Benefits of trees on farms

Report for Roslyn Estate

February 2025

Contents

Message from the Program Director

Thank you for your support for the *Farming for the Future* research program. We greatly appreciate the contribution you have made to understanding the value of natural capital to Australian agriculture.

Farming for the Future is a public good agricultural research and change activation program. We aim to provide the national-scale evidence and practical support that farmers need to incorporate natural capital as part of the foundation of their farming businesses, and to activate the supply chain and financial services organisations to encourage and reward that shift.

This project, supported with funding from the Commonwealth Bank (CBA) is designed to help farmers, their farm accountants and advisors to quantify the contribution that trees are making to livestock businesses. It leverages research conducted by CSIRO and La Trobe University. As part of this research, we aim to provide you with some science, tools and resources you can use to estimate the contribution that trees are making to your farm business.

By participating in the project and contributing data and insights to the program, you are helping to advance research and understanding in several key areas. Firstly, your participation is helping in the development and testing of methods of quantifying some of the ecosystem services provided by trees on farms in an objective, repeatable and robust way. Second, your participation is helping advance knowledge of how to value natural capital as assets of a farm business, which is, as far as we know, a world first. The outputs of the research are regarded as being preliminary in nature – more industry consultation and experimentation will be needed before it is possible to confidently quantify natural capital as assets of a farm business.

We have aimed to produce this information in a way that helps you make decisions about the natural capital of your farm and how it might work in better supporting your goals for your family and business. Your report is confidential, and we won’t publish it unless you ask us to or give us permission to publish.

As with the research, the designs of these individual farm reports should be considered to be preliminary and experimental – the first version of how this information should be presented. We expect to gain significant insights with further feedback from you and other stakeholders, but we expect that further research is needed to improve the science, technology and tools underpinning the valuation of trees as assets of farm businesses.

We are very proud of the achievements of the *Farming for the Future* program so far and we thank you again for the significant contribution you have made to the work.

Yours sincerely

Sue Ogilvy

Program Director

Acknowledgements

Farming for the Future acknowledges the traditional owners of the lands on which we live and of the lands involved in the research. We pay our respect to their Elders past, present and emerging.

We appreciate the support of our philanthropic and industry partners such as MLA, AWI, NAB & ANZ that have enabled the program's core work. This research for this report has been made possible by funding provided by the Commonwealth Bank.

This project has greatly benefitted from the leadership and experience of Rayne van den Berg who is an experienced Chief Financial Officer and a global champion of Natural Capital Reporting. We gratefully acknowledge the assistance of Dr Steve Stewart and the CSIRO Perennial Prosperity project, and Dr Alex Maisey, Dr Jim Radford, Dr Fred Rainsford and Dr Grace Sutton of La Trobe University for the significant work in advancing techniques for modelling ecosystem services on farms. For our full list of partners see the About Us section of www.fftf.org.au.

Commonwealth Bank

NatCap+

We also acknowledge the work of many other scientists whose work we have been able to draw on in the development of these approaches as well as the significant contribution of farmers, farm advisors, farm accountants, our industry partners, and our natural resource management partners. These have been very important in the project, and we have greatly enjoyed working with them.

Cover image credit: Imogen Semmler.

Disclaimer

Introduction

Farming for the Future's research program aims to help build a better understanding of the relationship between the natural capital of a farm and the efficiency, productivity, profitability and resilience of the farm business and the wellbeing of the farming family.

Shelterbelts contribute positively to livestock and crop productivity, but to date methods to put a monetary value on these benefits have not been easily available to farmers and the wider industry. This project is working with farmers, accounting and property valuation experts to develop methods for monetary valuations of shelterbelts that reflect the positive contribution they make to crop and livestock productivity, biodiversity and ecosystem services. It has been made possible with the generous support of the Commonwealth Bank (CBA) who are investing in this work to support farmers and industry to further understand the value of farm natural capital.

This report provides the modelled results for selected ecosystem services delivered by the trees on Roslyn Estate. It also contains some background information about natural capital and the benefits it can generate for production and for society (see Figure 1).

What is natural capital in agriculture?

Agricultural natural capital is the living parts of the farm - ecological assets like air, water, soil, plants, and animals. It represents significant ecological and commercial value and can be accounted for alongside agricultural assets like land size, infrastructure, and livestock to provide a full picture of a farm's assets.

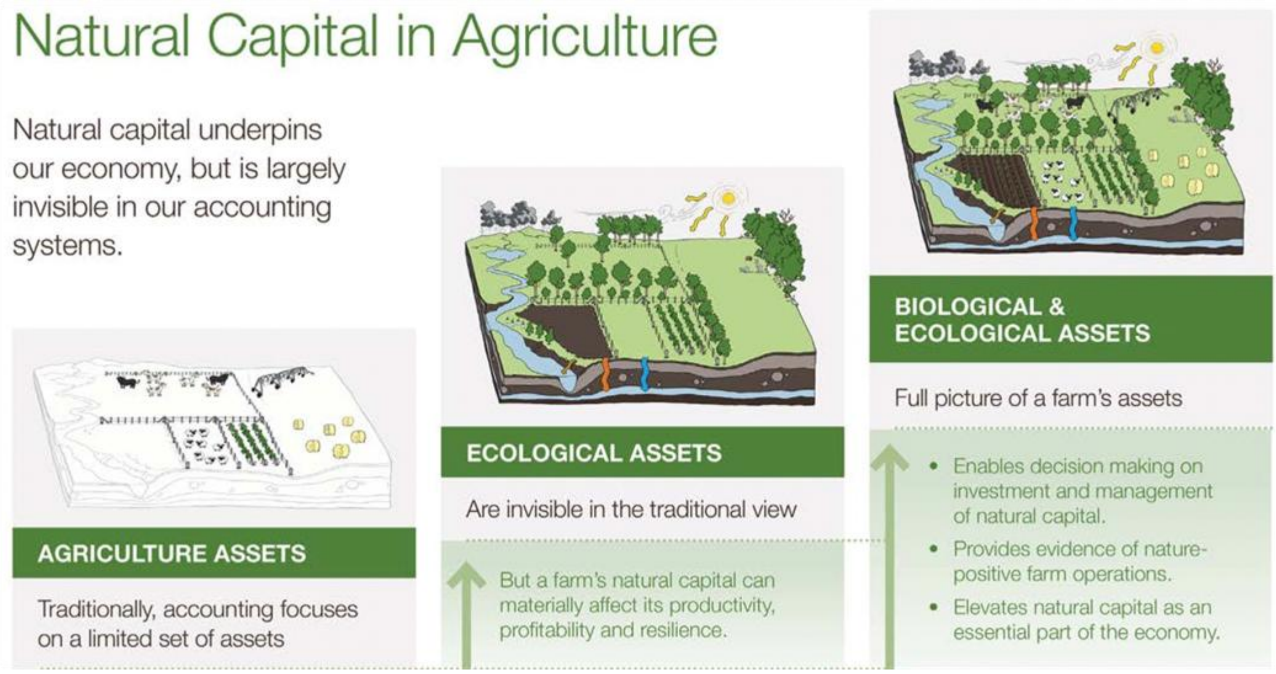


Figure 1: Natural Capital is not presently included in farm accounts. The inclusion of it would provide a more complete set of information about the assets of a farm and may assist with decision-making about farm business performance.

Illustrated in Figure 2, the natural capital[1] of a farm provides a range of different ecosystem services that can support production of crops and livestock. Depending on the types of natural capital it has, a farm business can benefit from shade, shelter and forage for livestock, habitat for beneficial insects and birds, regulation of soil and water quality and other services that support efficiency, profitability, and business resilience.

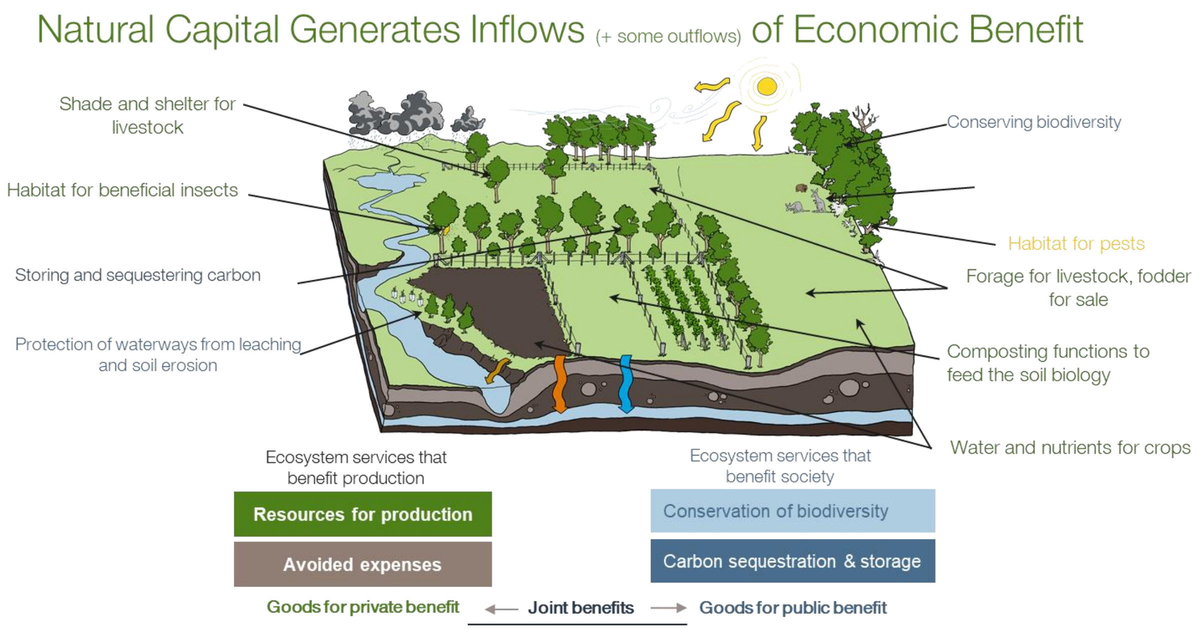


Figure 2: Overview of ecosystem services in agriculture. Different types of natural capital provide different types of resources that can benefit production (green) as well as providing benefits to society more broadly (blue). It is acknowledged that natural capital can also provide 'disservices' such as habitat for pests.

Farming for the Future focuses on measuring and valuing the benefits of natural capital on core production and on farm productivity and profit. Our work is designed to reveal opportunities for farmers to use their natural capital to optimise crop and livestock productivity, reduce expenses and maintain access to premium commodity markets. This is additional to any supplementary "non-core" income streams which may also be available for farms to participate in the emerging carbon and nature repair projects.

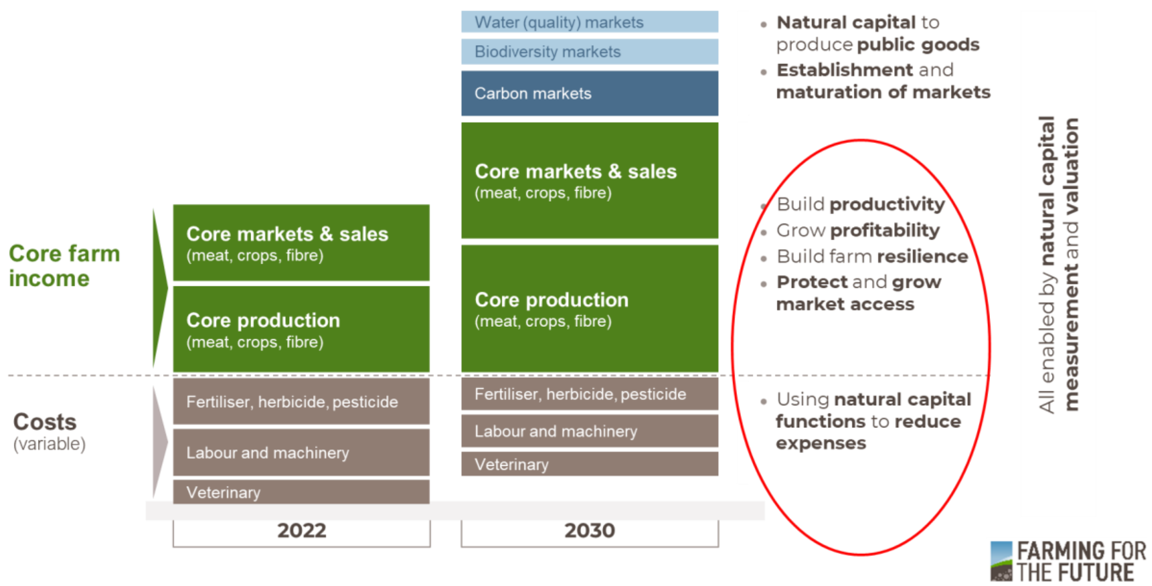


Figure 3: Illustration of the Farming for the Future focus (red circle) for its work on how natural capital supports farm business performance.

[1] The term natural capital can also be referred to as ecological capital or ecosystem assets.

Overview | Shade & Shelter services provided by trees

When trees are integrated into livestock production area they provide important ecosystem service to support livestock production. Integrated tree plantings are typically planted as either shelterbelts – rows of trees planted around the edge of crops or paddocks, or as paddock trees – individual trees or clumps of trees that are interspersed in the productive landscape. Each of these different types of planting will provide different ecosystem services. Recent research conducted by Peisley (2017), Keenan et al. (2023) and Stewart et al. (2024) is summarised below.

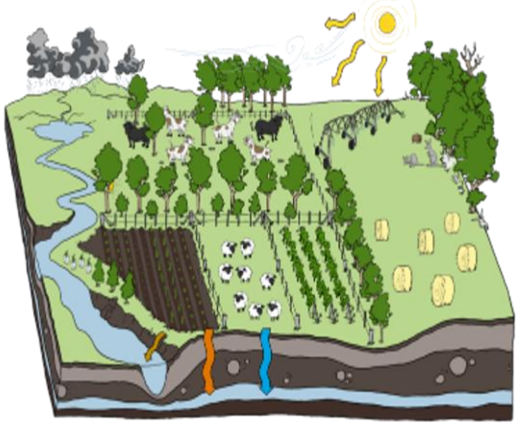
Trees improve animal welfare via shelter from heat and rain

Shelter from heat improves animal health and reduces mortality

Livestock with access to shade and shelter gain weight more quickly

Shade and shelter help to increase milk production in dairy cows

Shelterbelts improve lamb survival rates by 5 - 35% (plus higher survival rates for multiple births) via provision of privacy to avoid mismothering, and protection from wind chill



Shelterbelts provide biosecurity benefits, especially at the farm boundary, where they can prevent the spread of lice and other problems from neighbouring farms

Trees attract predatory birds that improve waste disposal in pastoral systems

Trees attract birds, bats and other wildlife that prey on pest insects

Decomposition of leaf litter from trees can improve soil carbon and water retention

Trees can increase productivity of crops and pastures by protecting them from drying winds

In this report, the area of ecosystem asset such as the shelterbelt, woodland, forest or pasture supplying the service is known as the 'supply area' and is distinguished from the area receiving the ecosystem services which is referred to as the 'benefits zone'.

Project approach

This project, supported with funding from CBA, aims to provide you with some science, tools and resources you can use to estimate the contribution that trees are making to your farm business. It leverages research conducted by CSIRO and La Trobe University to enable farmers, their farm accountants and advisors to quantify the contribution that trees are making to livestock businesses and to identify areas where investment in trees may further support the productivity and resilience of your operations. This report focuses on the physical measures of how much shade and shelter is available on the farm and provides a summary of predicted biodiversity (birds). The explanation of a proposed approach to the monetary value calculations will be provided separately.

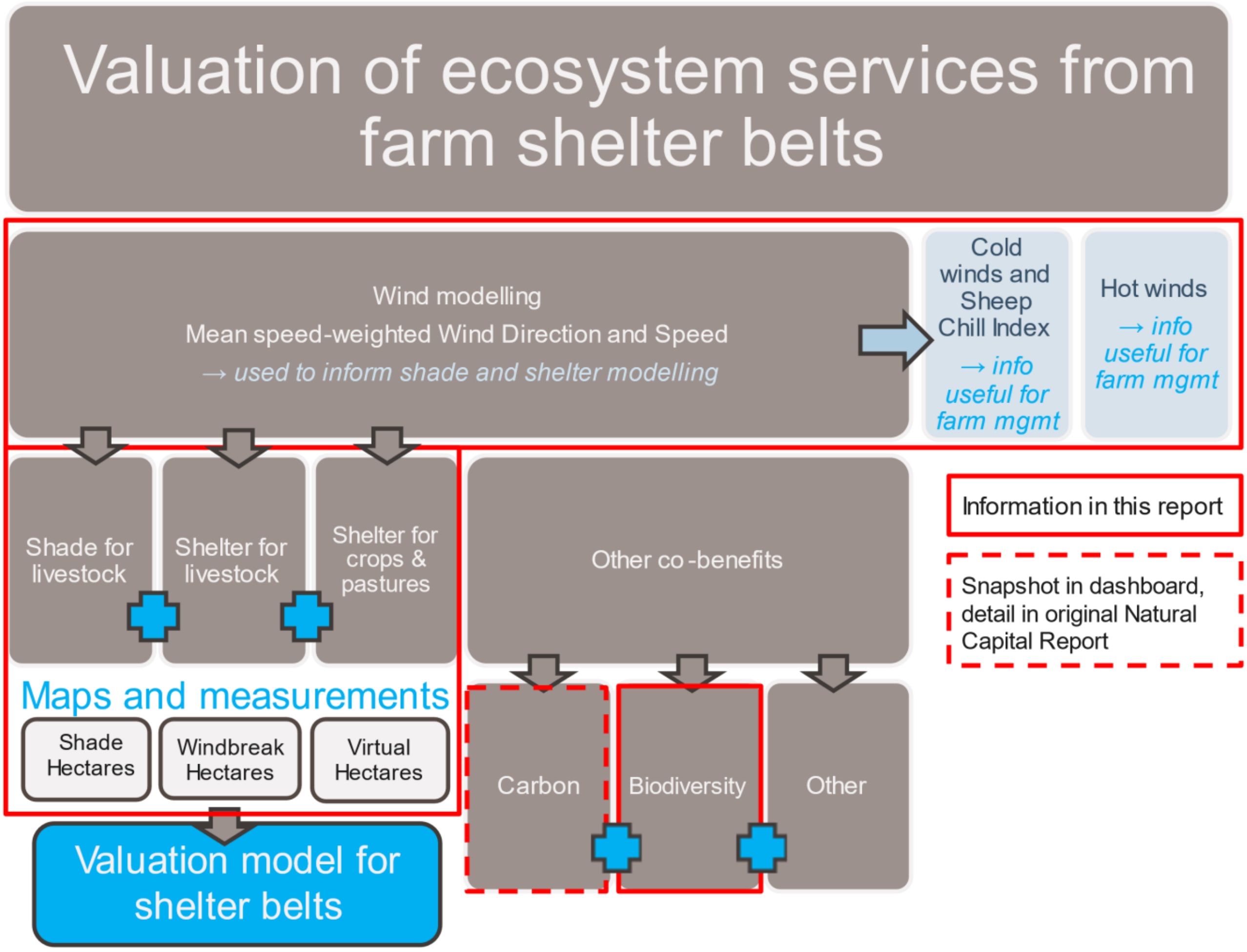


Figure 4: Illustration of information types and flows for this project. Indicated by the red boxes, the information provided in this report includes the modelled wind speed and direction and the maps for shade and shelter services from trees.

Where does data in this report come from?

A mix of sources including

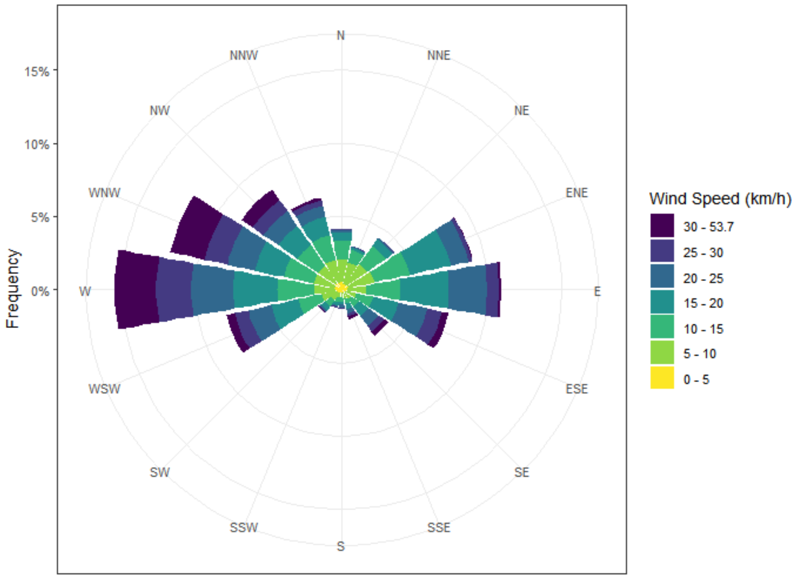
- Farm records (provided by you).
- Remote sensed data (e.g., satellites).
- Other industry or academic modelling.

Farming for the Future focus

FFTF is focused on understanding how natural capital contributes to production of crops and livestock. This report focuses on:

- Resources for production: shade and shelter for livestock, pastures and crops.

Highlights for Roslyn Estate



Roslyn Estate: 2014-2023

Dominant wind from 280^{0}

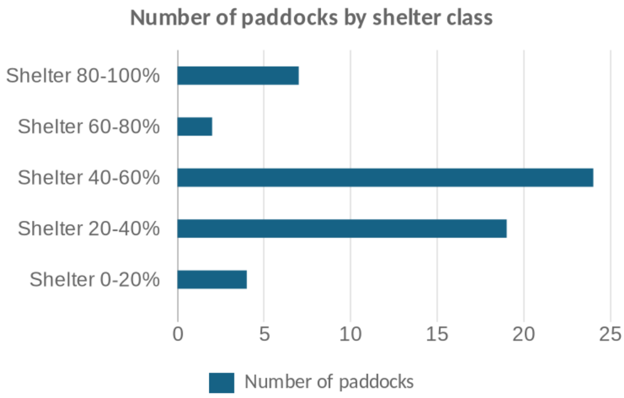
844.3 ha
Size of Property

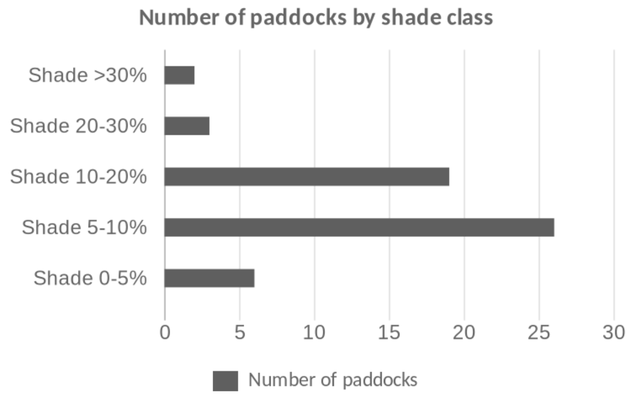
53.4 ha
Total area of shelterbelt & block plantings

-5.6 ha_v
Virtual hectares (plantings)
(see page 15 for definition)

Shelter services	Ha	%
Windbreak hectares in production zone	293.5	38%

Shade services	Ha	%
Shade hectares in production zone	65.0	8%





Carbon Stocks in plantings (2023): 6,957 tonnes C

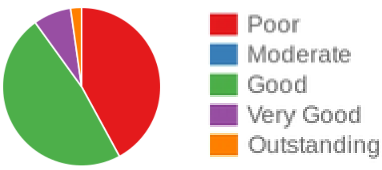
Mean cold days per season Wind chill > 1100 kJ/m2/hour:

Spring: 41.3 Summer: 14.4

Autumn: 32.7 Winter: 81.8

Biodiversity

Proportion of area by habitat quality for woodland birds



Mean hot days per year > 30 degrees C: 14.6

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Using the information

What does this information mean?

Information not advice	This report provides information about experimental methods and estimates developed to learn to quantify and value 'what type' and 'how much' of a selected set of ecosystem services are being delivered by the trees on your farm. No judgement is made on whether this is good or bad.
Your values and goals	'What good looks like' is up to you. The ideal amount and location of trees for your farm depends on your unique context, values, goals, and changing circumstances. The individual economic report you will also receive will help you understand how the natural capital of your farm compares with the natural capital in your region and in the study.
Your sweet spot	Every farmer has their own preferred mix of natural resources to support their enterprise and personal goals. These may change over time. There may be a 'sweet spot' where natural capital and economic performance are both optimised.

Development and testing of methods for monetary valuations for the economic benefits of trees on farms will build from the information contained in this report.

Insights | shade hectares – the area of shade services for livestock

Shade services can be provided by a range of vegetation types, including remnant vegetation, paddock trees and shelterbelts. The amount of shade provided will depend on a range of factors, including tree height, canopy density, and the height and direction of the sun. The shade services can be mapped and quantified. Further information about how this is calculated is included in the Key Concepts section.

The area of shade services for livestock on Roslyn Estate is shown in Table 1 and Table 2. Shaded areas are shown in maps on following pages.

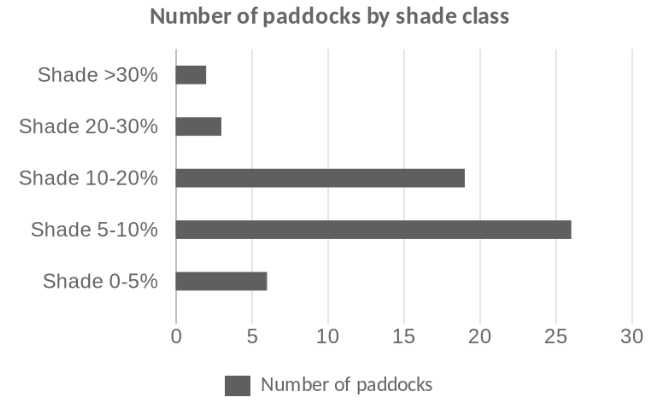

Table 1: Area of shade services for livestock with areas in production, conservation and infrastructure shown.

Primary Use	Area (ha)	Area of trees (ha)	Shaded area (ha) (includes trees)	Proportion Shaded
Production	777.0	54.4	65.0	8%
Conservation	61.2	51.6	53.1	87%
Infrastructure	6.1	2.3	2.6	43%

The following pages provide shade services map(s) for Roslyn Estate.

Table 2: Number of production paddocks in each category of shade proportion.

	Number of paddocks	Area (ha)
Shade 0-5%	6	123.9
Shade 5-10%	26	406.7
Shade 10-20%	19	244.1
Shade 20-30%	3	4.4
Shade > 30%	2	1.3
Total	**56**	**780.5**

Shade services farm map(s)

Map 1. Shade services map for Roslyn Estate

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Insights | windbreak hectares - the area of shelter for livestock

For shelterbelt plantings, the orientation of the planting can be important, and livestock need to be able to get close enough to access the shelter. Shelterbelts should run perpendicular to the dominant winds to maximise the shelter provided from the most damaging types of wind. Given the variability of the winds, we have modelled shelter services for livestock in all directions around shelter belts, block plantings, and remnant woodlands and forests.

The extent of shelter services is measured in 'tree heights' distance from the planting itself. The provision of shelter services is greatest close to shelterbelt plantings (0-1 tree heights from the planting) and reduces with increasing distance (up to 5 tree heights from the planting).

Shelter services beside very wide plantings (Block plantings), woodlands and forests extend for 2 tree heights due to the different effect of the extensive area of trees on the behaviour of the wind. Further information about how this is calculated is included in the Key Concepts section.

The areas that receive shelter services are presented in Table 3 and Table 4.

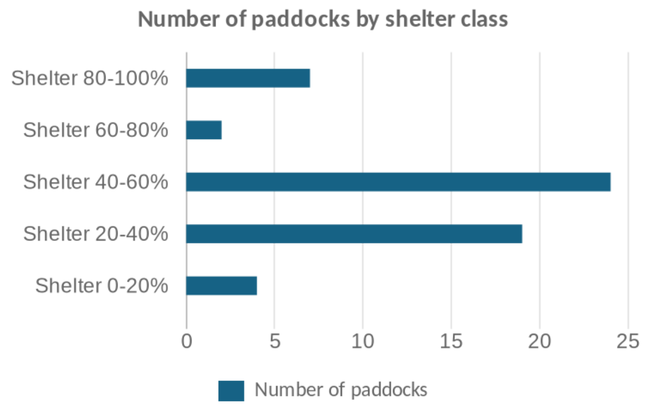


Table 3: Area of shelter services for livestock with areas in production, conservation and infrastructure shown.

Primary Use	Area (ha)	Sheltered area (ha)	Proportion Sheltered
Production	777.0	293.5	38%
Conservation	61.2	60.8	99%
Infrastructure	6.1	5.3	87%
Total area sheltered by trees (ha)		296.9	

The following pages provide shelter services maps for Roslyn Estate.

Table 4: Number of paddocks in each category of shelter proportion.

	Number of paddocks	Area (ha)
Shelter 0-20%	4	87.4
Shelter 20-40%	19	330.2
Shelter 40-60%	24	331.2
Shelter 60-80%	2	14.7
Shelter 80-100%	7	16.9
Total	**56**	**780.5**

Map 2. Shelter services map for Roslyn Estate

Insights | virtual hectares – shelter for crop and pasture production yield

Shelterbelt planting can improve the productivity of crops and pastures by protecting them from drying winds, helping to maintain soil moisture. There may be trade-offs (dis-benefits) arising from a planting, such as loss of productive land or competition for nutrients and water. Shelterbelts can be oriented and placed so that net gain from planting is maximised or loss of crop and pasture production is minimised.

The Key Concepts section (page 19) has information about virtual hectares and how they are calculated.

Roslyn Estate has planted 53.4 ha of shelterbelts. The net effect of the competition and benefit zones provided by the trees given their location and orientation is estimated to be equivalent to -5.6 ha in land for production (in addition to loss of production in the planted area).

Net gains (losses) for pasture / crop production

Table 5: Net gains (losses) for pasture / crop production due to the net effect of shelterbelt plantings. A negative net change (last row) may indicate shelterbelts are too close together.

Whole of farm			Notes
Starting area (property size) (ha)		844.3	The size of the farm.
Planted Area (ha) "lost" to production (ha)		-53.4	The area planted to trees and therefore lost to production of crops / pastures.
Remaining crop / pasture area (ha)		790.9	The net remaining area for crop / pasture production
Competition zone physical hectares (ha)	129.4		The area (ha) of the competition zone where crop/pasture yields are reduced due to the effect of trees.
Competition zone virtual hectares (ha_v)	94.7		The equivalent 'virtual' hectares of the competition zone due to reduced yields in this zone.
Net yield change in competition zone (ha_v)		-34.7	The loss of production in equivalent 'virtual' hectares due to the competition zone impacts on crop/pasture adjacent to trees.
Benefit zone physical hectares (ha)	275.5		The area (ha) of the benefit zone where yields are increased.
Benefit zone virtual hectares (ha_v)	304.6		The equivalent 'virtual' hectares of the benefit zone due to increased yields due to shelter benefits to crop/pasture in this zone.
Net yield change in benefit zone (ha_v)		29.1	The gain of production in equivalent hectares due to the benefit of the trees.
Net change in crop / pasture production (ha_v)		-5.6	The gain (loss) of equivalent hectares of production due to the shelterbelts

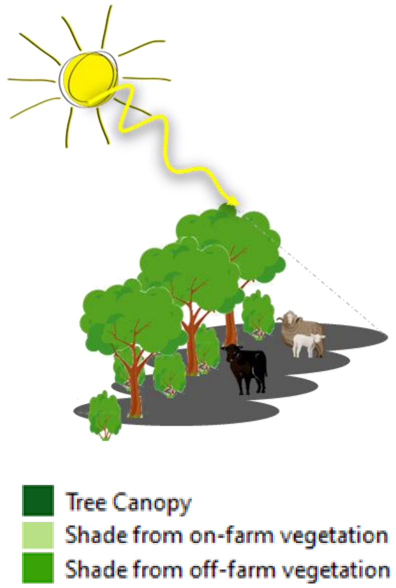
Productivity Change farm map(s)

Map 3. Productivity Change map for Roslyn Estate

Key concepts | Shade & Shelter, Productivity gains

The quantity and quality of ecosystem services provided by integrated tree plantings depends on the configuration of trees in the landscape relative to productive areas, and on the specific ecosystem service being delivered. The following figures provide explanations of the key concepts.

Shade Services



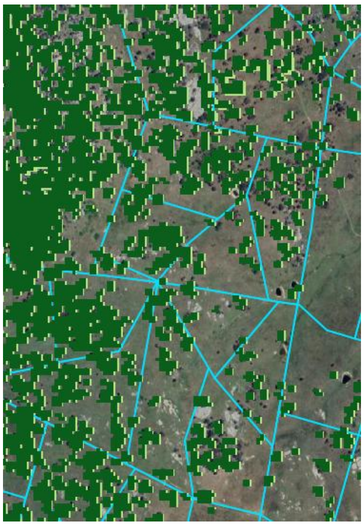
Shade services can be provided by a range of vegetation types, including remnant vegetation, paddock trees and shelterbelts. The amount of shade provided will depend on a range of factors, including tree height, canopy density, and the height and direction of the sun and whether the animals can access the shade.

Sun angle and direction will vary by location, but values will be in the order of 60 degrees and 295 degrees from North respectively.

Adapting the modelling approach from the La Trobe FSNCA project[2], shade services are modelled using a 10-metre resolution tree mask created for each farm plus the ecosystem state models and paddock maps prepared for the natural capital reports and the global canopy height model (S2GEDI) (Lang et al., 2023).

Shade is modelled based on the direction (azimuth) and height (altitude) of the sun at 15:00 on the summer solstice. To prepare a finer scale analysis and less pixelation, the tree mask and S2GEDI models are reprojected to 5m resolution. The shaded area and other statistics are calculated for each ecosystem type and for each paddock.

Shade services on a farm with significant remnant woodlands and paddock trees

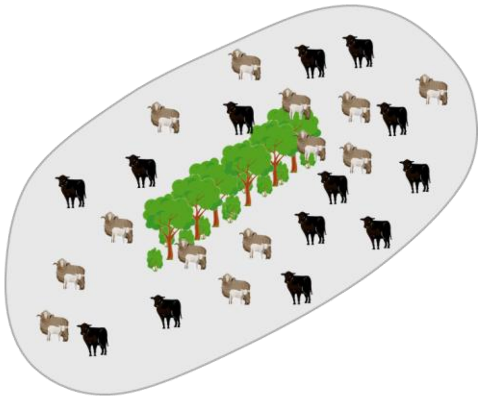


Shade services on a farm with tree lane plantings between the production areas

[2] https://www.latrobe.edu.au/__data/assets/pdf_file/0007/1528981/Blueprint-Farm-scale-Natural-Capital-Accounting-methods.pdf

Shelter for livestock

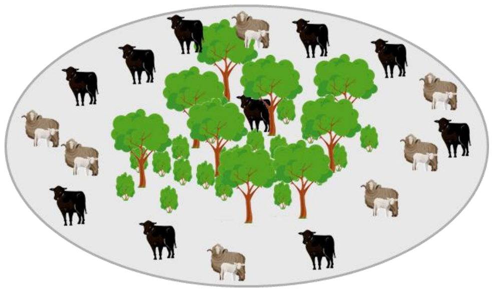
Shelter for livestock refers to the protection that livestock can receive from hot or cold wind and weather by standing close to a group of trees.



Shelter belts

Scientific analysis indicates that assemblies of trees such as a relatively narrow shelter belt planting can shelter livestock from harsh hot or cold winds and rain for up to 5 tree heights from the wind direction (depending on the porosity of the shelter belt).

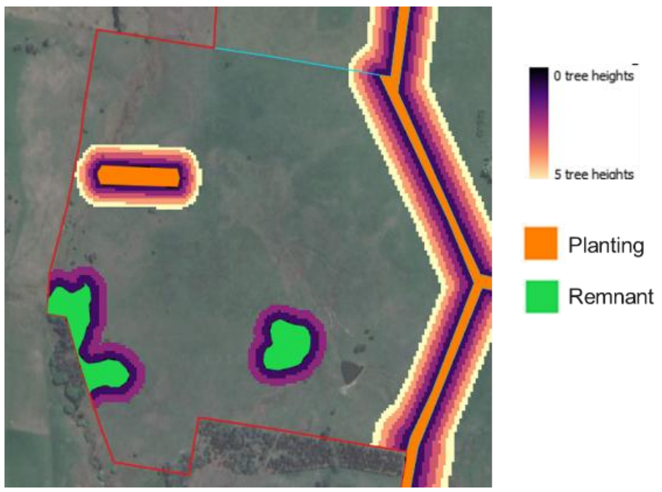
We have assumed an optimal porosity of 35% for each of the shelter belts in the modelling as we don't have empirical data for structure of the shelter belt assets on the farm.



Block plantings and forests/woodlands

Scientific analysis indicates that shelter services from a wide and deep block planting (or forest or woodland) can extend for 2 tree heights.

The reduced area of shelter from deep block versus narrow plantings is because wind travelling over a block of trees tends to 'dump' towards the ground when it passes the trees.



Sheltered areas for livestock are modelled (estimated) by using the ecosystem state models prepared in the pilot study (used in the natural capital reports) and the global canopy height model (S2GEDI) (Lang et al., 2023).

We identify assets such as shelter belts, block plantings, woodlands and forests that supply the services and the areas such as pastures and crops (paddocks) that use the services. Shelter statistics are generated for each paddock and for the whole farm.

The services are then presented as a set of maps for visualisation and to input into farm planning.

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Shelter that improves crop and pasture productivity

Shelterbelt planting can improve the productivity of crops and pastures by protecting them from drying winds, helping to maintain soil moisture, and providing protection from chill and heat stress. There may also be trade-offs (dis-benefits) arising from a planting, like loss of productive land or competition for nutrients and water.

This project leverages the work done in a global meta-study published by CSIRO (Stewart et al., 2024). This work concluded that it would be reasonable to consider that trees generate production benefits in the form of yield gains for the area between 3 to 20 tree heights (green bars in Figure 5) from shelterbelt plantings (within 3 to 10 tree heights for block plantings, or woodlands/forests), but that it would be reasonable to expect a competition zone with reduced production in the area between 1 and 2 tree heights (orange bars in Figure 5) from shelterbelt (and block) plantings.

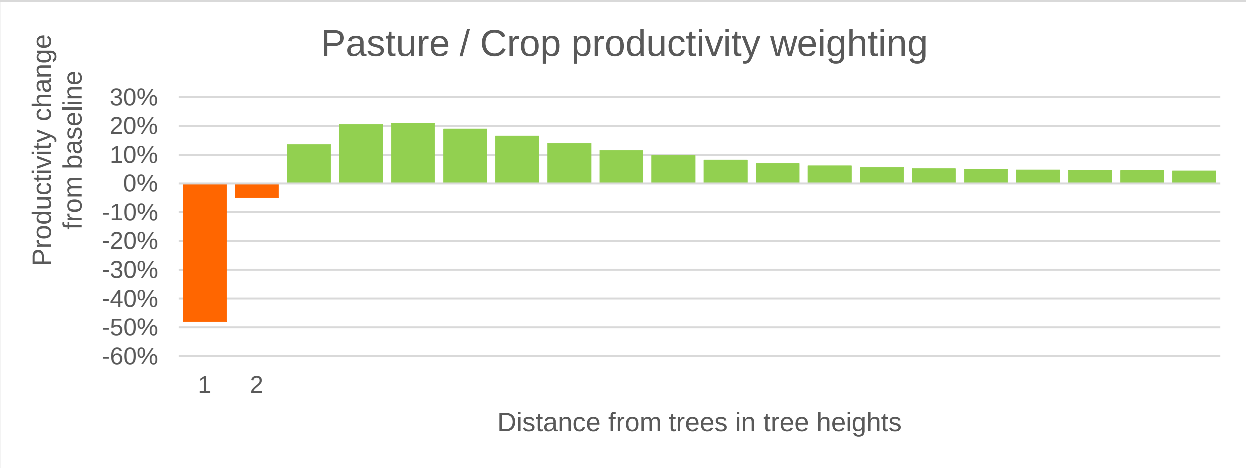

Figure 5: Pasture / Crop productivity weighting adapted from CSIRO Perennial Prosperity Project. The chart shows the relationship between productivity change from baseline (y-axis) and distance from trees in tree heights (x-axis). The orange bars indicate reduced productivity compared to baseline (in the absence of the trees). The green bars indicate increased productivity compared to baseline.

Virtual hectares (experimental concept)

In this report, we have quantified the area of land receiving the benefits (or competition) from the trees as normal (physical) hectares, and the productivity change associated with the benefits or competition as 'virtual hectares' (ha_v) to indicate the increase (or decrease) of production as equivalent to having extra (or fewer) hectares of land under production.

Assumptions in the model:

- The tree planting area is considered a complete loss of pasture.
- Productivity growth is impacted by a competition zone near the tree in all directions, and a benefit zone in the leeward of the dominant wind direction.
- Woodlands and forests were not considered to have a productivity impact within the treed area (the area supplying the services known as the supply area).
- In this model, scattered trees in paddocks were not considered to have a productivity impact.

The concept of virtual hectares is illustrated in Figure 6 overleaf.

Example of virtual hectares

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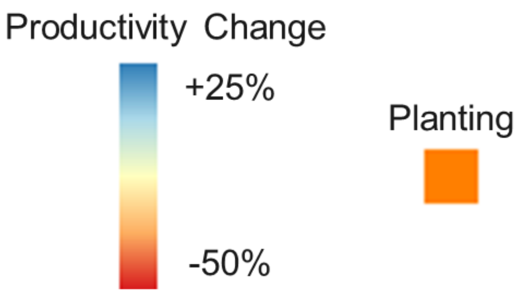
<td>
</td>
<td> Legend:
The productivity change is illustrated by colours indicating the size of the gain (green to blue) or reduction (yellow to red) in crop / pasture yields associated with the shelterbelts.
The planting area is indicated in orange. </td>
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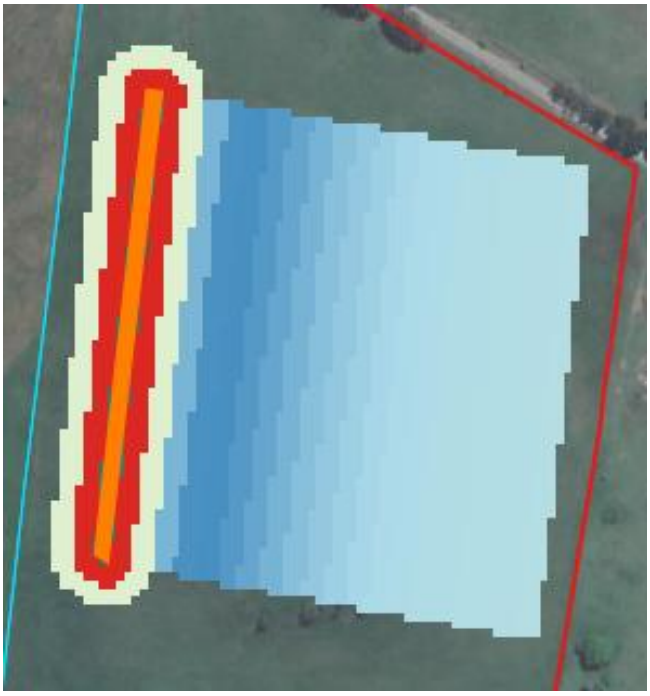
<td></td>
<td> In this example where the shelterbelt is perfectly located with proximity to crop / pasture production areas and oriented perpendicular with respect to the prevailing wind, the following statistics are illustrated

The area of planting (orange) is 0.33ha
The area of the competition zone is 1.90ha
The area of the benefit zone is 7.27ha.

We apply the model of the effect of competition and benefit on yield of crop / pasture and find:

The reduced production in the competition zone is the equivalent of losing 0.47ha of crop / pasture land.
The increased production in the benefit zone is the equivalent of gaining 0.73ha of crop / pasture land.
The net effect is 0.26ha of gain of crop / pasture land. We denote this as $0.26ha_v$ to indicate the notion of ‘equivalent’ hectares.

When the area of the planting is included in this calculation, the total gain (loss) of crop / pasture area is $-0.33ha + 0.26ha_v = -0.07ha_v$
A positive number indicates that the planting location and orientation has optimised the crop / pasture shelter services. </td>
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<td> Shelterbelts that are oriented along the wind direction provide limited area of crop / pasture protection.
The benefit zone of one shelterbelt can be reduced by planting another shelterbelt within the benefit zone (too close to the original shelterbelt). </td>
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</table>

Figure 6: Illustration of competition and benefit zones associated with shelterbelts depending on their orientation to the prevailing wind.

Effect of Block planting on crop / pasture production

A block planting is defined as an area of planting that has a perimeter (m) to area (ha) ratio of less than 555 m/ha. Figure 7 below illustrates the benefits of block plantings of trees on the crop / pasture production in the area downwind of the plantings. This also applies to fairly dense woodlands and forests.

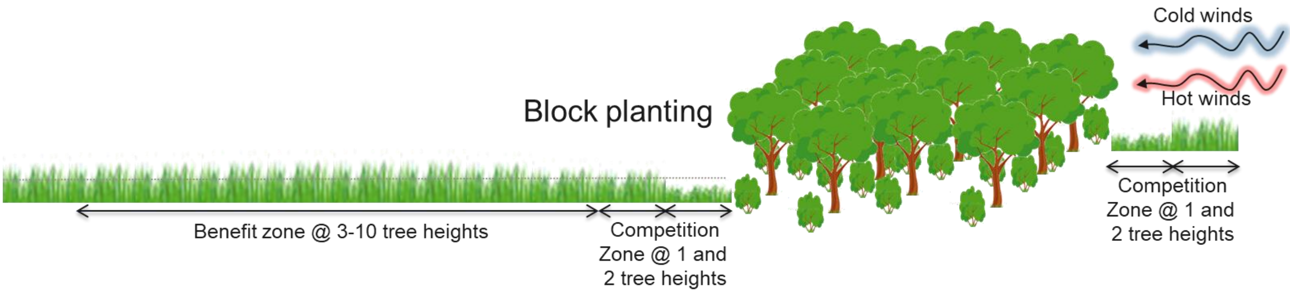


Figure 7: Illustration of the effect of Block planting on crop and pasture production downwind of the planting. The competition and benefit zones are indicated by the height of the crop/pasture with the area's location with respect to the prevailing wind direction indicated.

Effect of shelter belt planting on crop / pasture production

Figure 8 below illustrates the benefits of shelter belt plantings (need definition) of trees on the crop / pasture production in the area downwind of the plantings.

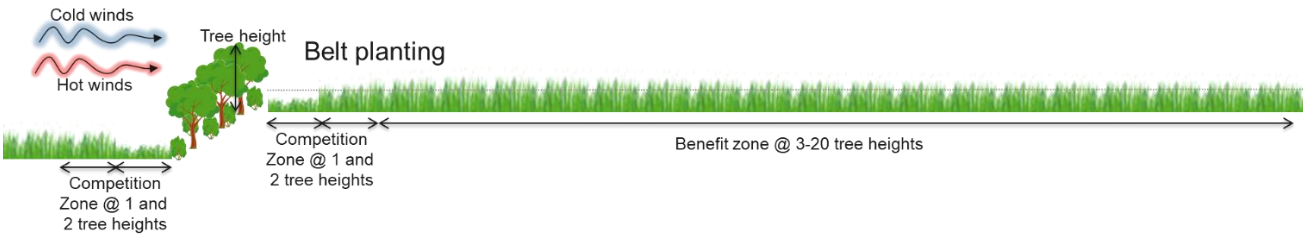


Figure 8: Illustration of the effect of Belt planting on crop and pasture production downwind of the planting. The competition and benefit zones are indicated by the height of the crop/pasture with the area's location with respect to the prevailing wind direction.

Pasture / crop productivity modelling

To model the impacts of planted trees (shelterbelts and block plantings) on pasture and crop yields nearby, we use the ecosystem types and paddock maps that were prepared for each farm participating in the FFTF research project along with the global canopy height model (S2GEDI) (Lang et al., 2023).

We modelled the productivity change as a factor of distance from the supplying asset (the shelterbelt or block planting) following the methods developed CSIRO in the Perennial Prosperity project (Stewart et al., 2024). This included:

- determining the dominant wind direction (weighted by wind speed),
- determining the suppliers (tree belts, tree blocks, woodlands and forests) and the users (pastures, crops) of shelter services,
- modelling the competition and benefit zones based on the tree height of the supplying assets
- modelling the net productivity impact for the pastures and crops.

Optimising the configuration of trees

Alignment of shelter belts with respect to the dominant wind direction and the width of plantings are significant drivers of the pasture / crop production increases or decreases. Also important is the porosity of the shelter belt (ideally between 30-70%). We have assumed optimal porosity for our modelling (as practical on-farm methods for measurement of this do not currently exist in a cost-effective form).

According to the models, an optimally oriented planting (perpendicular to the dominant wind) can have yield gains in the benefit zone that exceed the yield losses in the competition zone. However, once the loss of production associated with the planted area is considered, there will be an overall loss of production area. This is further exacerbated if the plantings are not perpendicular to the dominant wind.

The optimal width of a shelter belt will be a balance between making the belt wide enough to ensure it can deliver the shelter services whilst being narrow enough to minimise the area lost in the planting zone. Research suggests that a shelter belt with a mix of trees and shrubs should be at least 30m wide[3], but any width will deliver some form of shelter services. The optimal width based on the productivity modelling is to have a shelter belt that is the width of 1 tree height at maturity. For example, if the trees are expected to grow to 20m then the shelter belt should be 20m in width.

Furthermore, planting shelter belts along existing roadways can limit the size of the competition zone as some of the competition zone will be in non-production areas (the side of the trees towards the road/infrastructure area).

Farms that have a significantly negative ha_v might have shelter belts planted too closely together (where the competition zone of a shelter belt overlaps and cancels out some or all of the benefit zone from an up-wind shelter belt), the shelter belts might not be perpendicular to the dominant wind (thus reducing their effectiveness), or the shelter belts are overly wide (increasing the lost area to planting without gaining additional shelter services in the paddock).

IMPORTANT NOTE

The change in virtual hectares is only one aspect of the overall impact of trees on a farm.

It is important to also consider the livestock shelter effects and the potential for the trees to provide habitat for crop / pasture pest predators as well as general biodiversity, carbon and amenity value.

These elements likely have complex interactions with each other and result in a net benefit to the farm business. Further research is needed to expand this picture and to refine the models for different regions and landscape types

We hope that this work leads to further development of methods, tools and services to make it easier for farmers to optimise the location of trees to meet their business and personal goals and also to supply nature repair services to citizens.

[3] https://www.sustainablefarms.org.au/on-the-farm/shelterbelts/

Insights | Wind analysis

Wind direction is a key input to the calculation of the shelter services provided by the woody vegetation on the farm. However, it is not as simple as calculating the mean wind direction for the whole farm over time, as different aspects of the shelter services provided by the trees are realised during different weather conditions. For this reason, different aspects of wind conditions are modelled to provide the appropriate wind direction inputs for the various ecosystem service calculations.

The weather data (wind, temperature, rainfall) used in our models is sourced from the BARRA2 dataset (Su et al., 2022) published by the Australian Bureau of Meteorology. The methods for the calculation of the mean wind direction metrics are adapted from methods developed in the CSIRO Perennial Prosperity project (Stewart et al., 2024).

How to read a wind rose

The hypothetical wind rose illustration below shows the direction (from each compass point), the speed (the colour of the wedges) and the frequency of that direction/speed combination (the length of the wedge – the longer the wedge, the more often the wind is seen from that direction and at that speed).

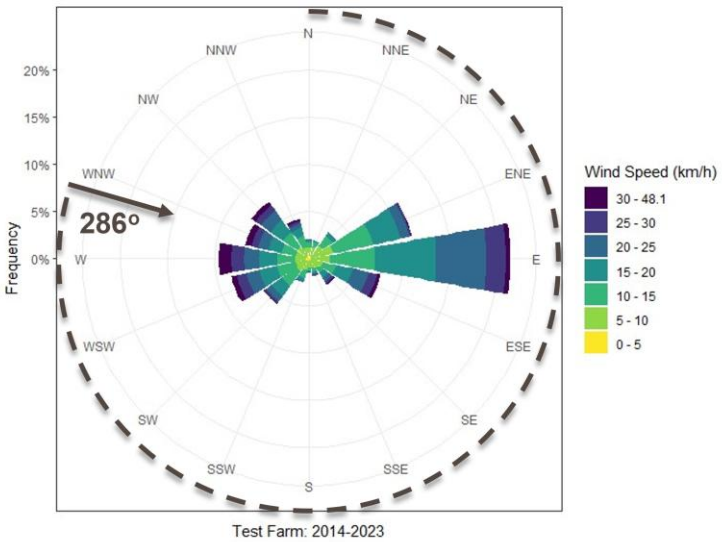


Figure 9: Sample wind rose showing mean wind direction.

Calculating mean wind direction

The mean wind direction is calculated as a **wind speed weighted average** of the wind observations (the stronger the wind speed, the greater the weighting for that observation). Calculations are based on 87,648 hourly modelled observations over 10 years (2014-2023). Windspeeds of less than 5.4 km/h (a gentle breeze in the Beaufort scale) were considered calm and excluded from the mean wind direction calculation (but are included in the wind rose graphical display).

Analysis of the data underlying the hypothetical wind rose in Figure 9 has concluded that the:

- **Wind speed weighted mean wind direction is 286^{0}.**
- **Mean wind speed is 7.5km/hr.**

One observation evident from the illustration in Figure 9 is that the winds in this location are typically east-west oriented, and fewer winds from the north and south. This visualisation by the wind rose helps to indicate what the orientation should be for shelterbelts to be placed perpendicular (north-south) to the dominant winds (east-west).

Whilst the mean wind direction of 286º may not appear obvious from the illustration in Figure 9 (the wedge to the east is much longer), the easterly winds are generally slower speeds (lighter colour) and so get lower weighting than the winds from the westerly directions (there are more parts of the westerly wedges in the darkest blue colour). The observations relating to the darker elements get more significance when calculating the mean wind direction.

Wind analysis has been performed for Roslyn Estate. Results for the annual average wind speed and direction, the wind speed and direction by season, cold winds by season and hot winds by season are shown on following pages. Wind speed and direction by month is shown in Appendix 1.

Wind speed weighted mean wind direction and speed for Roslyn Estate

Figure 10 shows the mean wind direction and speed across the 10-year analysis window for Roslyn Estate.

ALL MONTHS (2014-2023)

Wind speed weighted mean wind direction	Mean wind speed (km/h)
280^{o}	9.4

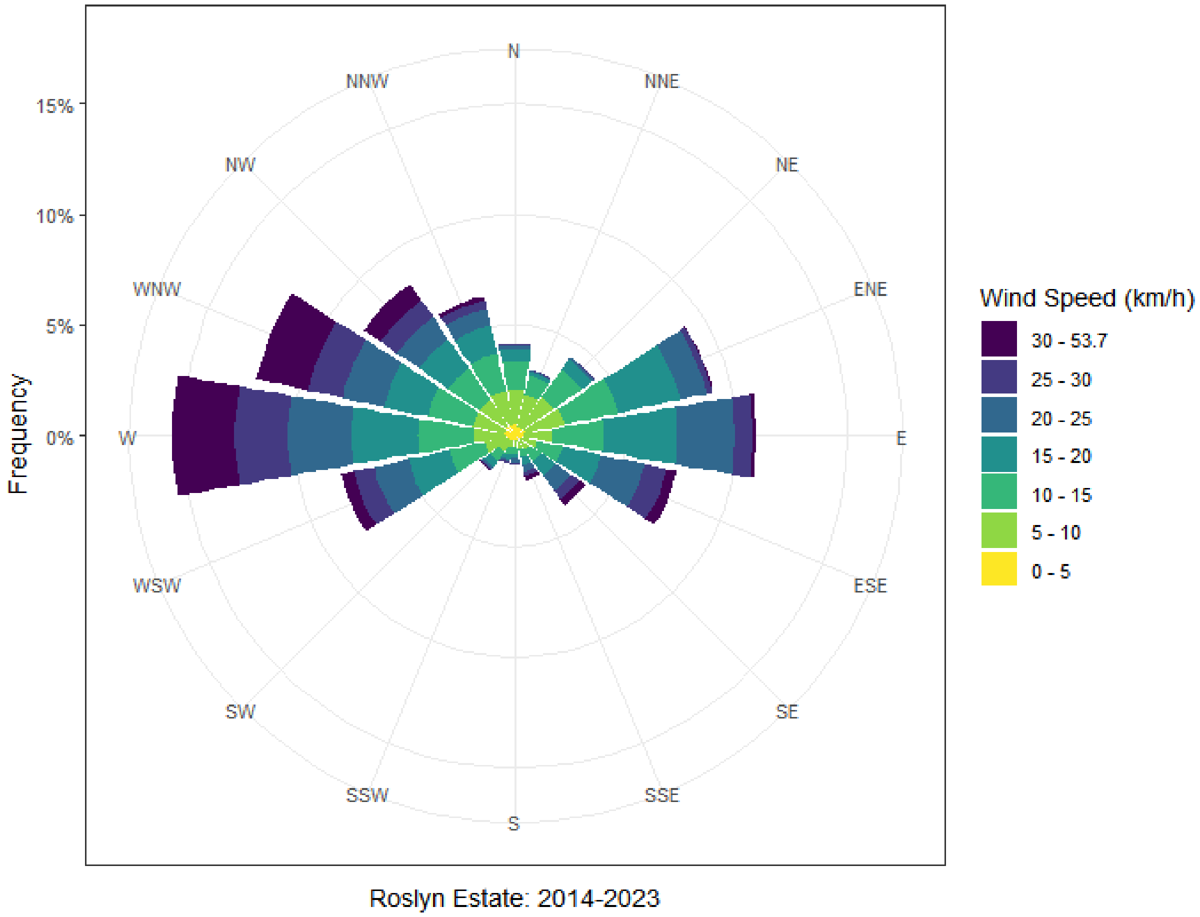


Figure 10: Analysis of the mean annual wind speed and direction for the period shows that the wind generally comes from 280 degrees from North and the mean wind speed is 9.4 km/h.

Wind speed and direction by season

Figure 11 shows the mean wind direction and speed for Spring, Summer, Autumn and Winter for Roslyn Estate.

BY SEASON (2014-2023)

Metric / Season	Spring	Summer	Autumn	Winter
Wind speed weighted mean wind direction	284°	94°	269°	279°
Mean wind speed (km/h)	9.7	8.9	8.0	11.0

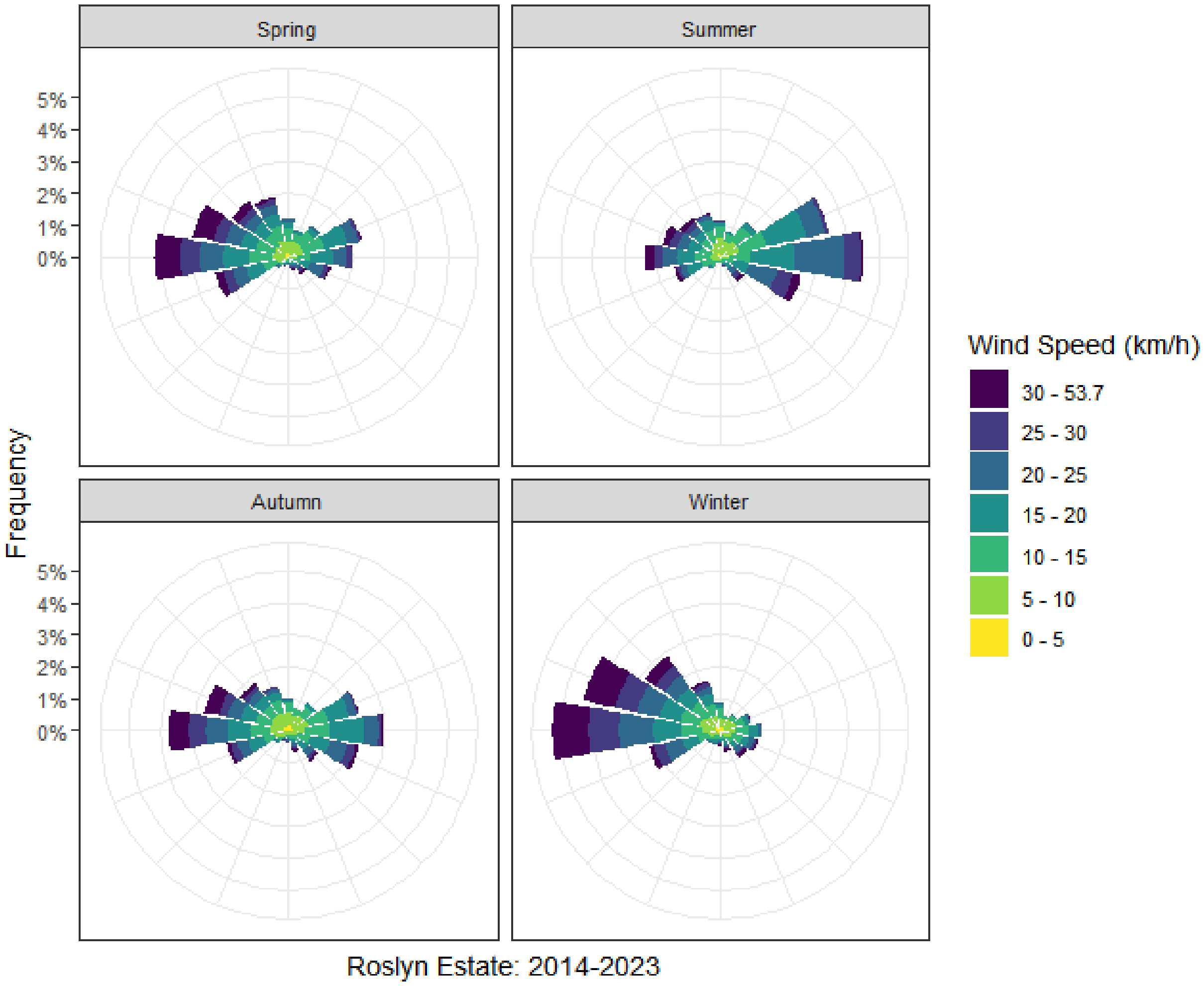


Figure 11: The mean speed and wind direction by season.

Cold winds

Cold winds have a number of implications from a production perspective:

- Livestock mortality of lambs and newly shorn sheep
- Decreased liveweight gain (or liveweight loss)
- Pasture and crop yield impacts

The mean wind direction for cold winds is calculated as a sheep chill index weighted average (the higher the sheep chill index, the greater the weighting for that observation). Calculations are based on 87,648 hourly modelled observations over 10 years (2014-2023), with observations with a sheep chill index < 1100 excluded from the mean wind direction calculations.

The sheep chill index (Nixon-Smith 1972) considers the impact of temperature, rainfall (past 24 hours) and wind speed on animal survival, with values greater than 1100 kJ/m2/hour considered to be high, and > 1200 kJ/m2/hour to be severe (McCaskill et al., 2010).

Figure 12 shows the results of analysis of the cold winds by season.

COLD WINDS BY SEASON (2014-2023)

Metric / Season	Spring	Summer	Autumn	Winter
Chill index weighted mean wind directions	263°	138°	262°	274°
Mean days per season exceeding threshold of 1100 kJ/m2/hour	41.3	14.4	32.7	81.8

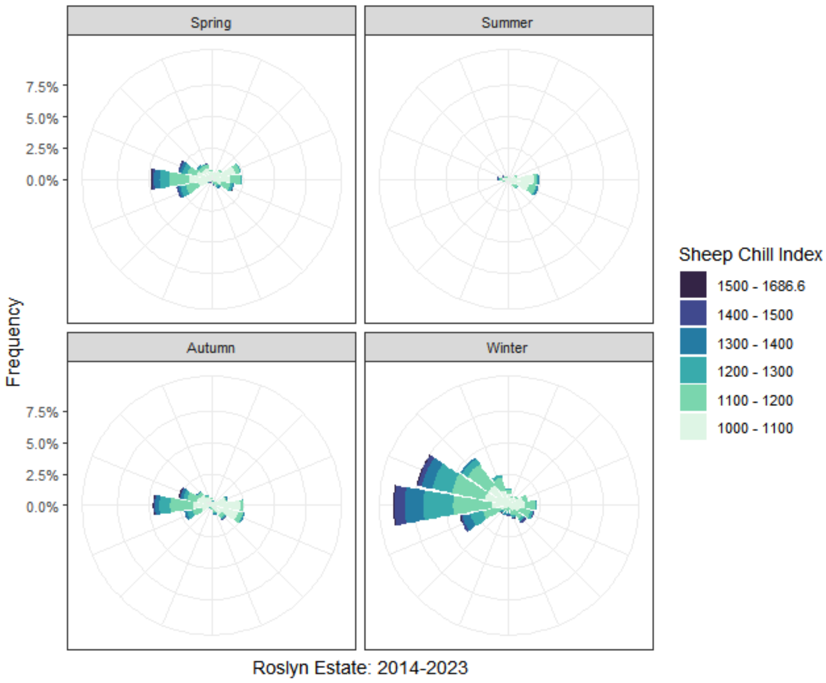


Figure 12: Analysis of cold winds by season indicating the dominant direction of cold winds and the mean number of days each season that exceed the threshold of 1100kJ/m2/hour.

Hot winds

Hot winds have a number of implications from a production perspective:

- Decreased liveweight gain (or liveweight loss)
- Pasture and crop yield impacts

The mean wind direction for hot winds is calculated as a wind speed weighted average (the higher the wind speed, the greater the weighting for that observation). Calculations based on 87,648 hourly modelled observations over 10 years (2014-2023), with observations with a temperature < 300C excluded from the mean wind direction calculations.

Figure 13 shows the results of analysis of hot winds for Roslyn Estate.

HOT WINDS (2014-2023)

Wind speed weighted mean wind direction	Mean wind speed (km/h)	Mean days per year > 30 degrees
292º	0.2	14.6

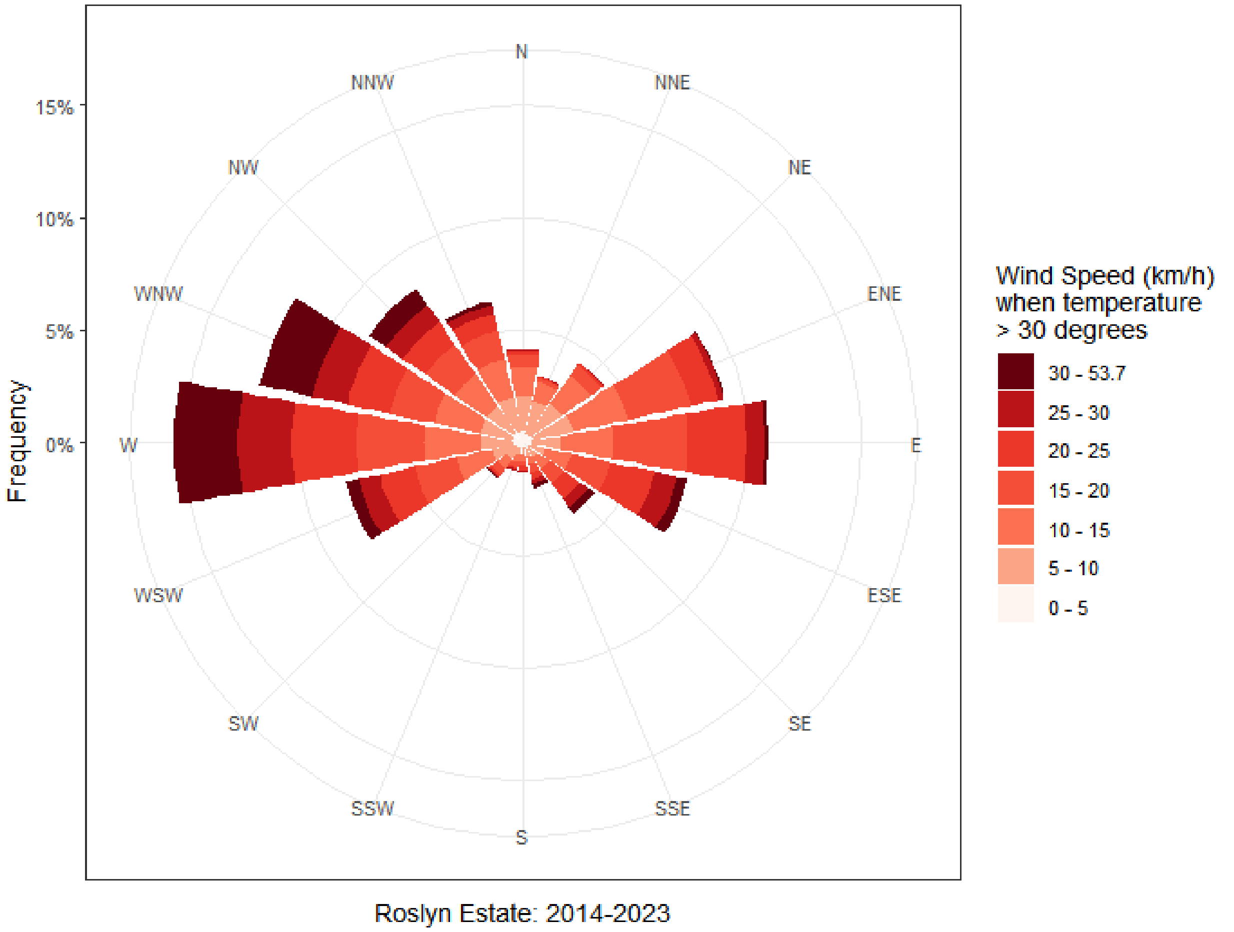


Figure 13: Analysis of hot wind direction and speed with mean days per year > 30 degrees Celsius indicated.

FARMING FOR THE FUTURE

Insights | biodiversity

This section provides summary accounts of the biodiversity values of Roslyn Estate, focusing on the predicted bird species richness. It provides information about the number of species of birds that could be found on the farm as well as the extent and quality of habitat on the farm for each group of birds. The measure of bird diversity gives 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. We would like to acknowledge and thank the La Trobe University Farm-scale Natural Capital Accounting project for their work in compiling the data and performing the analysis.

The maps presented on the following pages show predicted species richness (i.e., number of species) per hectare (Rainsford et al., 2025). They are derived from statistical models that used ecosystem state (Rainsford et al., 2024), 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 on farms across south-eastern Australia (Note: This farm was not surveyed as part of the development of the models. The results shown are modelled extrapolations from the surveyed farms). 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.

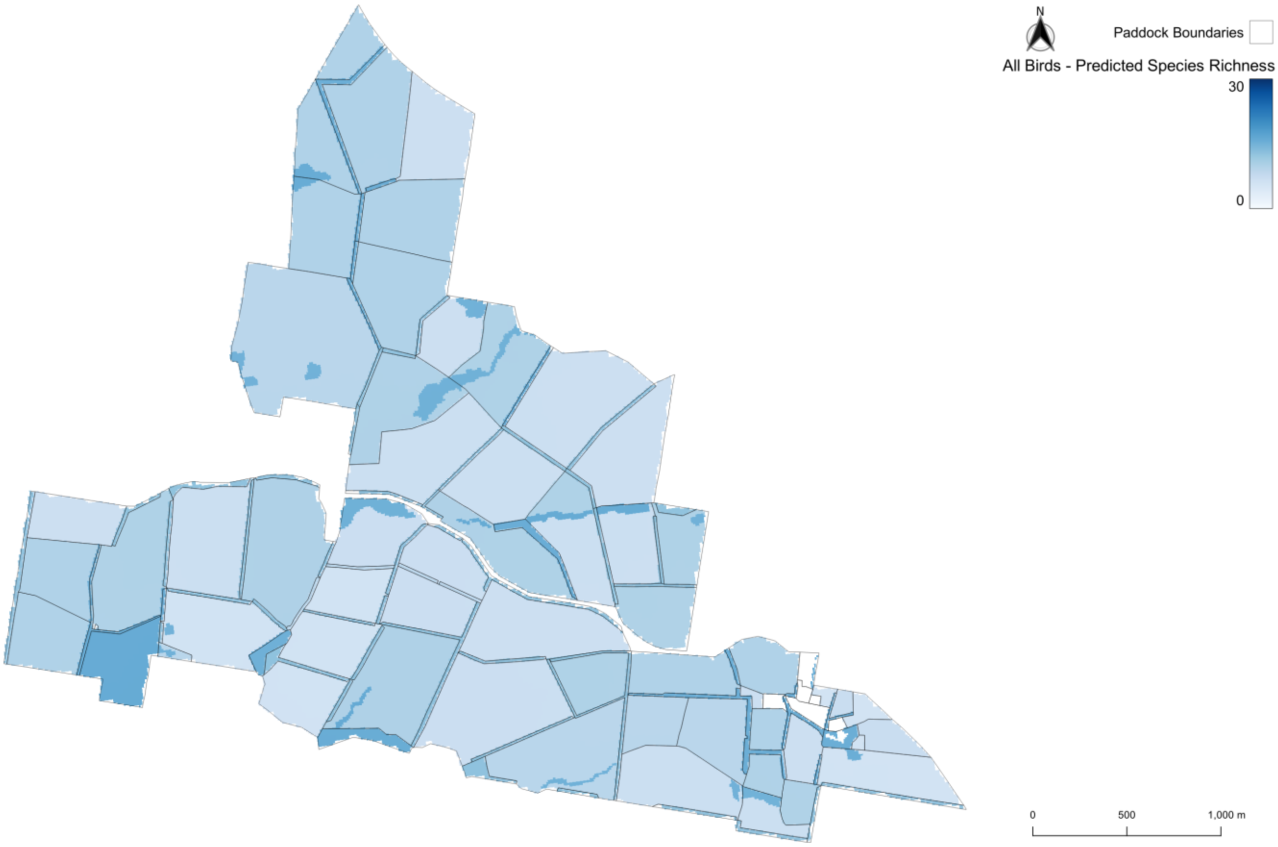
We generated models, predictions and maps of habitat quality for three groups of birds:

1) All bird species. This group includes any bird, no matter what type (includes woodland and grassland birds, as well as shrubland, open-tolerant, open country, and water birds).
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.

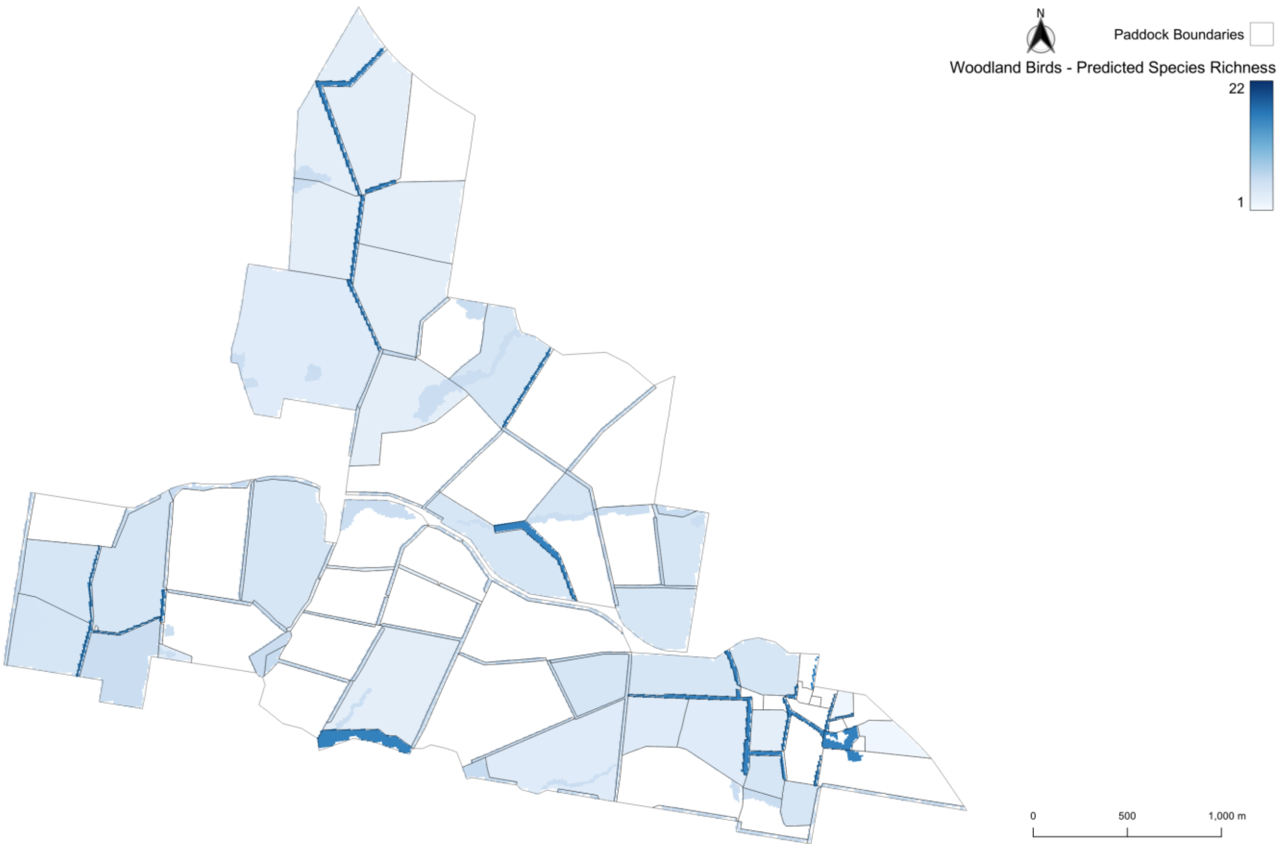
The following table provides measures (in hectares and percentage of the production area of the farm) of the amount of habitat on Roslyn Estate considered to be of ‘poor’, ‘moderate’, ‘good’, ‘very good’, or ‘outstanding’ quality for birds. The habitat quality classes were determined for each group of 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. 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.

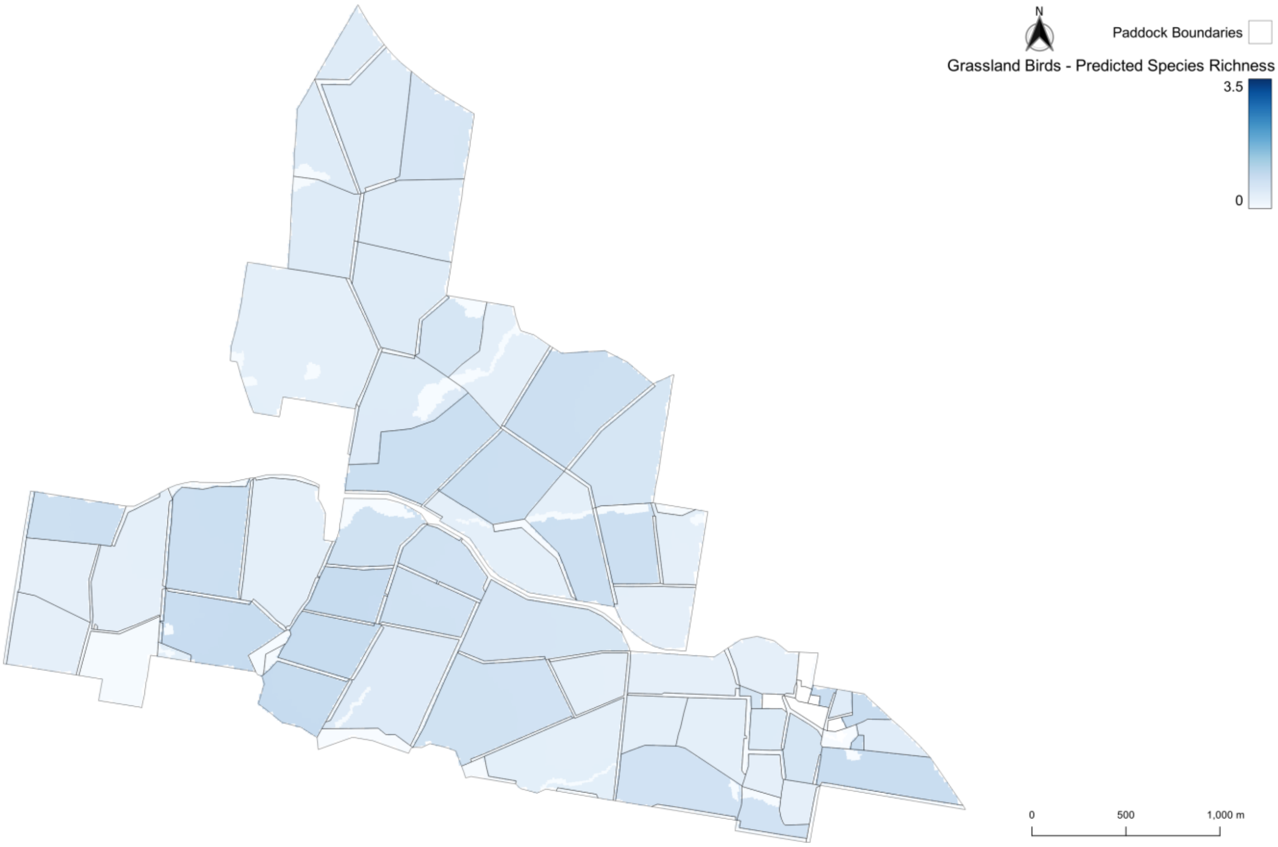
Bird Group	Metric	Habitat Quality				
		Poor	Moderate	Good	Very Good	Outstanding
All birds	Area (ha)	68.8	685.9	46.9	36.6	0.0
	% of farm	8.2%	81.8%	5.6%	4.4%	0.0%
Woodland birds	Area (ha)	352.6	0.0	402.1	64.8	18.8
	% of farm	42.1%	0.0%	48.0%	7.7%	2.2%
Grassland birds	Area (ha)	485.6	N/A	352.6	N/A	0.0
	% of farm	57.9%	N/A	42.1%	N/A	0.0%



Map 4. Predicted species richness map for all birds on Roslyn Estate



Map 5. Predicted species richness map for woodland birds on Roslyn Estate



Map 6. Predicted species richness map for grassland birds on Roslyn Estate

Appendix 1: Wind speed weighted mean wind direction by month

Figure 14 shows the wind speed weighted mean wind direction by month for Roslyn Estate.

BY MONTH 2014-2023

Wind speed weighted mean wind direction:

September: 282°

October: 290°

November: 283°

December: 300°

January: 95°

February: 104°

March: 118°

April: 272°

May: 276°

June: 281°

July: 280°

August: 277°

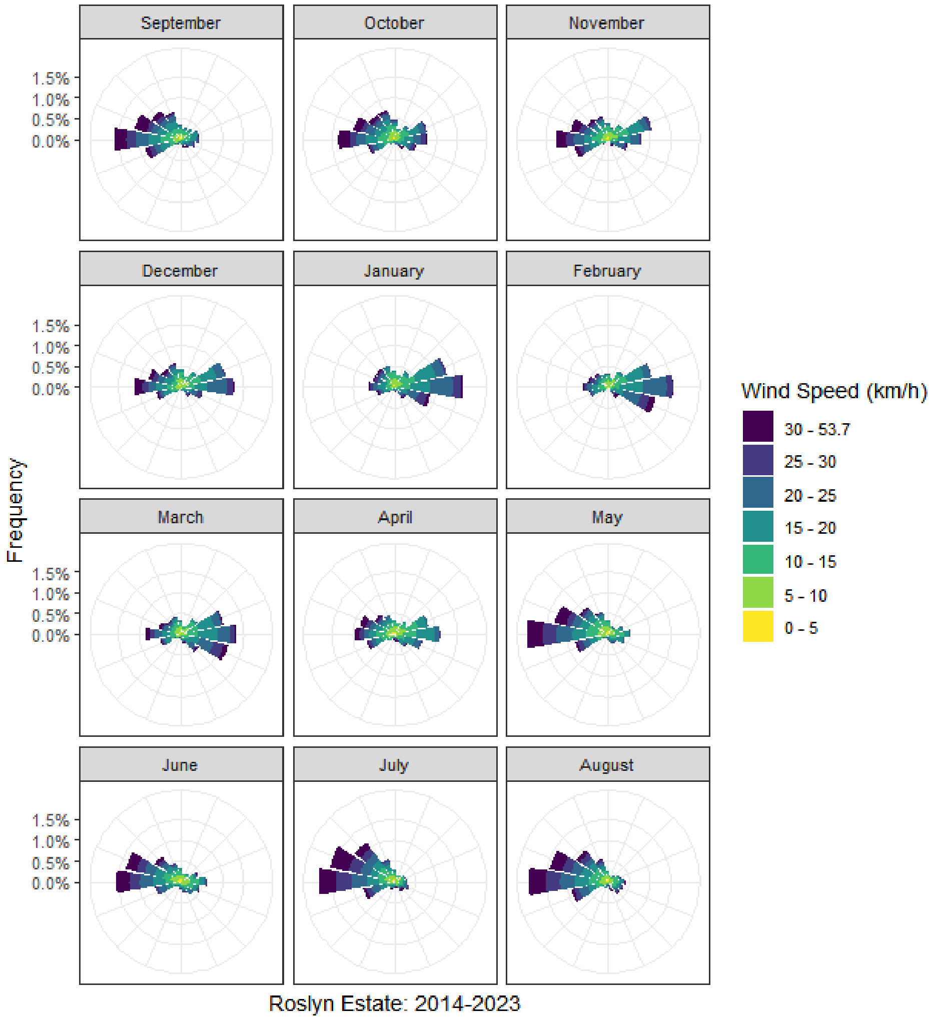


Figure 14: The mean speed and wind direction by month

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