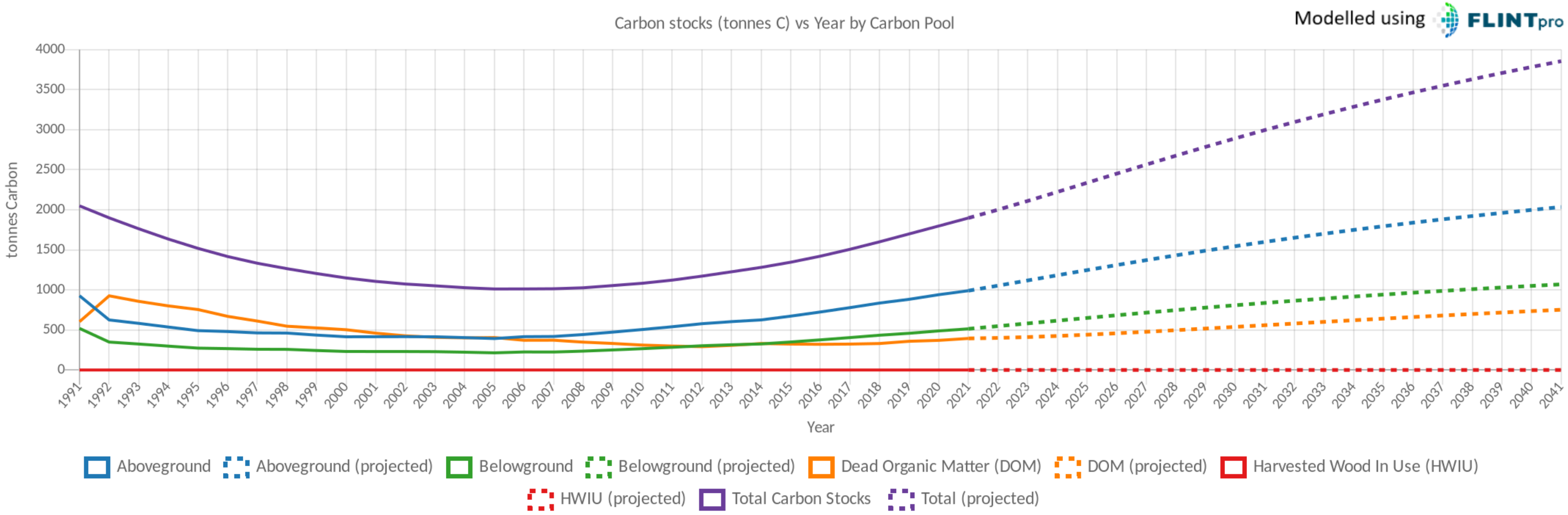


Figure 5. Estimated carbon stocks and sequestration in woody vegetation on Orana, 1991-2021 (and projected to 2041)

---

[5] For application within FLINTpro, a forest is considered to be land that contains woody vegetation which has, or has the potential to, obtain more than 20% canopy cover in vegetation more than 2m in height, consistent with the definition above. The forest potential extent was defined as land that has woody vegetation (>5%) and achieves 'forest' cover at least three times over the simulation period (1989-2021) according to the National Forest and Sparse Woody Vegetation Data (Version 6.0 - 2021 Release). The data product used also contains the other classes detailed in the forest definition, and therefore classifies the landscape into non-woody vegetation (<5% canopy cover), sparse woody vegetation (5-19% canopy cover) and forest (>20% canopy cover). Where land does not achieve forest cover at least three points in time (between 1989 and 2021), it is treated as non-forest for the whole simulation and excluded from the assessment. The approach of treating sparse vegetation as 'forest' when it achieves forest cover was taken to reduce loss and gain events when an area fluctuates between just over and just under the 20 percent canopy threshold. This approach results in a conservative outcome of emissions and removals.

Carbon stocks and sequestration in soil

To calculate the annual carbon stock for a property over a study period, Downforce Technologies (www.downforce.tech) produces a digital twin of a property at 10m spatial resolution every 10 days. The digital twin is built by creating a localised model which combines national soil data, multiple environmental layers and high temporal and spatial resolution satellite data. Through this modelling process annual average SOC % layers are produced over the study period (e.g. 5 or 6 years). These annual SOC % layers provide a high-resolution overview of the spatial variability in SOC over a property. They are a valuable resource, particularly when linked to climate and management practices to determine which practices are having a positive and negative impact on soil carbon stores.

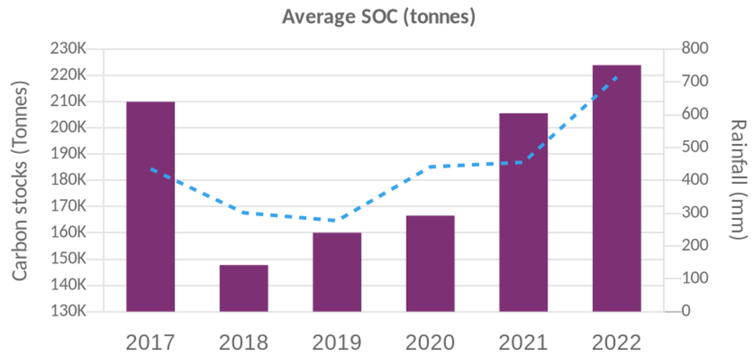
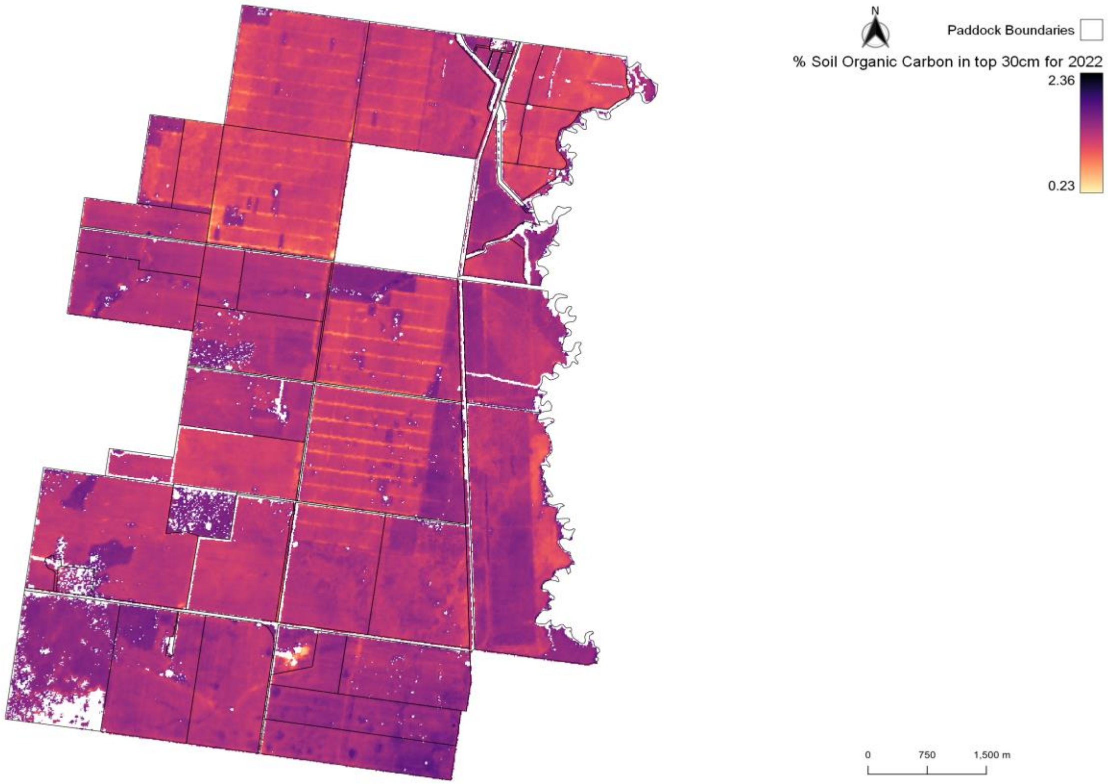


Figure 6. Soil Carbon Stocks on Orana, 2017-2022

From these annual SOC layers, in combination with bulk density and coarse fraction the Carbon stock (t/ha and TCO_2eq) for the property is calculated. Changes in the annual carbon stock values provide a view on the carbon sequestered within the property each year.

The modelled carbon stocks in the top 30 cm of soil for Orana in 2022 is 223,882 tonnes of carbon.

It is important to note that SOC in the top 30cm of the soil will vary with soil moisture, and so it can be expected that SOC % values will vary significantly over time. It is for this reason that we have excluded SOC from the overall farm carbon balance.



Map 20. Percentage of soil organic carbon in top 30cm for Orana for 2022.

Summary resource use efficiency and pollution generation

Table 12: Selected resource use efficiency and pollution estimates for the whole farm business.

Enterprise / Metric	Description	Estimate
Livestock Enterprise		
Rainfall use efficiency	The amount of production given the amount of rainfall. Dry Sheep Equivalent per ha per 100mm of rainfall.	0.27 DSE/ha/100mm rainfall
Water use	Livestock drinking and embedded water in fodder	7.33 Litres H_2O / kg liveweight
Water pollution generated	Includes estimates of Nitrogen leeched from fertiliser on pastures and crops fed to livestock	0.00 kg N leached / kg liveweight
Waste generated	Packaging waste associated with purchased inputs for the production systems (e.g. wrapping on bales, containers for liquid inputs)	0.00 kg waste / kg liveweight
Cropping Enterprise		
Rainfall use efficiency	The amount of production given the amount of rainfall. Tonne of crop per ha per 100mm of rainfall.	0.33 T/ha/100mm rainfall
Water use	Irrigation of crops for sale and embedded water in purchased inputs	210.31 Litres H_2O / Tonne crop
Water pollution generated	Includes estimates of Nitrogen leeched from fertiliser on crops	0.00 kg N leached / Tonne crop
Waste generated	Packaging waste associated with purchased inputs for the production systems (e.g. containers for liquid inputs)	0.01 kg waste / Tonne crop

Environmental Performance (per product)

The following tables provide estimates of resource use intensity and pollution associated with each product produced by the business. We use multi-year averages to represent the usual performance of the business. Apportionment of resources or pollution to a product is based on the biophysical proportion, not the value in monetary terms. We have explained how the estimates are produced in 'Notes' to the Environmental Performance Estimates (see Table 16).

Table 13: Summary of resource use and pollution intensity of sheep meat production on Orana

Sheep – based on kg liveweight sold				**Benchmark**
Metric	**Units**	**4-year average**	**Notes (see Table 16)**	**WA Wheet Sheep Zone - 300-600mm**[6]
Water Pollution Generated	kg N leached / kg liveweight	0.00	3	N/A
GHG emissions (livestock emissions + emissions associated with pasture and fodder management)	kg CO_2e / kg liveweight	9.76	4	9.4
Waste (non-biodegradable)	kg waste / kg liveweight	0.00	5	N/A
Water use (livestock drinking and embedded water in fodder)	litres H_2O / kg liveweight	19.36	6	84.5
Normalised stress weighted water consumption (including evaporation)	litres H_2O-eqiv/ kg liveweight	26.21	7	10
Nitrogen use efficiency	kg N applied / kg liveweight	0.07	8	N/A
Lime use efficiency	kg Lime applied / kg liveweight	0.00	9	N/A
Phosphorus use efficiency	kg P applied / kg liveweight	0.11	10	N/A

[6] S.G Wiedemann et al. (2016) Resource use and greenhouse gas emissions from three wool production regions in Australia. Journal of Cleaner Production 122: 121e132

Table 14: Summary of resource use and pollution intensity of crop production (including fodder crops) on Orana

Crop – based on TONNE of crop produced				Benchmark
Metric	**Units**	**4-year average**	**Notes (see Table 16)**	**TBA[7]**
Water Pollution Generated	kg N leached / Tonne crop	0.00	3	TBA
GHG emissions (fuel use, fertiliser use)	Tonne CO_2e / Tonne crop	1.07	4	TBA
Waste (non-biodegradable)	kg waste / Tonne crop	0.01	5	TBA
Water use (including water used in preparation of applied fertilisers)	litres H_2O / Tonne crop	210.31	6	TBA
Normalised stress weighted water consumption	litres H_2O-eqiv/ Tonne crop	284.82	7	TBA
Nitrogen use efficiency	kg N applied / Tonne crop	28.25	8	TBA
Lime use efficiency	kg Lime applied / Tonne crop	0.00	9	TBA
Phosphorus use efficiency	kg P applied / Tonne crop	13.76	10	TBA

[7] Benchmarks for crops are still under development, as it is not practical to have a generic benchmark across a consolidated set of crops, but rather benchmarks at individual crop types (or classes of crops – e.g. coarse grains) is more appropriate. These benchmarks will need to be locally relevant as well, as yields vary dramatically across different agro-ecological zones.

Non-renewable (finite) resources

An important consideration in assessment of farm enterprise sustainability is the degree of dependence on finite resources. These include phosphorous and lime supplied from mines and water sourced from fossil aquifers[8].

We estimate that the proportion of inputs that are finite is 2.3% of total inputs (by weight).

Table 15: Estimates of proportion of finite resources used in enterprise (that the enterprise has no present substitute for).

Finite resource[9]	4-year average (tonnes)	Proportion
Phosphorous	76.60 Tonnes from mined stocks	2.3% of nutrient replenishment (tonnes)
Lime	0.00 Tonnes from mined stocks	0% of pH remediation (tonnes)
Fossil Water	0 Litres from fossil aquifers	0% of total water use

[8] Aquifers that contain fossil water and that are not able to be significantly recharged from surface water or other aquifers.
[9] Fossil fuel amounts are already reported. The entity considers that suitable substitutes (e.g., electric vehicles) will be available in future. Accordingly, the entity considers that it has no obligate dependence on fossil fuel.

Notes to Environmental Performance reporting

This section explains the estimation methods. The detailed calculations and scientific references for these are available in an open access publication[10]. Search in Sustainability Account, Management and Policy Journal for: "A natural capital accounting framework to communicate the environmental credentials of individual wool-producing businesses". Authors: Ogilvy, O'Brien, Lawrence, Gardner. https://www.emerald.com/insight/content/doi/10.1108/SAMPJ-06-2021-0191/full/html.

Table 16: Notes to the Environmental Performance Estimates

Note	Reporting element	Estimation method
1	GHG from geosphere	This is an estimate of the GHG emissions associated with the use of fossil fuels (oxidation of materials sourced from geological storages).
2	GHG from biosphere	This is an estimate of the GHG emissions generated from biological sources including livestock and clearing and oxidation of vegetation.
3	Water Pollution Generated	This is an estimate of nitrogen from fertiliser and manure leeching into waterways and storages.
5	GHG emissions (livestock emissions + emissions associated with pasture and fodder management)	This is a summary of the total GHG emissions (all sources) associated with a product.
6	Waste (non-biodegradable)	This estimates the generation of non-biodegradable waste from packaging e.g., silage wrappers, chemical containers.
7	Water use (livestock drinking and embedded water in fodder)	This estimates the consumption of water by livestock and the water embedded in fodder consumed by livestock.
8	Normalised stress weighted water consumption (including evaporation)	This is a reflection of the use of water in the context of the amount of rainfall (water stress) of the region of operation. It adjusts water use estimates to reflect relative rainfall.
9	Nitrogen use efficiency	This estimates the amount of nitrogen used to produce a product.
10	Lime use efficiency	This estimates the amount of lime used to produce a product.
11	Phosphorus use efficiency	This estimates the amount of phosphorus used to produce a product.

[10] Publication and open access of this article was made possible with the support of Australian Wool Innovation (AWI).

Biodiversity – Bird species list

The following bird species were observed on the property during the field assessments done to date. The '# of sites at which species detected' refers to the number of biodiversity survey sites at which each species was recorded. Species' 'reporting rate' refers to the proportion of surveys during which a species was recorded (total number of surveys = number of sites x number of visits). 'Habitat preference' refers to the type of habitat in which the species typically occurs: either 'open country', 'open-tolerant', 'wetland' or 'woodland-dependant'. Conservation status refers to current status according to national and state threatened species conservation legislation: the Commonwealth Environmental Protection and Biodiversity Conservation Act 2000 (EPBC) or the Victorian Flora and Fauna Guarantee Act 1988.

Table 17: Bird Species Observations on Orana

Habitat Preference	Common Name (* = introduced species)	Scientific Name	Conservation Status		# Sites at which species detected	Reporting Rate
			EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Woodland	Common Bronzewing	Phaps chalcoptera			3	0.03
Woodland	Peaceful Dove	Geopelia placida			2	0.02
Woodland	Tawny Frogmouth	Podargus strigoides			1	0.01
Woodland	Sacred Kingfisher	Todiramphus sanctus			1	0.01
Woodland	White-throated Treecreeper	Cormobates leucophaea			1	0.01
Woodland	Brown Treecreeper	Climacteris picumnus	Vulnerable		6	0.16
Woodland	Black-chinned Honeyeater	Melithreptus gularis			1	0.01
Woodland	Noisy Friarbird	Philemon corniculatus			1	0.01
Woodland	Spiny-cheeked Honeyeater	Acanthagenys rufogularis			1	0.01
Woodland	Red Wattlebird	Anthochaera carunculata			3	0.04
Woodland	Yellow-plumed Honeyeater	Ptilotula ornata			2	0.02
Woodland	Spotted Pardalote	Pardalotus punctatus			2	0.02
Woodland	Weebill	Smicrornis brevirostris			1	0.01
Woodland	Yellow Thornbill	Acanthiza nana			1	0.04
Woodland	Crested Shrike-tit	Falcunculus frontatus			1	0.01
Woodland	Golden Whistler	Pachycephala pectoralis			1	0.01

Habitat Preference	Common Name (* = introduced species)	Scientific Name	Conservation Status		# Sites at which species detected	Reporting Rate
			EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Woodland	Grey Shrike-thrush	Colluricincla harmonica			3	0.05
Woodland	Grey Fantail	Rhipidura albiscapa			1	0.01
Woodland	Restless Flycatcher	Myiagra inquieta			3	0.05
Woodland	White-winged Chough	Corcorax melanorhamphos			5	0.09
Woodland	Red-capped Robin	Petroica goodenovii			2	0.02
Woodland	Eastern Yellow Robin	Eopsaltria australis			1	0.01
Woodland	Rufous Songlark	Megalurus mathewsi			2	0.02
Woodland	Diamond Firetail	Stagonopleura guttata	Vulnerable	Vulnerable	1	0.01
Waterbirds	Australian Shelduck	Tadorna tadornoides			1	0.01
Waterbirds	Australian Wood Duck	Chenonetta jubata			2	0.02
Waterbirds	Pacific Black Duck	Anas superciliosa			1	0.01
Waterbirds	Grey Teal	Anas gracilis			1	0.01
Waterbirds	Dusky Moorhen	Gallinula tenebrosa			1	0.01
Waterbirds	Yellow-billed Spoonbill	Platalea flavipes			1	0.01
Waterbirds	White-faced Heron	Egretta novaehollandiae			1	0.01
Shrub	Superb Fairy-wren	Malurus cyaneus			6	0.11
Shrub	White-fronted Chat	Epthianura albifrons			3	0.03
Shrub	Singing Honeyeater	Lichenostomus virescens			1	0.01
Shrub	Southern Whiteface	Aphelocephala leucopsis	Vulnerable		1	0.01
Shrub	House Sparrow*	Passer domesticus			2	0.02
Rank grass/swamp	Purple Swamphen	Porphyrio porphyrio			1	0.01
Rank grass/swamp	Australian Reed-warbler	Acrocephalus australis			1	0.01
Open-tolerant	Whistling Kite	Haliastur sphenurus			1	0.01
Open-tolerant	Laughing Kookaburra	Dacelo novaeguineae			2	0.02

Habitat Preference	Common Name (* = introduced species)	Scientific Name	Conservation Status		# Sites at which species detected	Reporting Rate
			EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Open-tolerant	Australian Hobby	Falco longipennis			1	0.01
Open-tolerant	Sulphur-crested Cockatoo	Cacatua galerita			2	0.05
Open-tolerant	Red-rumped Parrot	Psephotus haematonotus			8	0.12
Open-tolerant	Crimson Rosella	Platycercus elegans			1	0.01
Open-tolerant	Eastern Rosella	Platycercus eximius			12	0.22
Open-tolerant	White-plumed Honeyeater	Ptilotula penicillata			7	0.21
Open-tolerant	Noisy Miner	Manorina melanocephala			5	0.11
Open-tolerant	Striated Pardalote	Pardalotus striatus			9	0.21
Open-tolerant	Yellow-rumped Thornbill	Acanthiza chrysorrhoa			5	0.08
Open-tolerant	Black-faced Cuckoo-shrike	Coracina novaehollandiae			5	0.07
Open-tolerant	Pied Butcherbird	Cracticus nigrogularis			4	0.06
Open-tolerant	Dusky Woodswallow	Artamus cyanopterus			2	0.05
Open-tolerant	Willie Wagtail	Rhipidura leucophrys			10	0.16
Open-tolerant	Corvid	Corvus			1	0.01
Open-tolerant	Jacky Winter	Microeca fascinans			1	0.01
Open-tolerant	Tree Martin	Petrochelidon nigricans			3	0.03
Open country	Crested Pigeon	Ocyphaps lophotes			6	0.07
Open country	Black-shouldered Kite	Elanus axillaris			3	0.03
Open country	Black Kite	Milvus migrans			2	0.02
Open country	Nankeen Kestrel	Falco cenchroides			6	0.06
Open country	Brown Falcon	Falco berigora			4	0.04
Open country	Galah	Eolophus roseicapilla			17	0.34
Open country	Long-billed Corella	Cacatua tenuirostris			4	0.06
Open country	Australian Magpie	Gymnorhina tibicen			22	0.41

Habitat Preference	Common Name (* = introduced species)	Scientific Name	Conservation Status		# Sites at which species detected	Reporting Rate
			EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Open country	Magpie-lark	Grallina cyanoleuca			3	0.04
Open country	Little Raven	Corvus mellori			10	0.11
Open country	Australian Raven	Corvus coronoides			5	0.05
Open country	Welcome Swallow	Hirundo neoxena			6	0.07
Open country	Common Starling*	Sturnus vulgaris			4	0.04
Grassland	Stubble Quail	Coturnix pectoralis			5	0.08
Grassland	Horsfield's Bushlark	Mirafra javanica			4	0.06
Grassland	Eurasian Skylark*	Alauda arvensis			1	0.01
Grassland	Brown Songlark	Cincloramphus cruralis			1	0.01
Grassland	Australian Pipit	Anthus australis			9	0.16

Biodiversity – Plant species list

The following plant species were observed on the property during the field assessments done to date. The '# of sites at which species detected' refers to the number of biodiversity survey sites at which each species was recorded. Species' 'reporting rate' refers to the proportion of sites at which a species was recorded. 'Life form' refers to general form the species takes: 'Tree', 'Shrub (perennial or annual)', 'Graminoid' (grasses, sedges, rushes) (perennial or annual), 'Forb (perennial or annual)', 'Fern', 'Climber (perennial or annual)'. Conservation status refers to the species' current status according to national and state threatened species conservation legislation: the Commonwealth Environmental Protection and Biodiversity Conservation Act 2000 (EPBC) or the Victorian Flora and Fauna Guarantee Act 1988.

Table 18: Plant Species Observations on Orana

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Tree	Acacia salicina - Willow Wattle			2	0.08
Tree	Acacia stenophylla - River Myall			1	0.04
Tree	Allocasuarina luehmannii - Buloke		Critically Endangered	1	0.04
Tree	Eucalyptus camaldulensis - River Red-gum			3	0.12
Tree	Eucalyptus melliodora - Yellow Box			1	0.04
Tree	Eucalyptus microcarpa - Grey Box			6	0.24
Shrub (Perennial)	Acacia acinacea - Gold-dust Wattle			1	0.04
Shrub (Perennial)	Acacia pycnantha - Golden Wattle			1	0.04
Shrub (Perennial)	Atriplex semibaccata - Berry Saltbush			4	0.16
Shrub (Perennial)	Enchylaena tomentosa - Ruby Saltbush			13	0.52
Shrub (Perennial)	Eutaxia microphylla - Spiny Bushpea			1	0.04
Shrub (Perennial)	Lycium ferocissimum - African Box-thorn*			3	0.12
Shrub (Perennial)	Marrubium vulgare - Horehound*			7	0.28
Shrub (Perennial)	Melaleuca lanceolata - Moonah			1	0.04
Shrub (Perennial)	Olea europea - Common Olive*			5	0.20
Shrub (Perennial)	Rhagodia spinescens - Hedge Salt-bush			1	0.04

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Shrub (Perennial)	Sclerolaena muricata - Black Roly-poly			1	0.04
Shrub (Perennial)	Solanum nigrum - Black Nightshade*			2	0.08
Other	Chenopodiaceae sp.*			1	0.04
Other	Isolepis sp.*			3	0.12
Other	Juncus sp.*			1	0.04
Other	Spergularia sp.*			1	0.04
Graminoid (Perennial)	Aristida behriana - Bunch Wiregrass			9	0.36
Graminoid (Perennial)	Arthropodium fimbriatum - Nodding Chocolate-lily			4	0.16
Graminoid (Perennial)	Austrostipa blackii - Crested Speargrass			3	0.12
Graminoid (Perennial)	Austrostipa elegantissima - Feather Speargrass			2	0.08
Graminoid (Perennial)	Austrostipa gibbosa			6	0.24
Graminoid (Perennial)	Austrostipa oligostachya			1	0.04
Graminoid (Perennial)	Austrostipa scabra - Speargrass			3	0.12
Graminoid (Perennial)	Austrostipa scabra subsp. falcata			9	0.36
Graminoid (Perennial)	Austrostipa setacea - Corkscrew Grass			2	0.08
Graminoid (Perennial)	Austrostipa stuposa			2	0.08
Graminoid (Perennial)	Carex inversa - Knob Sedge			1	0.04
Graminoid (Perennial)	Carex tereticaulis - Poong'ort			1	0.04
Graminoid (Perennial)	Chloris truncata - Windmill-grass			6	0.24
Graminoid (Perennial)	Enneapogon nigricans - Dark Nineawn-grass			1	0.04
Graminoid (Perennial)	Enteropogon acicularis - Spider-grass			7	0.28
Graminoid (Perennial)	Eragrostis elongata - Close-headed Love-grass			1	0.04
Graminoid (Perennial)	Lolium sp.*			20	0.80
Graminoid (Perennial)	Paspalidium sp.			1	0.04

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Graminoid (Perennial)	Paspalum dilatatum - Paspalum*			1	0.04
Graminoid (Perennial)	Phalaris aquatica - Toowoomba Canary-grass*			3	0.12
Graminoid (Perennial)	Romulea rosea - Onion-grass*			8	0.32
Graminoid (Perennial)	Rytidosperma caespitosum - Common Wallaby-grass			4	0.16
Graminoid (Perennial)	Rytidosperma erianthum			1	0.04
Graminoid (Perennial)	Rytidosperma indutum			1	0.04
Graminoid (Perennial)	Rytidosperma monticola		Endangered	1	0.04
Graminoid (Perennial)	Rytidosperma setaceum - Bristly Wallaby-grass			10	0.40
Graminoid (Perennial)	Rytidosperma sp.			2	0.08
Graminoid (Perennial)	Tricoryne elatior - Yellow Rush Lily			2	0.08
Graminoid (Perennial)	Walwhalleya proluta - Rigid Panic			7	0.28
Graminoid (Annual)	Aira sp.*			6	0.24
Graminoid (Annual)	Avena barbata - Bearded Oat*			10	0.40
Graminoid (Annual)	Avena fatua - Wild Oat*			6	0.24
Graminoid (Annual)	Brachypodium distachyon - False Brome*			2	0.08
Graminoid (Annual)	Bromus diandrus - Great Brome*			4	0.16
Graminoid (Annual)	Bromus hordeaceus - Soft Brome*			7	0.28
Graminoid (Annual)	Bromus rubens - Red Brome*			7	0.28
Graminoid (Annual)	Ehrharta longiflora - Annual Veldt-grass*			1	0.04
Graminoid (Annual)	Hordeum distichon - Two-rowed Barley*			4	0.16
Graminoid (Annual)	Hordeum hystrix - Mediterranean Barley Grass*			4	0.16
Graminoid (Annual)	Poa annua - Annual Meadow-grass*			1	0.04
Graminoid (Annual)	Schismus barbatus - Arabian Grass*			1	0.04
Graminoid (Annual)	Triticum aestivum - Wheat*			2	0.08

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Graminoid (Annual)	Vulpia bromoides - Squirrel-tail Fescue*			1	0.04
Graminoid (Annual)	Vulpia muralis - Wall Fescue*			10	0.40
Graminoid (Annual)	Vulpia myuros - Rat's-tail Fescue*			1	0.04
Forb (Perennial)	Chenopodium desertorum			4	0.16
Forb (Perennial)	Crassula helmsii - Swamp Crassula			3	0.12
Forb (Perennial)	Einadia nutans - Climbing Saltbush			3	0.12
Forb (Perennial)	Epilobium billardiereanum			1	0.04
Forb (Perennial)	Euchiton sp.			2	0.08
Forb (Perennial)	Euphorbia dallachyana - Mat Spurge			12	0.48
Forb (Perennial)	Haloragis aspera - Rough Raspwort			2	0.08
Forb (Perennial)	Helminthotheca echioides - Ox-tongue*			8	0.32
Forb (Perennial)	Hypochaeris radicata - Cat's-ear*			7	0.28
Forb (Perennial)	Lepidium africanum - Common Peppercress*			10	0.40
Forb (Perennial)	Maireana enchylaenoides - Wingless Bluebush			8	0.32
Forb (Perennial)	Maireana excavata - Bottle Bluebush			4	0.16
Forb (Perennial)	Maireana humillima			1	0.04
Forb (Perennial)	Maireana pentagona - Hairy Bluebush			1	0.04
Forb (Perennial)	Marsilea drummondii - Common Nardoo			1	0.04
Forb (Perennial)	Medicago sativa - Lucerne*			1	0.04
Forb (Perennial)	Oxalis perennans - Grassland Wood-sorrel			14	0.56
Forb (Perennial)	Ptilotus spathulatus - Pussy-tails			1	0.04
Forb (Perennial)	Rhodanthe anthemoides - Chamomile Sunray			1	0.04
Forb (Perennial)	Rumex brownii - Slender Dock			4	0.16
Forb (Perennial)	Rumex dumosus - Wiry Dock			2	0.08

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Forb (Perennial)	Rumex tenax - Narrow-leaf Dock			1	0.04
Forb (Perennial)	Salvia verbenaca - Wild Sage*			6	0.24
Forb (Perennial)	Senecio quadridentatus - Cottony Fireweed			2	0.08
Forb (Perennial)	Sida corrugata - Variable Sida			13	0.52
Forb (Perennial)	Solanum elaeagnifolium - Silver-leaf Nightshade*			1	0.04
Forb (Perennial)	Spergularia media - Greater Sea-spurrey*			1	0.04
Forb (Perennial)	Trifolium repens - White Clover*			1	0.04
Forb (Perennial)	Vittadinia cuneata - Fuzzweed			1	0.04
Forb (Perennial)	Vittadinia gracilis - Woolly New Holland Daisy			12	0.48
Forb (Perennial)	Wahlenbergia capillaris			1	0.04
Forb (Perennial)	Wahlenbergia luteola			3	0.12
Forb (Annual)	Alternanthera nodiflora - Common Joyweed			4	0.16
Forb (Annual)	Arctotheca calendula - Capeweed*			16	0.64
Forb (Annual)	Brassica napus - Rape*			4	0.16
Forb (Annual)	Brassica sp.*			3	0.12
Forb (Annual)	Cirsium vulgare - Spear Thistle*			4	0.16
Forb (Annual)	Cotula australis - Common Cotula			2	0.08
Forb (Annual)	Crassula colorata - Dense Crassula			7	0.28
Forb (Annual)	Crassula decumbens - Spreading Crassula			1	0.04
Forb (Annual)	Crepis sp.*			2	0.08
Forb (Annual)	Cucumis myriocarpus - Paddy Melon*			1	0.04
Forb (Annual)	Daucus glochidiatus - Australian Carrot			1	0.04
Forb (Annual)	Echium plantagineum - Paterson's Curse*			13	0.52
Forb (Annual)	Erodium botrys - Big Heron's-bill*			2	0.08

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Forb (Annual)	Erodium brachycarpum - Heron's-bill*			1	0.04
Forb (Annual)	Erodium cicutarium - Common Heron's-bill*			9	0.36
Forb (Annual)	Erodium crinitum - Blue Heron's-bill			3	0.12
Forb (Annual)	Heliotropium europaeum - Common Heliotrope*			2	0.08
Forb (Annual)	Hypochaeris glabra - Smooth Cat's-ear*			4	0.16
Forb (Annual)	Lactuca serriola - Prickly Lettuce*			10	0.40
Forb (Annual)	Lamium amplexicaule - Dead Nettle*			1	0.04
Forb (Annual)	Laphangium luteoalbum - Jersey Cudweed			3	0.12
Forb (Annual)	Lythrum hyssopifolia - Lesser Loosestrife			9	0.36
Forb (Annual)	Malva parviflora - Small-flowered Mallow*			5	0.20
Forb (Annual)	Medicago polymorpha - Burr Medic*			2	0.08
Forb (Annual)	Petrorhagia dubia - Hairy Pink*			4	0.16
Forb (Annual)	Plantago bellardii - Silky Plantain*			1	0.04
Forb (Annual)	Plantago lanceolata - Ribwort*			2	0.08
Forb (Annual)	Pogonolepis muelleriana			1	0.04
Forb (Annual)	Polygonum aviculare - Hogweed*			10	0.40
Forb (Annual)	Raphanus sativus - Radish*			2	0.08
Forb (Annual)	Silybum marianum - Variegated Thistle*			1	0.04
Forb (Annual)	Sisymbrium orientale - Indian Hedge-mustard*			3	0.12
Forb (Annual)	Sonchus oleraceus - Sow Thistle*			21	0.84
Forb (Annual)	Spergularia rubra - Red Sand-spurrey*			2	0.08
Forb (Annual)	Trifolium angustifolium - Narrow-leaved Clover*			5	0.20
Forb (Annual)	Trifolium arvense - Hare's-foot Clover*			10	0.40
Forb (Annual)	Trifolium campestre - Hop Clover*			9	0.36

Lifeform	Scientific Name – Common Name (* = introduced species)	Conservation Status		# Sites at which species detected	Reporting Rate
		EPBC	Victorian Flora and Fauna Guarantee Act 1988		
Forb (Annual)	Trifolium glomeratum - Clustered Clover*			17	0.68
Forb (Annual)	Trifolium subterraneum - Subterranean Clover*			7	0.28
Forb (Annual)	Triptilodiscus pygmaeus - Common Sunray			1	0.04
Forb (Annual)	Urtica urens - Small Nettle*			1	0.04
Forb (Annual)	Xanthium spinosum - Bathurst Burr*			4	0.16
Fern	Cheilanthes sieberi - Narrow Rock-fern			2	0.08
Climber (Perennial)	Convolvulus angustissimus - Native Bindweed			6	0.24
Climber (Perennial)	Convolvulus remotus - Grassy Bindweed			1	0.04
Climber (Annual)	Vicia sativa - Common Vetch*			2	0.08

Biodiversity – Invertebrate species list

The following arthropod species have been collected from the property during the field assessments. Samples were collected using the “sweep net” technique, whereby animals are captured from the air and brushed off vegetation with a hoop net. These taxa were identified using next-generation sequencing techniques (as per ‘Closest species match in GenBank’). The DNA of many of Australia’s arthropod taxa remain unknown, however most organisms can be classified to family level with a high degree of certainty, despite the identity of the species remaining unknown. This allows for inference of the taxon’s primary function in the ecosystem. The main function performed by each taxa has been provided, including whether this is likely to be beneficial or detrimental to the farm operation. This information should not be considered to be a comprehensive invertebrate survey, but rather a snapshot of the arthropod diversity on the farm.

Table 19: Invertebrate Observations on Orana

Function(s)	Beneficial / Pest	Order	Family	Closest species match in GenBank
Detritivore	Beneficial	Collembola	Entomobryidae	-unidentified-
Detritivore	Beneficial	Collembola	Sminthuridae	Sminthurus viridis
Detritivore	Beneficial	Psocoptera	Elipsocidae	Propsocus pulchripennis
Detritivore	Beneficial	Psocoptera	Lachesillidae	-unidentified-
Detritivore, Parasite, Pollinator	Beneficial	Diptera	Sarcophagidae	-unidentified-
Detritivore, Pollinator	Beneficial	Diptera	Calliphoridae	-unidentified-
Detritivore, Pollinator	Beneficial	Diptera	Chironomidae	Chironomus tepperi
Detritivore, Pollinator	Beneficial	Diptera	Drosophilidae	-unidentified-
Detritivore, Pollinator	Beneficial	Diptera	Muscidae	-unidentified-
Detritivore, Pollinator	Beneficial	Diptera	Sciaridae	-unidentified-
Herbivore	Pest	Coleoptera	Cerambycidae	Phytoecia caerulescens
Herbivore	Pest	Hemiptera	Alydidae	Leptocorisa acuta
Herbivore	Pest	Hemiptera	Aphididae	Acyrthosiphon pisum
Herbivore	Pest	Hemiptera	Aphrophoridae	-unidentified-
Herbivore	Pest	Hemiptera	Cicadellidae	Orosius orientalis
Herbivore	Pest	Hemiptera	Cicadidae	-unidentified-
Herbivore	Pest	Hemiptera	Lygaeidae	Nysius plebeius

Function(s)	Beneficial / Pest	Order	Family	Closest species match in GenBank
Herbivore	Pest	Hemiptera	Miridae	-unidentified-
Herbivore	Pest	Hemiptera	Oxycarenidae	-unidentified-
Herbivore	Pest	Hemiptera	Pachygronthidae	-unidentified-
Herbivore	Pest	Hemiptera	Rhyparochromidae	Udeocoris nigroaeneus
Herbivore	Pest	Lepidoptera	Lycaenidae	Zizina otis
Herbivore	Pest	Lepidoptera	Noctuidae	Helicoverpa punctigera
Herbivore	Pest	Lepidoptera	Oecophoridae	Philobota eremosema
Herbivore	Pest	Lepidoptera	Pieridae	Pieris rapae
Herbivore	Pest	Lepidoptera	Tortricidae	Merophyas divulsana
Herbivore	Pest	Orthoptera	Acrididae	-unidentified-
Herbivore	Pest	Orthoptera	Tettigoniidae	-unidentified-
Herbivore	Pest	Thysanoptera	Thripidae	-unidentified-
Herbivore, Detritivore, Pollinator	Pest	Diptera	Anthomyiidae	-unidentified-
Herbivore, Pollinator	Pest	Diptera	Chloropidae	-unidentified-
Parasite, Pollinator	Beneficial	Diptera	Culicidae	-unidentified-
Parasite, Pollinator	Beneficial	Diptera	Tabanidae	-unidentified-
Pollinator	Beneficial	Diptera	-unidentified-	-unidentified-
Pollinator	Beneficial	Diptera	Agromyzidae	-unidentified-
Pollinator	Beneficial	Diptera	Ceratopogonidae	-unidentified-
Pollinator	Beneficial	Diptera	Chamaemyiidae	-unidentified-
Pollinator	Beneficial	Diptera	Conopidae	-unidentified-
Pollinator	Beneficial	Diptera	Ephydridae	-unidentified-
Pollinator	Beneficial	Diptera	Heleomyzidae	-unidentified-
Pollinator	Beneficial	Diptera	Hybotidae	Chersodromia isabellae
Pollinator	Beneficial	Diptera	Pipunculidae	Clistoabdominalis trochanteratus

Function(s)	Beneficial / Pest	Order	Family	Closest species match in GenBank
Pollinator	Beneficial	Diptera	Simuliidae	-unidentified-
Pollinator	Beneficial	Diptera	Syrphidae	-unidentified-
Pollinator	Beneficial	Diptera	Tephritidae	-unidentified-
Pollinator	Beneficial	Diptera	Therevidae	-unidentified-
Pollinator	Beneficial	Hymenoptera	Apidae	Apis mellifera
Pollinator	Beneficial	Hymenoptera	Braconidae	Aphidius ervi
Pollinator	Beneficial	Hymenoptera	Encyrtidae	-unidentified-
Pollinator	Beneficial	Hymenoptera	Formicidae	-unidentified-
Pollinator	Beneficial	Hymenoptera	Ichneumonidae	-unidentified-
Pollinator	Beneficial	Hymenoptera	Trichogrammatidae	-unidentified-
Predator	Beneficial	Araneae	Araneidae	-unidentified-
Predator	Beneficial	Araneae	Ctenidae	-unidentified-
Predator	Beneficial	Araneae	Linyphiidae	-unidentified-
Predator	Beneficial	Araneae	Nephilidae	Nephila edulis
Predator	Beneficial	Araneae	Theridiidae	Cryptachaea veruculata
Predator	Beneficial	Coleoptera	Cleridae	Opilo whitei
Predator	Beneficial	Coleoptera	Coccinellidae	Hippodamia variegata
Predator	Beneficial	Mantodea	Mantidae	Phyllovates chlorophaea
Predator	Beneficial	Neuroptera	Hemerobiidae	Micromus tasmaniae
Predator	Beneficial	Odonata	Corduliidae	Hemicordulia mindana

Appendix 1: Survey locations for ecological assessments

To satisfy the requirements for confidence in the NCA's within the project budget for NC measurement, we have used a mix of measurement approaches to assess the natural capital of Orana. These include informal and formal farmer observations, remote sensing, rapid ecological assessments by performed independent experts. A detailed methodology document has been designed to underpin the NCA. It describes the sampling scheme (sampling strategy and protocols) used to assess the type and condition of the ecosystems. This is updated as required in response to changing management goals and practices.

52 surveys were undertaken by trained field ecologists as part of the Farm-scale Natural Capital Accounts program. The locations of the are shown in the adjacent map.

Imagery: Google; Image (c) 2022 Maxar Technologies, Image (c) 2022 CNES/Airbus

Table 20 summarises this information providing details of site locations for direct observations and which ecosystem units condition estimates have been imputed from these values.

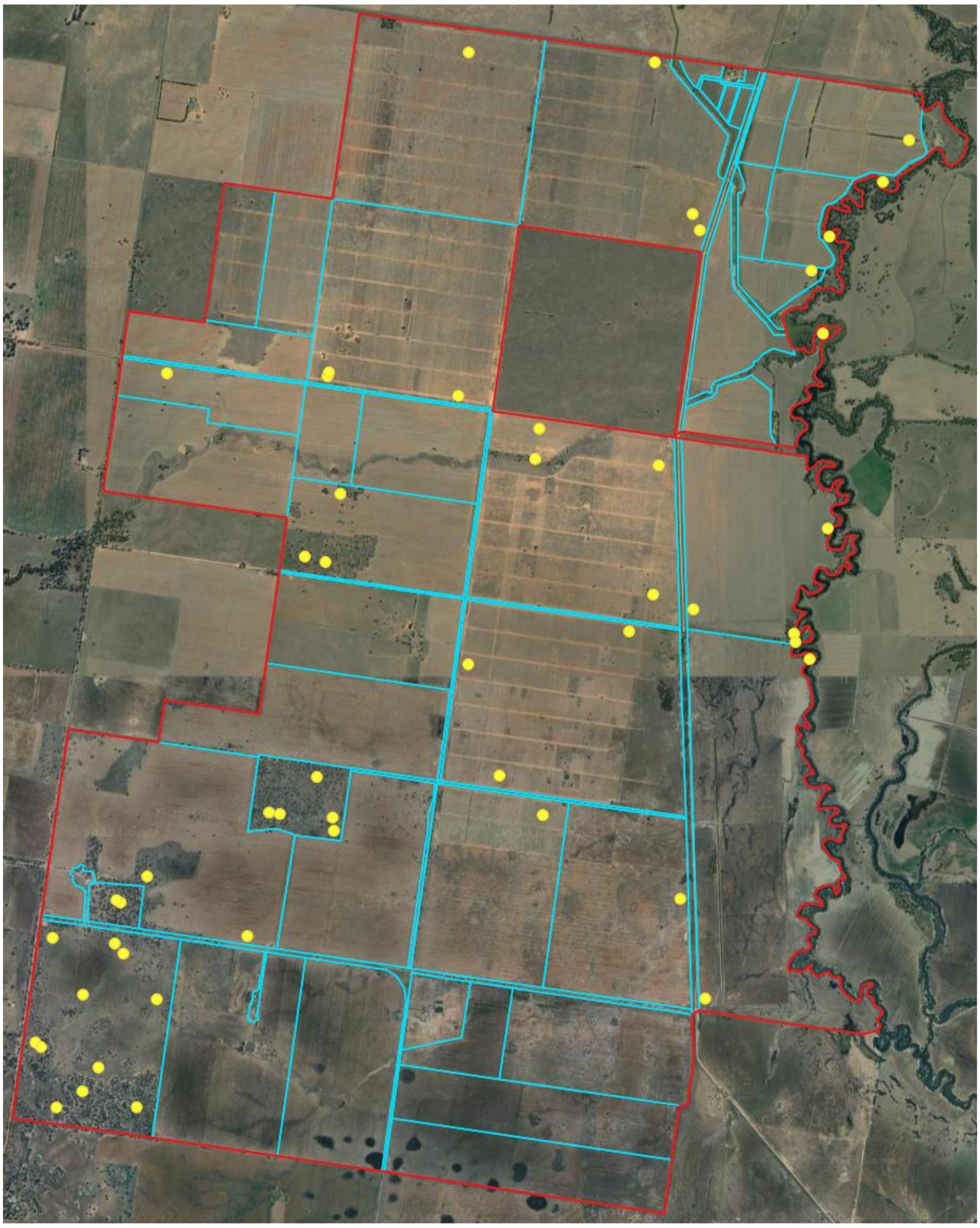


Table 20: Natural Capital measurement design for ecosystem condition assessments

Orana - Ecosystem condition measurement process as @ 18/10/2021		
Condition Data Source	**Ecosystem State**	**Paddocks where the source information was used to impute the Ecosystem State**
Visited - P21	C1	P16, P21, P23, P27
Visited - P14	C2	P2
Visited - P19	C2	P15, P17, P18, P21, P22, P24, P8
Visited - P23	C2	P32, P33, P34, P35, P36, P37
Visited - P29	C2	
Visited - P9	C2	P10, P11, P17, P20, P3, P5, P6, P7
Visited - P36	C3	P38
Visited - P37	C3	P39, P40, P41, P42, P43, P44
Visited - P42	C3	
Visited - P1	DG1	P1
Visited - P12	DG1	P12
Visited - P37	DW3	River1
Visited - River2	DW3	P14, P2, P28, P9, River1
Visited - P10	EWV3	P26
Visited - P17	EWV3	
Visited - P23	EWV3	
Visited - P27	EWV3	P25
Visited - P28	EWV3	P29
Visited - P23	MG5	P28, P30, River1, River2
Visited - P39	PNT2	
Visited - P1	TW1	
Visited - P1	TW1	
Visited - P12	TW1	
Visited - P13	TW1	P1, P36
Visited - P14	TW1	P1, P12, P2
Visited - P36	TW1	P36
Visited - P37	TW3	P37, P39, River1
Visited - P21	TW4	
Visited - River1	TW4	River2
Remote Imagery	PNT2	P38, P39, P40, River2, TL1, TL2

Appendix 2: Detailed description of state and transition models

For the purposes of natural capital accounting, it is necessary to assign a 'State' (or identity) to an area that summarised characteristics of that particular area of land. The condition of this area can then be considered in the context of the purpose for which that area of land is managed, as well as alternative ecosystem services such as protection of soil, capacity to filter and purify water, potential for carbon storage and sequestration. Other primary and secondary purposes of an area of land may include livestock grazing, timber production, honey production or conservation. Thus, a particular area of land may have multiple purposes. For example: scattered trees among native grasslands have livestock production, conservation of biodiversity, carbon storage/sequestration and honey production potential and also regulate climate, water quality, and protect soil; a timber plantation where plantings are less dense can be used for livestock grazing, shelter, timber production and carbon storage/sequestration.

Identity states are well established for many native ecosystems in Australia. The frameworks that describe these identity 'states', and the transitions between states, are referred to as 'State and Transition' models (STMs). As outlined above, generally, in areas modified for agriculture, there has been a move towards lower tree cover and conversion of the ground layer vegetation from native species to exotic improved pastures and/or crops.

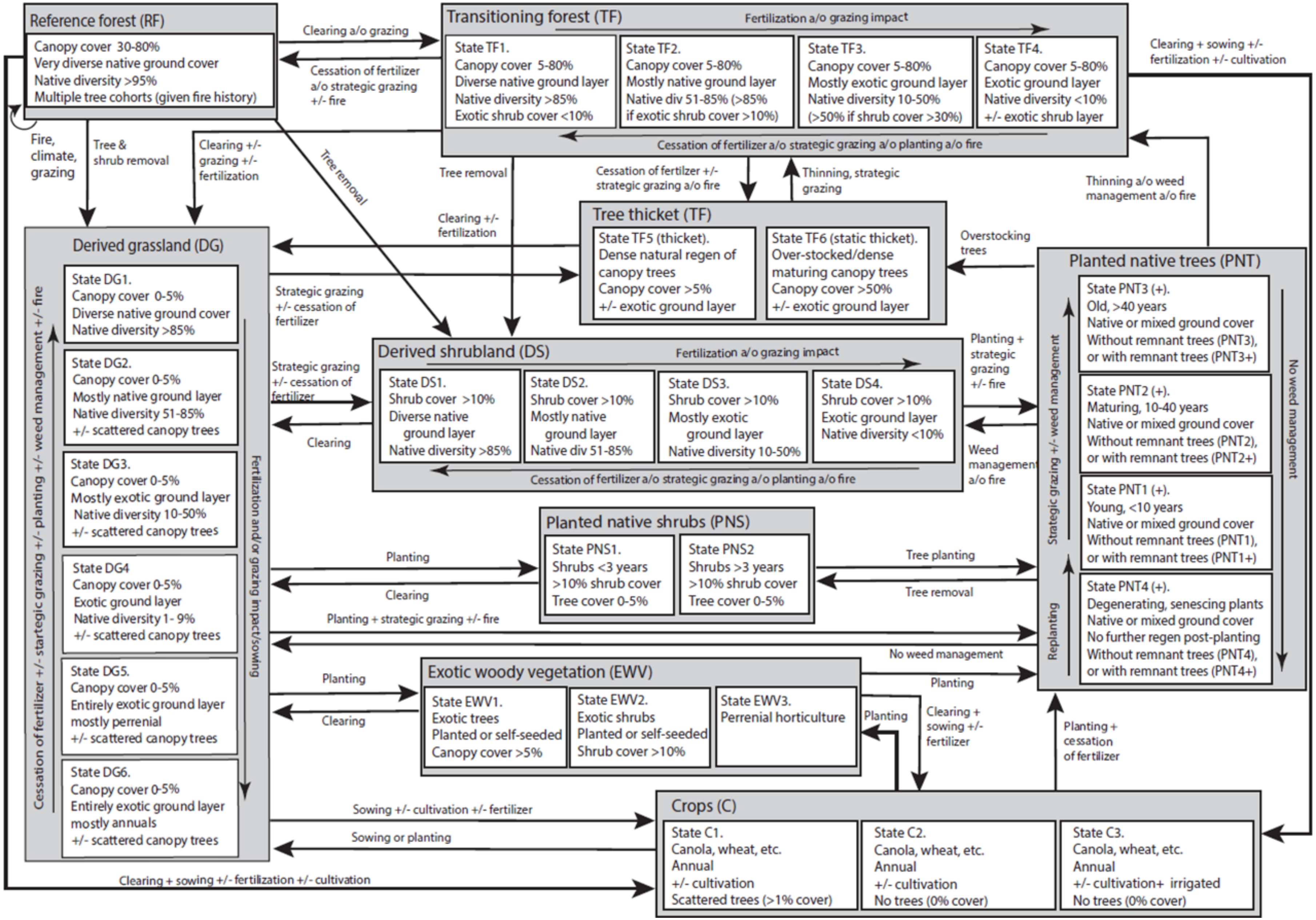
Some producers have chosen to restore characteristics of the original native ecosystem where there has been modification for agricultural production. However, the degree to which this is possible will depend on the level of modification of an area through past practices such as cultivation, fertiliser application, past cropping practices, and grazing management. 'Transitioning' to an identity state that more closely resembles the original native ecosystem is likely to impart greater resilience to a farm - as mentioned above. However, the end goal will depend on the goals of the landowners including whether the primary use for an area is for grazing production or for conservation. Management goals will also depend on the type of ecosystem services a farm business wishes to use as ‘free inputs from nature’ for livestock production i.e., the natural capital.

The FSNCA project has been built upon published 'state' and 'transition' identity classes for the temperate grassy woodland biome as outlined in Whitten et al., (2010). We apply these identity states to areas on a farm that retain general characteristics of the original native ecosystem such as remnant trees and some native herbaceous species. In some areas the original vegetation might have been a native grassland and the STM model used also applies to grasslands. In some places the original vegetation may have been more dense and scrubby forest but, for the purposes of this project, the basic principles in the simplified STM apply also. In the context of this project, determining the 'state' or 'transition' identity of an area enables a determination of the potential for provision of a range of ecosystem services. For the purposes of this project, we also created an extended State and Transition model to account for modified ecosystems that are common where land is managed for agriculture. This approach has been extended to produce STM for generic Forest, Grassland and Shrubland biomes.

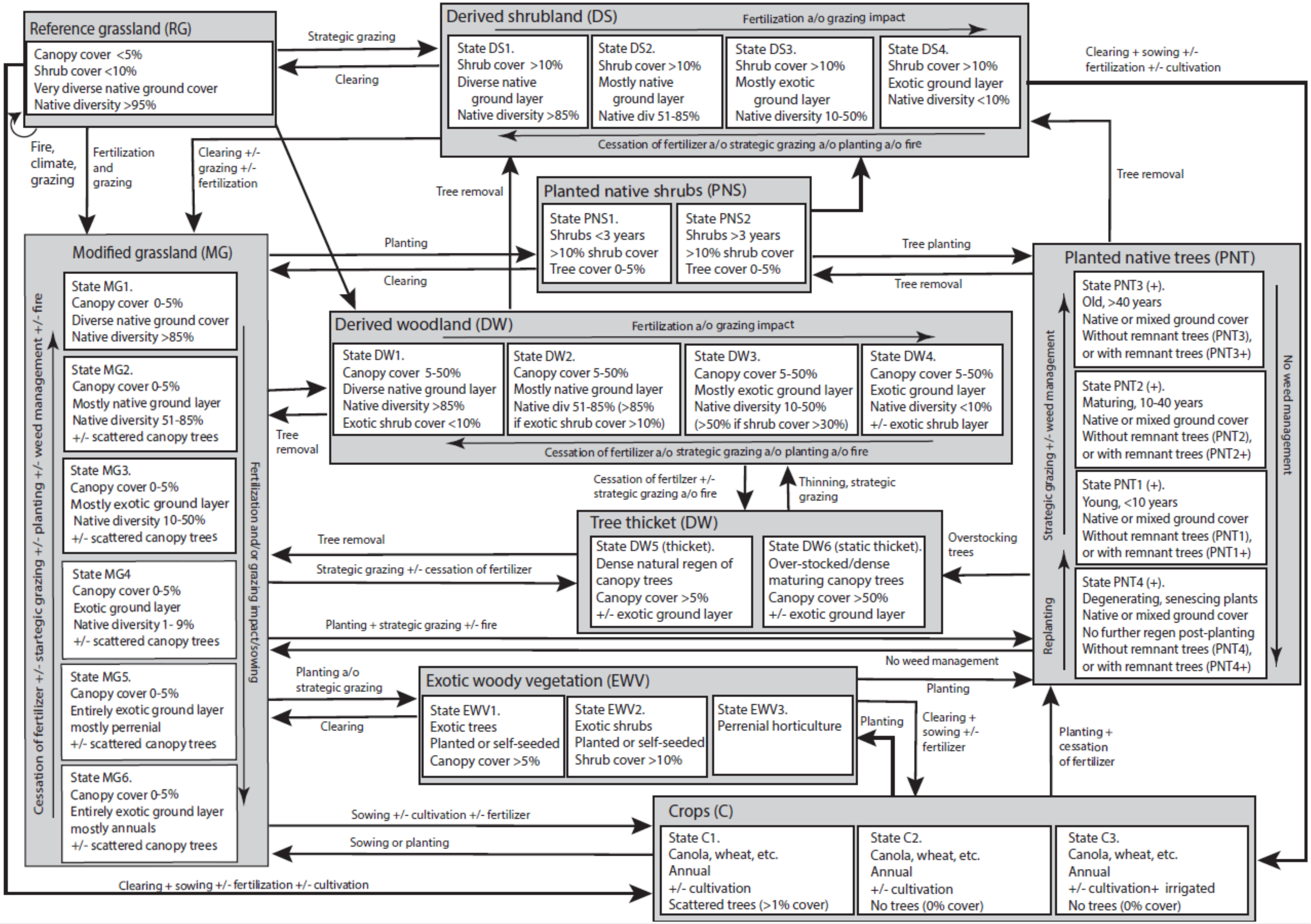
Each 'state' or 'transition' identity implies no value judgement. A value judgement only exists once management and production goals are considered. For example, a management goal for wool production may be to have persistent and palatable forage as well as areas for stock to shelter. These ecosystem services can be provided by a less modified native ecosystem or by an area forested with exotic or native timber if the canopy is open enough to allow good forage as well as timber production.

If, however, the primary management goal for an area is conservation and to serve markets for biodiversity should they emerge, it would be desirable to be moving towards an identity/state closer to 'reference' condition. It is all context and goal dependant.

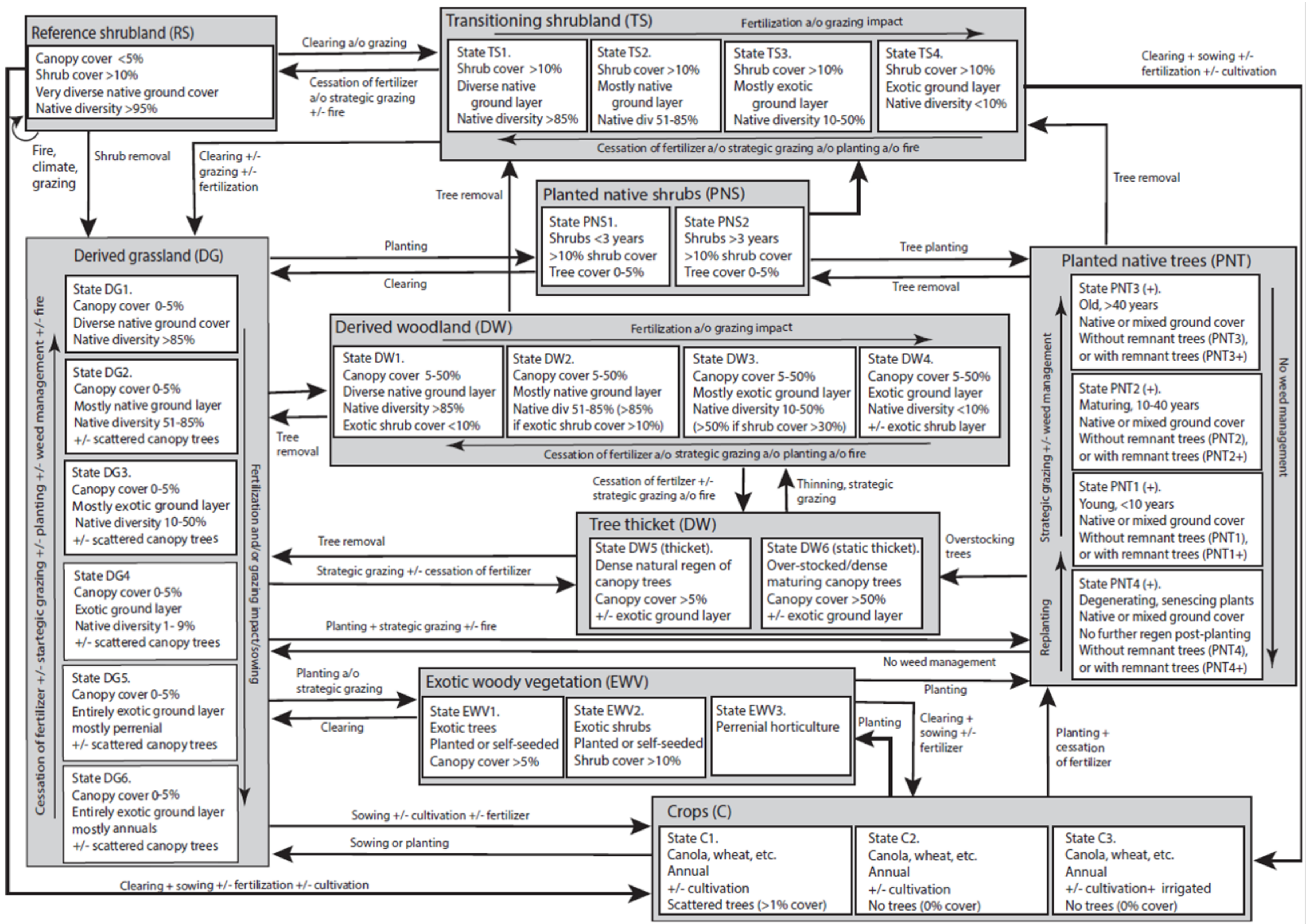
Forest State and Transition Model



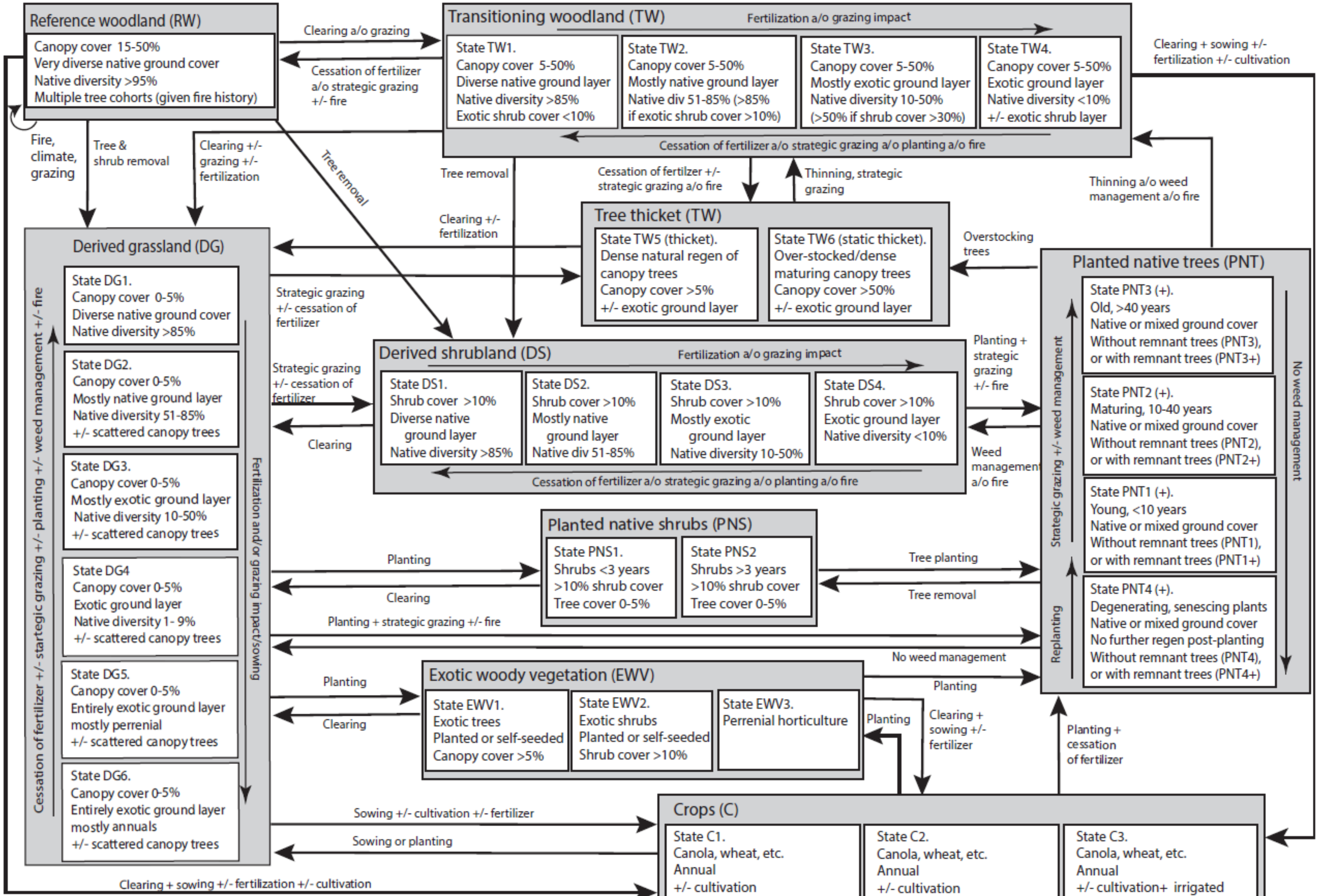
Grassland State and Transition Model



Shrubland State and Transition Model



Woodland State and Transition Model



Appendix 3: Calculation of Ecological Condition Score

An important aspect of natural capital is the degree of modification of a particular parcel of land from its 'natural' or 'reference' condition. For example, a grassy woodland that retains its tree canopy layer, shrub layer and a high proportion of native grasses and forbs in the ground layer has been modified substantially less (i.e., higher ecological integrity) than a grassy woodland that has had its tree canopy cleared, and the native ground layer replaced with introduced grasses. This is irrespective of land use – both parcels of grassy woodland may be used for grazing. This concept is analogous to that of 'ecosystem' or 'ecological condition' or 'vegetation condition' but is operationalised via the State and Transition models that classify discrete parcels of land into mutually exclusive ecosystem type and condition states.

Ecological condition will influence the extent to which a parcel of land contributes to the flow of virtually all ecosystem services but is particularly relevant to Supporting and Cultural ecosystem services, such as habitat for species (biodiversity) and maintenance of genetic diversity. It is well established that the amount (extent) of habitat in a landscape is the single most important factor affecting the diversity and abundance of native species in a landscape. Translated to a farm-scale, this equates to the area of habitat (native ecosystems) retained on a farm. However, given the variation in condition of native ecosystems on farms, allocating patches of vegetation that contribute to habitat for biodiversity is vexed, precluding an absolute measure of habitat extent. However, *Ecological Condition* is a useful surrogate for habitat extent – farms with higher values of Ecological Condition are likely to have a greater proportion of habitat (i.e., extent) that farms with lower values of Ecological Condition.

The nature of the relationship between Ecological Condition and flow of ecosystem services is likely to differ between services. An important point is that we are not making an *a priori* judgement on the *value* of parcels of land based on Ecological Condition (i.e., higher is not necessarily "better"). Rather, the value to the farmer will depend on the intended purpose of that land and any trade-offs between different ecosystem services that are inherent in that land use and management. For example, grassy woodland with high Ecological Condition may contribute significantly to the flow of ecosystem services such as habitat for species, carbon sequestration, pollination and shelter for livestock but only moderately to provision of forage for livestock. In contrast, an intensively managed exotic pasture with low Ecological Condition may contribute significantly to the provision of forage for livestock but only marginally, if at all, to provision of habitat for native species. It is up to the farmer to determine the balance of land uses on their farm necessary to achieve their business, production, lifestyle and environmental goals.

Method of calculation

Ecological Condition is an area-weighted measure that captures the overall level of ecological condition of a farm. All land parcels (ecosystem types) are included in the calculation. The first step involves assigning a weighting to every ecosystem type and condition state in the State and Transition models (see Table 21 for weightings and Appendix 2 for State and Transition models). The weighting represents the degree of modification for a particular ecosystem state, from 1 (reference state that retains its ecological integrity in full) to 0 (completely modified). Different systems for assigning the weighting have been considered (e.g., expert opinion, scaled to mid-point of attributes used to define condition states). For simplicity, we have included expert opinion in Table 21. Ecological Condition is then calculated as area-weighted sum of all ecosystem condition states present on a farm, divided by the total area of the farm:

Ecological condition = $\sum_i^k Ai * Wi$ / Total area of farm

where *Ai* is the total area of Ecosystem Condition State *i* and *Wi* is the assigned weighting for Ecosystem Condition State *i* (Table 21) for all *k* ecosystem condition states present on a farm.

Ecological Condition is a unitless index, that will be a continuous variable from 0 to 1.

NC2 (*Ecological condition*) is a unitless index, that will be a continuous variable from 0 to 1.

Table 21. Integrity weighting for ecosystem condition states

Category of Natural Capital Asset	Type of Asset	Condition State	Integrity weighting
Native ecosystems	Forest	RF	1
		TF1	0.9
		TF2	0.8
		TF3	0.6
		TF4	0.4
		TF5	0.5
		TF6	0.4
	Woodland	RW	1
		TW1	0.9
		TW2	0.8
		TW3	0.6
		TW4	0.4
		TW5	0.5
		TW6	0.4
		DW1	0.5
		DW2	0.4
		DW3	0.3
		DW4	0.2
		DW5	0.3
		DW6	0.2
	Shrubland	RS	1
		TS1	0.9
		TS2	0.8
		TS3	0.6
		TS4	0.4
		DS1	0.5
		DS2	0.4
		DS3	0.3
		DS4	0.2
	Grassland	RG	1
		MG1	0.9
		MG1+	0.9
		MG2	0.8
		MG2+	0.8
		MG3	0.6
		MG3+	0.6
Intensive land-use		MG4	0.4
		MG4+	0.4
		MG5	0.1
		MG5+	0.1
		MG5(i)	0.1
		MG6	0.1

		MG6+	0.1
		MG6(i)	0.1
Native ecosystems	Pasture	DG1	0.5
		DG1+	0.6
		DG2	0.4
		DG2+	0.5
		DG3	0.3
		DG3+	0.4
Intensive land-use		DG4	0.2
		DG4+	0.3
		DG5	0.1
		DG5+	0.2
		DG5(i)	0.1
		DG6	0.1
		DG6+	0.2
		DG6(i)	0.1
Planted vegetation	Planted vegetation	PNT1	0.15
		PNT1+	0.25
		PNT2	0.4
		PNT2+	0.5
		PNT3	0.6
		PNT3+	0.7
		PNT4	0.5
		PNT4+	0.6
		PNS1	0.2
		PNS2	0.4
Intensive land-use		EWV1	0.1
		EWV2	0.1
		EWV3	0.05
	Cropland	C1	0.15
		C2	0.05
		C3	0.05
	Infrastructure		0

Appendix 4: Detailed description of Grazing Classification

Forage Condition is a measure of the capacity of the farm to dependably produce quality forage for livestock. It is estimated using the proportion and diversity of perennial, palatable and productive forage plants (including native and exotic plants) on the land used for grazing.

Grasses that have these three characteristics are particularly favourable for livestock production and are called 3P grasses. The desired pasture mix for a farm will differ according to the management approach taken and the management goals of individual farmers. In most cases resilient forage production, including across variable seasons, will be a desirable goal. Thus, the approach taken for our forage condition assessments has been to consider native 3P species as equally valuable as introduced 3P pasture species. This differs a little from some industry approaches that can tend to focus more on introduced pasture species. It should be noted that in past industry programs such as Sustainable Grazing Systems and Evergraze/Prograze, native species that are perennial, palatable, productive – and also persistent – have been considered valuable and are also listed in industry guides as such. Native 3P species are often especially valuable in low input systems because they have evolved with a variable Australian climate and are therefore likely to persist very well in adverse climatic conditions. Thus, in the development of the forage condition indices for the FSNCA research, a diverse, mainly native pasture with several 3P native grasses and perennial forbs present will in many cases score the same as a pasture with a diverse mix of exotic grasses and perennial forbs, and possibly differently than a lower diversity pasture of exotic forage grasses. While this may differ a little from a more conventional, recent industry approach, it is the approach we have chosen for the Farm-scale NCA reports.

For every area visited on your farm, the ecologist assessed the pasture composition and assigned a forage classification value based on the criteria in the table below. Paddocks that weren't visited but had similar ground cover (evaluated using remote sensing) and management characteristics (from your farm records) to visited paddocks were assigned the same forage classification. The overall forage condition indicator is a weighted average of forage condition across the whole farm.

Table 22. Grazing classification definitions

Classification	***Description***
A	Very high levels of groundcover[1] (>90%), including perennial and palatable species and litter that contribute to soil protection and water and nutrient retention and an appropriate[2] mix of perennial, palatable and persistent species. Few invasive weeds (≤5%) are present and soil erosion is absent. A good amount of biomass is retained (e.g., a cricket ball wouldn't be easily seen from a few metres away), even when livestock are present, or after a grazing event.
B	High levels of groundcover (70-90%) with some decline in perennial and palatable species, including grass species and litter compared to class A and likely to be a minor presence of invasive weeds (>5-15%). There may be signs of previous erosion and potential for current erosion in some areas. Reasonable biomass (e.g., a golf ball wouldn't be easily seen from a few metres away) is retained even where grazing animals are present.
C	Moderate groundcover (40-70%), a low diversity of palatable and perennial species, and persistent species that protect soil assets in poor times are missing. Annual and/or perennial invasive weeds are significant (>15-50%). A high proportion of bare ground is likely to be present (up to 50%) and obvious signs of past erosion with current susceptibility to erosion high. Low biomass (e.g. a golf ball would very easily be seen from a few m away).
D	Low levels of groundcover (<40%) with a high proportion of bare ground (>50%), low pasture biomass most of the time and likely to very low in extended dry times, a low diversity of perennials and dominated by unpalatable species and/or annual weeds. Clear signs of past and current erosion present.

Appendix 5: Detailed methods for calculation of Proximity

Proximity captures the average distance of all production areas on the farm to wooded vegetation (native and exotic, planted and remnant). This metric will influence the likelihood and quality of some regulating ecosystem services received by production areas. For example, to receive micro-climate regulation benefits (e.g., shade, wind-reduction), the production land must be relatively close to wooded vegetation. Similarly, the extent of pollination and pest-suppression services delivered by beneficial invertebrates will be influenced the proximity of production areas to natural habitat (in combination with *Ecological condition*).

Proximity measures how close, on average, production areas are to wooded vegetation. All wooded vegetation (native and exotic, planted and remnant) that is captured by remote sensed imagery as canopy cover will be included in calculation of Proximity. It is calculated as the mean distance (*d*) from each pixel in the 'production' areas of a farm to the nearest wooded vegetation pixel (located either within/outside production areas).

The first step in the calculation of Proximity is to nominate which pixels are to be included in the 'production areas' on the farm. To do this, all ecosystem assets with production nominated as the primary or secondary purpose are identified. Areas of farm infrastructure (e.g., sheds, houses) are not included. Canopy cover is cropped to a 500 m buffer to include the contribution of areas of wooded vegetation beyond the farm boundary (i.e., on roadsides or neighbouring properties) in the calculation of *d*. Cells adjacent to tree cells are assigned the maximum obtainable value (*d* = 10). Treed cells are also given a value of 10 so as not to penalise farms based on their distribution of trees. The value, *d*, is then scaled to generate a value between 0 and 1 by calculating a ratio between 10 and the distance to the nearest tree for each cell (i.e. *d'* = 10/*d*; Figure 7). Proximity is calculated as the mean of *d'* across all production cells.

Proximity is a unitless index, that will be a continuous variable from 0 to 1. Values approaching 0 represent farms in which all production areas are at or close to the theoretical maximum distance from wooded vegetation and values approaching 1 represent farms in which all production areas are adjacent to wooded vegetation.

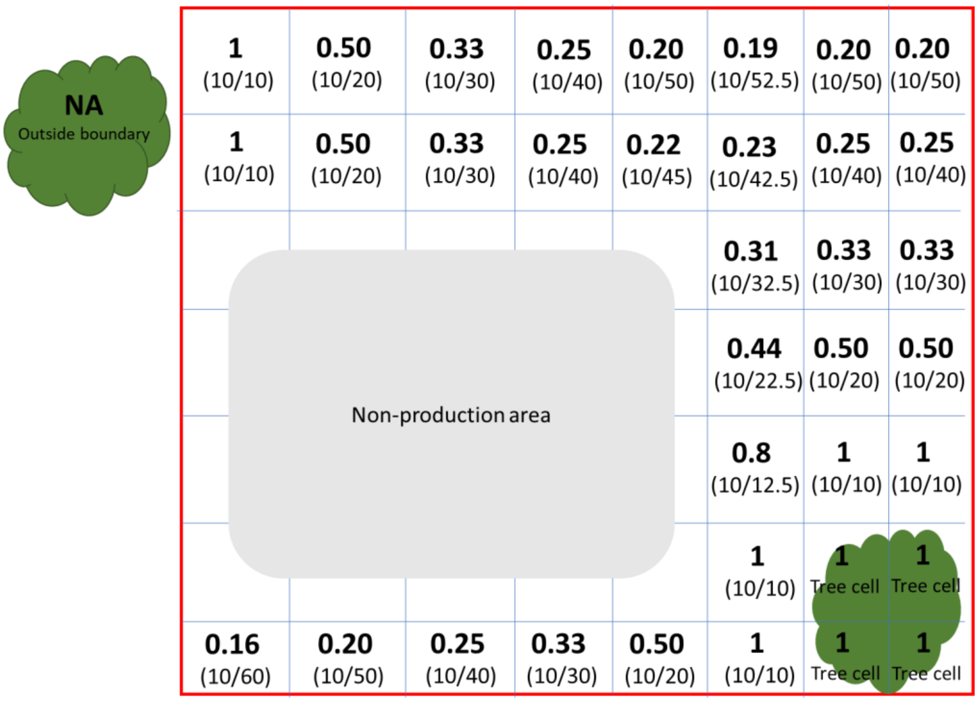


Figure 7. Conceptual diagram for Proximity. For each production cell, the distance to the nearest tree is calculated. All trees within a 500 m radius of the property are included. A ratio 10/distance is used to standardise the distance number between 0-1. Proximity is the mean across all production cells.

Appendix 6: Detailed methods for ecosystem service metrics

Detailed methods for generating invertebrate-related ecosystem services

Invertebrates were sampled from 130 transects (each transect was 210 m long) located on 38 farms across south-eastern Australia. Transects were located in paddocks containing canola and either high-species richness or low-species richness pastures. Transects stratified by the vegetation type adjacent to the paddock, being either remnant vegetation (typically woodland), replanted vegetation (usually a shelterbelt) or no woody vegetation (usually a grassy roadside verge or an adjacent paddock). In all cases, samples were collected from 5 locations along each transect (650 individual sites): in the vegetation adjacent to paddocks (-10 m), and 10 m, 30 m, 70 m and 200 m into the paddock.

For the decomposer community, invertebrates were sampled by scraping all litter and soil from the top 5 cm of two 15 cm X 15 cm quadrats randomly placed within a 1 m^2 quadrat at each sample point into a sealed plastic bag. In the laboratory, the contents of each sample bag was then placed into a Tullgren funnel to extract all invertebrates from the litter and soil, which were then identified to order level and counted. This allows a measure of abundance to be generated (i.e. the number of animals per square metre). To sample pollinators and beneficial predatory invertebrates, sweep netting was conducted, whereby animals are swept from the air and vegetation with a hoop net, using 50 ‘sweeps’ along a 50 m transect running perpendicular to the sampling transect (or parallel to the paddock boundary). Any invertebrates captured in the nets were stored in ethanol in plastic vials to transport back to the laboratory. From these samples, DNA was extracted and sequenced to provide high-resolution identification of taxa. This technique allows for the identification of cryptic species that may be difficult to identify visually. While DNA sequencing identifies unique species very well, the gene sequences of many taxa are not yet known. For these species, the nearest species match is provided from existing databases (usually a different species in the same genus). This allows for their ecological function to be inferred.

In the main accounts, we present spatially explicit models using remote sensed variables to predict ecosystems services across the entire farm. Prior to this, a ‘field model’ was developed for each group of interest (decomposers, pollinators and predators). This model included field data that was collected at the time of sampling, with the aim of identifying fine-scale habitat influences on arthropods. Data were collected relating to habitat structure in a 1 m^2 quadrat at each sampling site. Habitat features expected to influence abundance or species richness were measured, such as litter cover, soil moisture, vegetation structure, ground cover, grass height, presence of flowering and plant species richness. This ‘field model’ provides information about what is influencing each group of interest at the paddock scale and helps us understand what management actions may be important to regulate arthropod services on the farm.

Decomposers

The most widespread and numerous invertebrate detritivores found in surveys were members of the springtail order Poduromorpha. The species most commonly found are likely to be introduced to Australia and appear to prefer to live in disturbed ecosystems such as crops. Springtails, regardless of their origin, are likely to be having a beneficial impact on decomposition, though introduced populations of springtail may outcompete native detritivores.

At the paddock scale, several habitat features were found to show relationships with the abundance of detritivores. As detritivores live in the litter and topsoil, it follows that organic litter cover would impact their abundance (and potentially *vice versa*). Detritivore abundance decreased at litter levels above 60% cover (see Figure 8), potentially reflecting the impact of detritivores themselves on the litter (where fewer detritivores exist, litter breakdown is slower). This relationship may also reflect the preference of springtails for crops with low litter cover overall. Soil moisture also had a strong influence on the predicted detritivore abundance within the paddock: with increasing soil moisture, there is a predicted increase in detritivore abundance (see Figure 8).

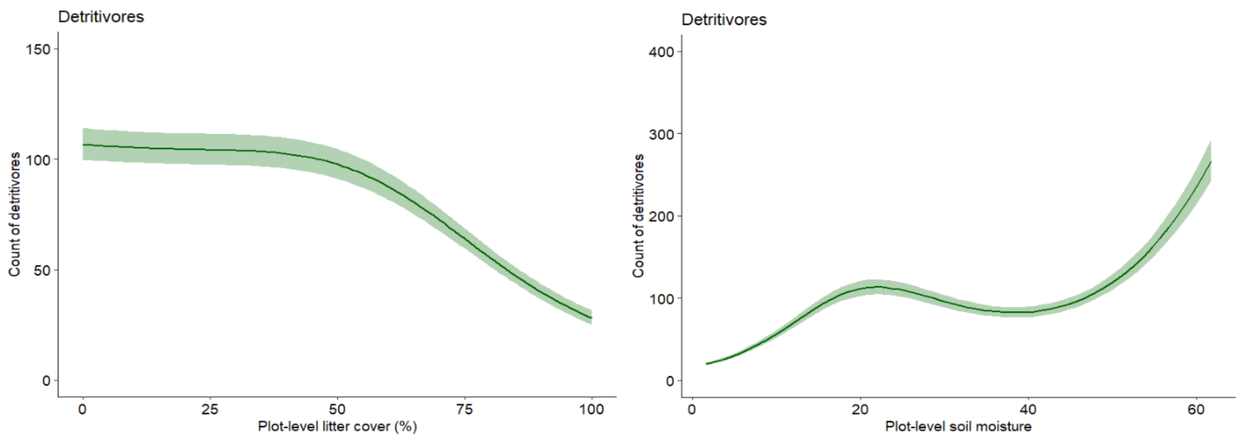


Figure 8. Predicted abundance of arthropod detritivores in the topsoil (number per 2,250 cm^3) in relation to litter cover (left) and soil moisture (right).

The field model identified an 'edge effect' in production areas, in which detritivore abundance peaked around 30 m into the paddock (see Figure 9). This relationship differed slightly depending on whether the edge of the paddock was comprised of revegetation, remnant woodland or non-woody vegetation. Detritivore abundance in production areas adjacent to remnant woodland (depicted by the green line in the graph below) showed a less pronounced peak, but a greater abundance further into the paddock than for revegetation. There was still a strong edge effect where there was no woody vegetation, suggesting that the diversity of plants in different habitats (e.g., road verges with diverse grasses and herbs) provide resources for detritivores, while having suppressive effects around the fringe of the production areas.

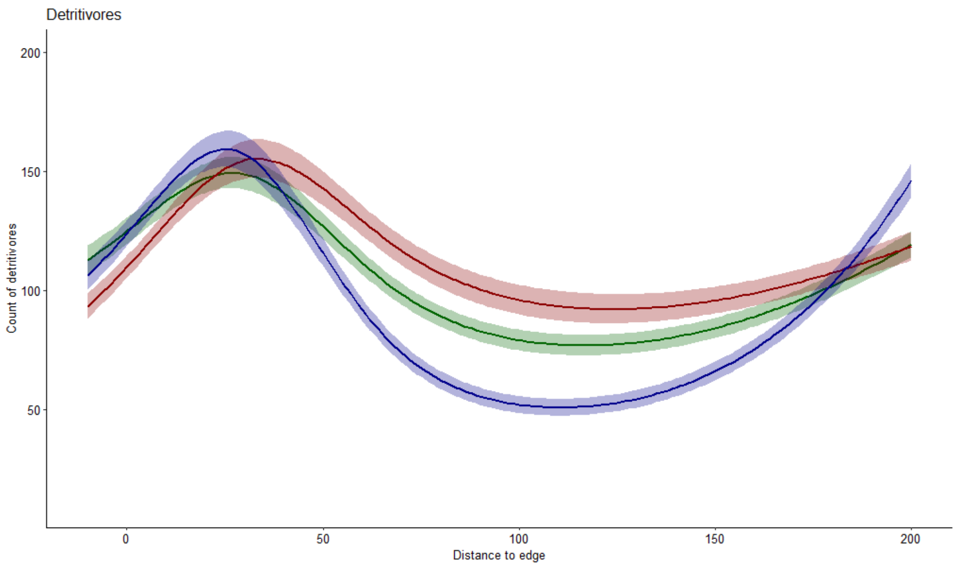


Figure 9. Predicted abundance of arthropod detritivores in the first 5 cm of topsoil (number per 2,250 cm3) in relation to distance into the paddock. The green line represents paddocks adjacent to remnant woodland; the blue line represents paddocks adjacent to revegetation; and the red line represents paddocks without adjacent woody vegetation.

Pollinators and predators

A similar field model (as described for decomposers above) was developed to identify the relationships between pollinator and predator species richness and ecological attributes at the paddock scale. Pollinator richness was positively associated with the edges of ecosystem types and increased with high groundcover (Figure 10).

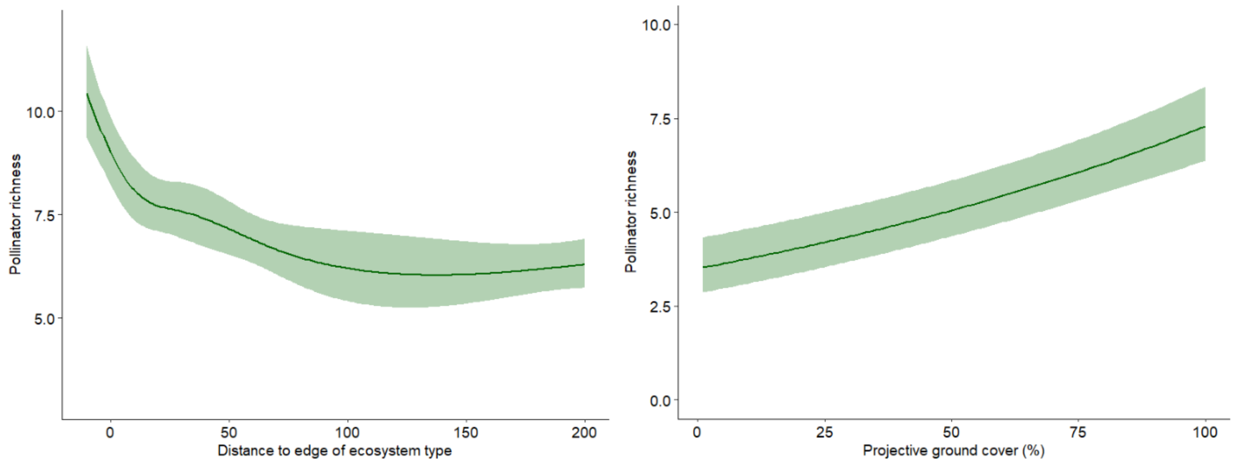


Figure 10. Pollinator richness in relation to distance from the edge of a paddock (left) and % ground cover (right).

Landscape context, including the availability of natural vegetation adjacent to crops and pastures, can determine the effectiveness of beneficials. Areas of natural vegetation can provide population reservoirs and access to additional resources for arthropods that are not available in production areas. Models of arthropod predators showed that areas closer to trees had more species (Figure 11).

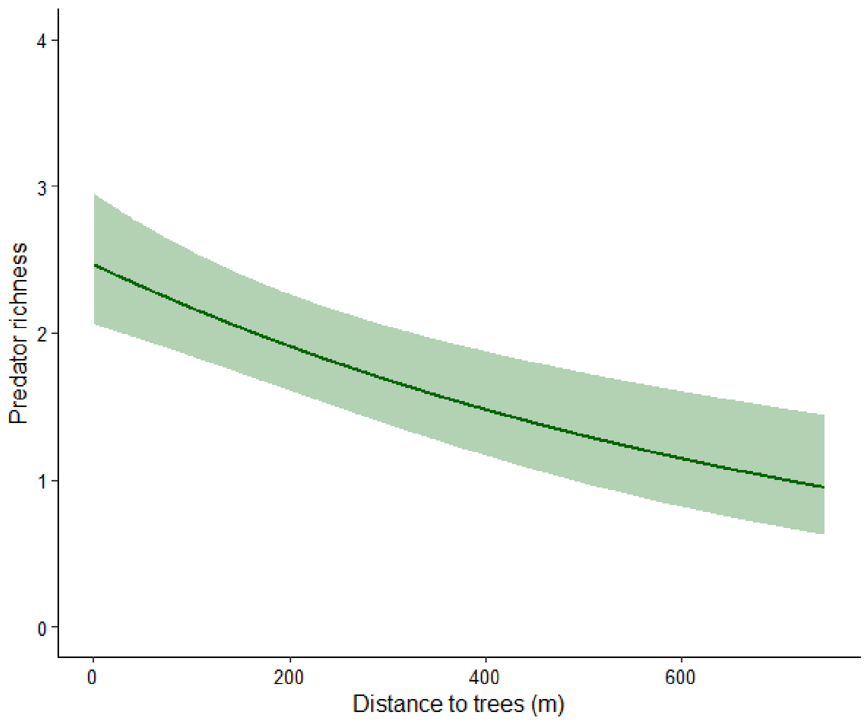


Figure 11. Richness of predatory arthropods in relation to distance from trees.

Table 23. Ecological variables included in arthropod field-based models.

Field variable	Model		
	Detritivores	Pollinators	Predators
Adjacent vegetation (remnant, revegetation or non-woody vegetation)	✓	✓	✓
Cover of bare ground	✓	✓	✓
Cover of vegetation		✓	✓
Crop type	✓	✓	
Distance from paddock edge	✓	✓	✓
Ecosystem type (state and transition model)		✓	
Litter cover	✓	✓	✓
Mean litter depth	✓		✓
Mean plant height	✓	✓	✓
Mean soil moisture	✓		
Plant species richness	✓		
Proximity to trees			✓

Shade

The Shade Index (ShdI) is calculated by overlaying the tree canopy and a canopy height model. To standardise across farms, the angle of the sun is determined by the farm location (a centroid latitude and longitude point) at 15:00 on the summer solstice using the oce package in R. The SI is then calculated using the sun angle divided by the height of the tree (ShdI = tan(sun angle) /canopy height).

The values are calculated per pixel of tree cover and spatially projected in the approximate direction of afternoon shade (i.e., from west to east). A 200 m buffer beyond the farm boundary is used to include the shade contribution of trees outside the farm boundary to the production areas. The SI is calculated for production areas only and presented as the proportion of production area shaded (%).

$ShdI_{PRODUCTION}$ = Shaded production area/Total production area

As areas of the farm may benefit from shade services differently, SIPRODUCTION is separated into proportion of grazing areas shaded and proportion of cropping area shaded.

$ShdI_{GRAZING}$ = Shaded grazing area/Total grazing area

$ShdI_{CROPPING}$ = Shaded cropping area/Total cropping area

$ShdI_{X}$ were further categorised by the location of tree that is provisioning shade (i.e., the tree was present within the farm boundary or outside the farm boundary).

$ShdI_{X}$ is presented as percentage s. Farm with values approaching 0 have very little shaded production areas and farms with values approaching 100 have nearly all production areas are shaded.

Shelter

Shelter is calculated by overlaying the tree canopy with a canopy height model for all trees within a 500 m buffer beyond the farm boundary. For trees within the farm boundary, the location of the tree was intersected with the ecosystem type which was used to assign relevant protection factors. Three types of shelter were identified across the farm each with varying degrees of protection capacity. These were linear shelter belts (Planted Native Trees, Exotic Woody Vegetation Category 1), scattered trees (Reference Grasslands, Derived/Modified Grasslands, Derived Shrublands, Crops and Infrastructure) and contiguous blocks of trees (all other areas, see Appendix 2 for details of the State and Transition Models). The protection factors assigned were 16, 5 and 7 times the tree height, respectively.

For trees located outside the farm boundary, it was not possible to categorise woody vegetation by ecosystem state. However, much of this is likely to be road-side woody vegetation with shelter properties synonymous with shelterbelts. As such, they were assigned a conservative maximum protection factor (i.e., 16 times tree height).

Shelter was calculated for each pixel of tree cover and spatially projected to map the shelter afforded to production areas for harsh cold winter (south-west) and hot summer (north-west) winds.

$Shelter_{PRODUCTION}$ = Sheltered production area/Total production area

As areas of the farm may benefit from shade services differently, $Shelter_{PRODUCTION}$ is separated into proportions based on production type (i.e., proportion of grazing or cropping area afforded shelter).

$Shelter_{GRAZING}$ = Sheltered grazing area/Total grazing area

$Shelter_{CROPPING}$ = Sheltered cropping area/Total cropping area

$Shelter_X$ are further categorised by the location of tree that is provisioning shade (i.e., if the tree was present within the farm boundary or outside the farm boundary).

$Shelter_X$ is presented as a percentage from 0 to 100. Farms with values approaching 0 have very little wind protection and farms with values approaching 100 have nearly complete protection of the production areas from wind.

Appendix 7: Detailed method for calculation carbon stocks and sequestration in woody vegetation

Modelling the carbon stocks

The carbon stocks stored in the woody vegetation have been modelled using FLINTpro (www.flintpro.com). The modelling is based on a spatial and temporal assessment of the woody vegetation on the farm as defined in the National Forest and Sparse Woody Vegetation Data (Version 6.0 - 2021 Release), combined with updated overlays for plantings undertaken by the property manager that may not appear in the National Forest and Sparse Woody Vegetation Data. The detailed planting information has been included to ensure that we are able to provide a more realistic picture of the carbon stocks as these plantings will often not appear in the NFSWV data for many years or may never appear if the planting is narrow (the National Forest and Sparse Woody Vegetation Data has a resolution of 30m, and currently spans from 1989 through to 2021). Other inputs to the model include ANUClimate[11] 2.0 rainfall and temperature data, as well as Australian Annual Fire Data[12]

For application within FLINTpro, a forest is considered to be land that contains woody vegetation which has, or has the potential to, reach more than 20% canopy cover in vegetation more than 2m in height, consistent with the definition above. The forest potential extent was defined as land that has woody vegetation (>5% canopy cover) and achieves 'forest' cover in at least three years over the simulation period (1989-2021) according to the National Forest and Sparse Woody Vegetation Data (Version 6.0 - 2021 Release). The data product used also contains the other classes detailed in the forest definition, and therefore classifies the landscape into non-woody vegetation (<5% canopy cover), sparse woody vegetation (5-19% canopy cover) and forest (>20% canopy cover). Where land does not achieve forest cover at least three points in time (between 1989 and 2021), it is treated as non-forest for the whole simulation and excluded from the assessment. The approach of treating sparse vegetation as 'forest' when it achieves forest cover was taken to reduce loss and gain events when an area fluctuates between just over and just under the 20 percent canopy threshold. This approach results in a conservative outcome of emissions and removals.

It is also important to understand that the model may underestimate the carbon stored in scattered paddock trees. Scattered paddock trees will typically not appear in the National Forest and Sparse Woody Vegetation Data and are not dense enough or large enough to be included as plantings in the overrides applied. This can be seen in Figure 12 where the green shading shows areas included in the estimation, and non-shaded areas will not be included in the carbon calculations (even where there are trees).

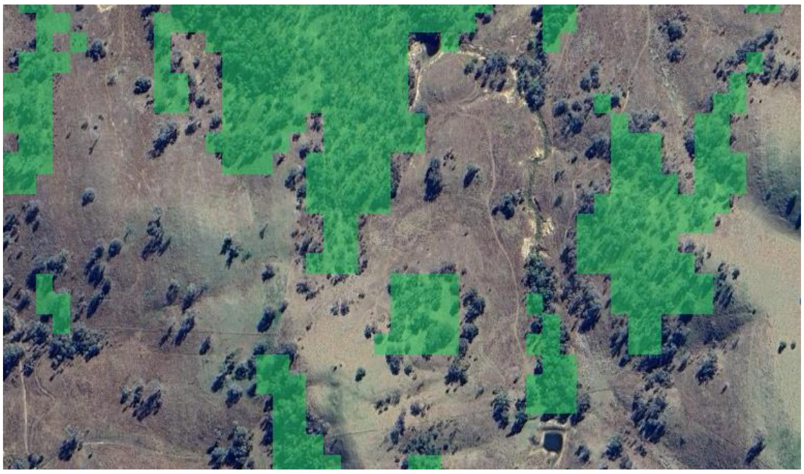


Figure 12. Example of forest and sparse woody cover (green shading)

The simulation was run from 1920 through to 2050, and any pixels defined as forest in 1989 of the National Forest and Sparse Woody Vegetation Data were modelled to be planted in 1920. This provides sufficient time for the model to 'spin up' and stabilise. Forest cover changes detected in the National Forest and Sparse Woody Vegetation Data are then applied

[11] ANUClimate 2.0 model developed by the Australian National University (Hutchinson, Kesteven and Xu) and automated in collaboration with the University of Sydney (Marang and Evans)

[12] Based on an Australia wide dataset of Historical Bushfire Boundaries (https://dx.doi.org/10.26186/147763), with NAFI data used for NT. Method based on: DISER. 2021. National Inventory Report 2019

from 1989 to 2021. Data from 2022 onwards show a growth model without any clearing/loss or planned planting events. The exception to this is where a farm enterprise has plans to clear woody vegetation (thin/harvest in plantations), in which case the planned harvest events have been included in the modelled data.

The modelling may show a loss event (removal of carbon from the sink and emission to the atmosphere) for a number of reasons, including:

- Deliberate clearing events – thinning and clearing of remnant vegetation and plantations
- Fire events
- Thinning events – where the forest has thinned due to die-back, pest infestation or drought

A farm manager may not have control over all these events, although management decisions can have some influence over the severity of some of them.

It is important to understand that a loss event is not instantaneous, and that not all the carbon from a tree is considered to be emitted in the year of clearing. The model allows for some of the biomass to move into the woody debris pool, which is then emitted to the atmosphere (and also stored in soil) over a number of years following the event. This is demonstrated in Figure 13. The rate of emission from the dead organic matter pool to the atmosphere in the years following the clearing event is dependent upon local climatic factors.

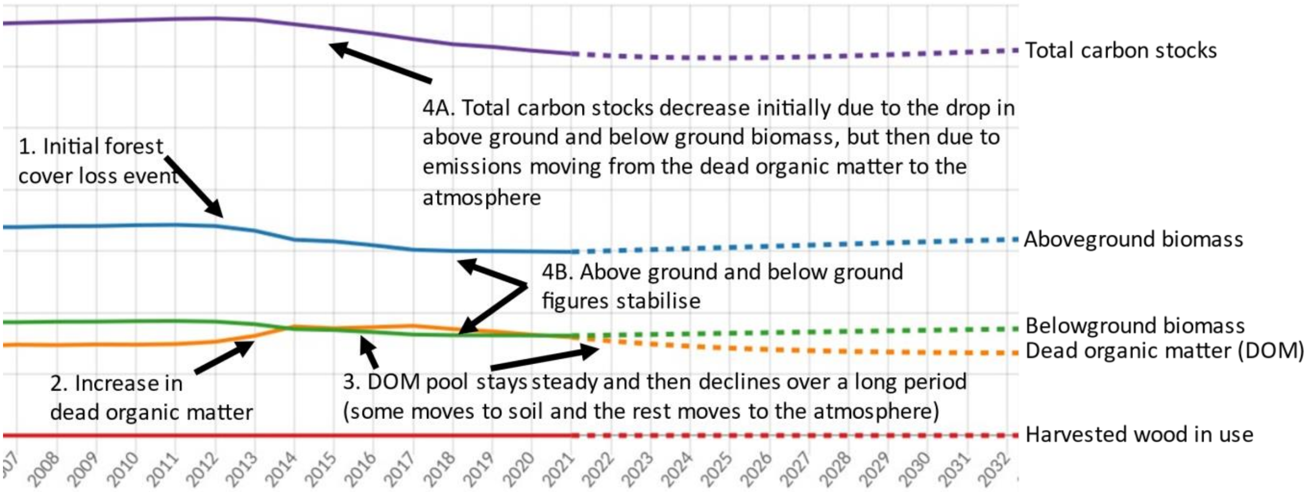


Figure 13. Carbon stock changes following a clearing event

Calculating the sequestration rate

The sequestration rate figure (used in the carbon summary in the dashboard, as well as Figure 4 and Table 11) is calculated using the change in total carbon stocks over the 5 years leading up to and including the latest year of production data. The time-period has been chosen to align with the timeframe of the production data used to calculate the emissions figures.

The consequence of this is that the sequestration rate figure is sensitive to the events occurring leading up to and during the 5-year window used. This can have an impact on determining whether a farm has a negative or positive carbon balance for the reporting window.

Appendix 8: Glossary of terms

Benchmark: A standard against which the value of a particular indicator may be compared. In this account, the benchmark often represents the average value of the indicator across multiple farms based on empirical research. The benchmark is not necessarily the best or most desirable value but the average of the farms studied.

Biospheric source: Of biological origin; used in the context of greenhouse gas emissions, refers to emissions from livestock and clearing and oxidation of vegetation.

Carbon cycle: That part of the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of Earth.

Carbon sequestration: Is the process by which carbon dioxide (CO^2) is captured from the atmosphere and stored in natural or artificial reservoirs. It primarily occurs through photosynthesis by algae, plants and trees, and carbon is 'bound' in carbon pools in vegetation, soil or water. Technological methods like carbon capture and storage (CCS) may also remove carbon dioxide from the atmosphere. Carbon sequestration helps reduce the concentration of greenhouse gases in the atmosphere and mitigate climate change.

Carbon stock: Carbon stock refers to the amount of carbon stored in a particular ecosystem or natural resource. It includes carbon stored in vegetation, soils, biomass, and other dead and living organic matter (excluding geological storages like fossil fuel reserves).

Condition: In the context of natural capital, condition refers to the quality of an ecosystem state or natural resource asset. In the context of the State and Transition models used to classify ecosystem assets, condition is a measure of departure from the reference condition state.

Ecosystem assets: Natural capital assets that comprised of areas of a specific ecosystem type.

Environmental assets: Natural capital assets that are the individual components of the biophysical environment (e.g., minerals, water, soil).

Environmental performance indicators: These are indicators used to evaluate the environmental performance of an organization or project beyond natural capital indicators. They may include measures of energy efficiency, waste management, greenhouse gas emissions, pollution levels, and other environmental factors.

Ecosystem state: These refer to the categories defined in the State and Transition models, which are based on the level of departure from a pre-European, ''reference' condition (e.g., transitioning woodland 1, derived grassland 1, etc.).

Extent: Extent refers to the spatial coverage or size of an ecosystem or natural resource. It measures the physical distance (for linear resources), area or volume occupied by a particular habitat, landscape, or natural feature. Evaluating the extent helps understand the distribution and availability of natural capital and assess its vulnerability to degradation or loss.

Fossil water: Water contained in underground aquifers that are not able to be significantly recharged from surface water or other aquifers.

Geospheric source: Of geological origin; used in the context of greenhouse gas emissions, refers to emissions from the use of fossil fuels.

Greenhouse gas (GHG) emissions: Release of greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide) into the atmosphere through natural processes and human activities. Greenhouse gases absorb infrared radiation (net heat energy) emitted from the Earth's surface and trap it in the atmosphere, thus contributing to climate change.

Natural capital: All biotic (living) and abiotic (non-living) natural resources that are present in a particular area that combine to generate a flow of services that are of benefit or value to people and society. Natural capital is made up of **assets** (sometimes called **stocks**) that are physical entities that can be described in terms of their extent and condition. On a farm, natural capital includes both naturally occurring ecosystems (e.g., forests, woodlands, shrublands, grasslands and wetlands) and ecosystems that have been established and maintained by humans (e.g., pastures, crops, orchards, shelterbelts).

Natural capital accounting: A method of measuring and quantifying the value of natural capital resources and assets. Natural capital accounting involves assessing the extent and condition of natural capital assets (or stocks), and the flow of ecosystem services from the natural capital stocks for a specified area (or organisation) for a particular point in time. Re-assessment enables changes in natural capital assets and ecosystem services to be accounted for.

Non-renewable (finite) resources: A natural resource that cannot be readily replaced by natural processes at a pace quick enough to keep up with consumption (e.g., fossil fuels).

Reference state (or condition): The reference state represents the original or unmodified pre-industrial development condition of a particular ecosystem or natural resource. It serves as a baseline against which the current condition can be compared.

Riparian (zone): Associated with rivers, stream and wetlands; refers to the area between the waterline of a waterway and the top of the bank or the transition to upland vegetation.

Renewable resource: A substance of economic value that is replenished by natural processes at a rate faster than or equal to its rate of consumption.

Scope 1 (GHG emissions): Direct greenhouse gas emissions from sources that are owned or controlled by an organization. On a farm, this includes emissions from livestock, fuels for operating vehicles, and fertilisers.

Scope 2 (GHG emissions): Indirect greenhouse gas emissions associated with the consumption of purchased electricity, heat, or steam by an organization. These emissions occur during the production of the energy consumed by the organization.

Scope 3 (GHG emissions): Indirect greenhouse gas emissions that occur throughout an organization's value chain, including both upstream and downstream activities. On a farm, this includes emissions generated by off-farm suppliers in producing and transporting inputs such as sheep and cattle purchases, synthetic fertiliser, superphosphate, urea, and feed (grain, hay/silage, lucerne). Also included are off-farm emissions from electricity use (e.g., transmission losses) and upstream fuel consumption (e.g., extraction of fossil fuels).

State and Transition Model (STM): Conceptual models of ecosystem dynamics that represent alternative condition states for a particular ecosystem and the processes or disturbances that trigger and drive changes (transitions) between states. State-and-transition models can be used to summarize relationships between land management and disturbances and the ecological state (or condition) of a site.