‘TOOLANGI’

Carbon & Natural Capital for Resilient Farming Systems

Status & Opportunities

Prepared by Daniel Hanisch (Project Manager/Ecologist – RegenCo)

for Brad & Tessa Tiver (Trading under “Mount Razorback Pastoral Company”),

Primary Industries & Regions SA (PIRSA), and

Upper North Farming Systems (UNFS)

June 2025

COMMERCIAL-IN-CONFIDENCE

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WHAT ARE WE DOING TODAY

Australian Farmers have been working the land for centuries, each generation motivated to leave the land more resilient, productive, and profitable than how they found it. It's this spirit of being stewards of the land that inspires Regenco's mission; we exist to help farmers sustain the land that sustains Australia. This generation, and every generation to come.

We value and respect this expertise that comes from years of working the land. So, we built a natural capital business that complements farmers existing land management practices. As a group of pastoralists, grazing land management specialists and scientists with over 100 years combined experience working with the land, we have first-hand experience of the unique challenges farmers face. We listen to what farmers want and work in partnership to create mutually beneficial land management plans that help them make the most of their land. One that maximises their profits and productivity, while regenerating the land. It's an investment in our farmers, and our future.

A future that's good for producers, paddocks and the planet.

Regenco, value that grows.

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Dear Brad and Tessa, Primary Industries & Regions SA (PIRSA), and Upper North Farming Systems,

We are grateful firstly for the opportunity to be involved, and secondly for your contribution of time and resources to help us develop this report.

The broader PIRSA program that funded this project was an important investigation into identifying where environmental market opportunities align with improving productivity, profitability and resilience to a changing climate. Based on our findings in this report, we believe there are clear opportunities for the Tiver’s enterprise to deliver subtle management changes that can drive both economic and environmental improvement, while continuing to maintain agricultural production into the future.

This important case study highlights ways in which other landholders in the region could consider the value of natural capital and environmental markets being integrated into their current enterprise mix. While each enterprise and its landholdings is unique, there are some valuable take-away messages in this report for other regional businesses, which are highlighted in the executive summary, climate resilience being key.

We have to expect that the future is not going to be a simple repetition of the past- either for markets or the environment. Taking on board the findings of this report will stand the Tivers (and other landholders in the region, and indeed across the State) in a much stronger position to capitalise on opportunities that emerge, while keeping a key focus on agricultural production and the financial drivers of their business.

We wish you well in the implementation of the aspects of this report that you see having significant positive impacts for your business, and standby to provide any further assistance you require moving forward.

Dr Tim Moore
Head of Science and Strategy, RegenCo
Greg Noonan
CEO and Managing Director, RegenCo

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1. LANDSCAPE & CLIMATE CONTEXT

LANDSCAPE – TOPOGRAPHY & BIOREGIONAL CONTEXT

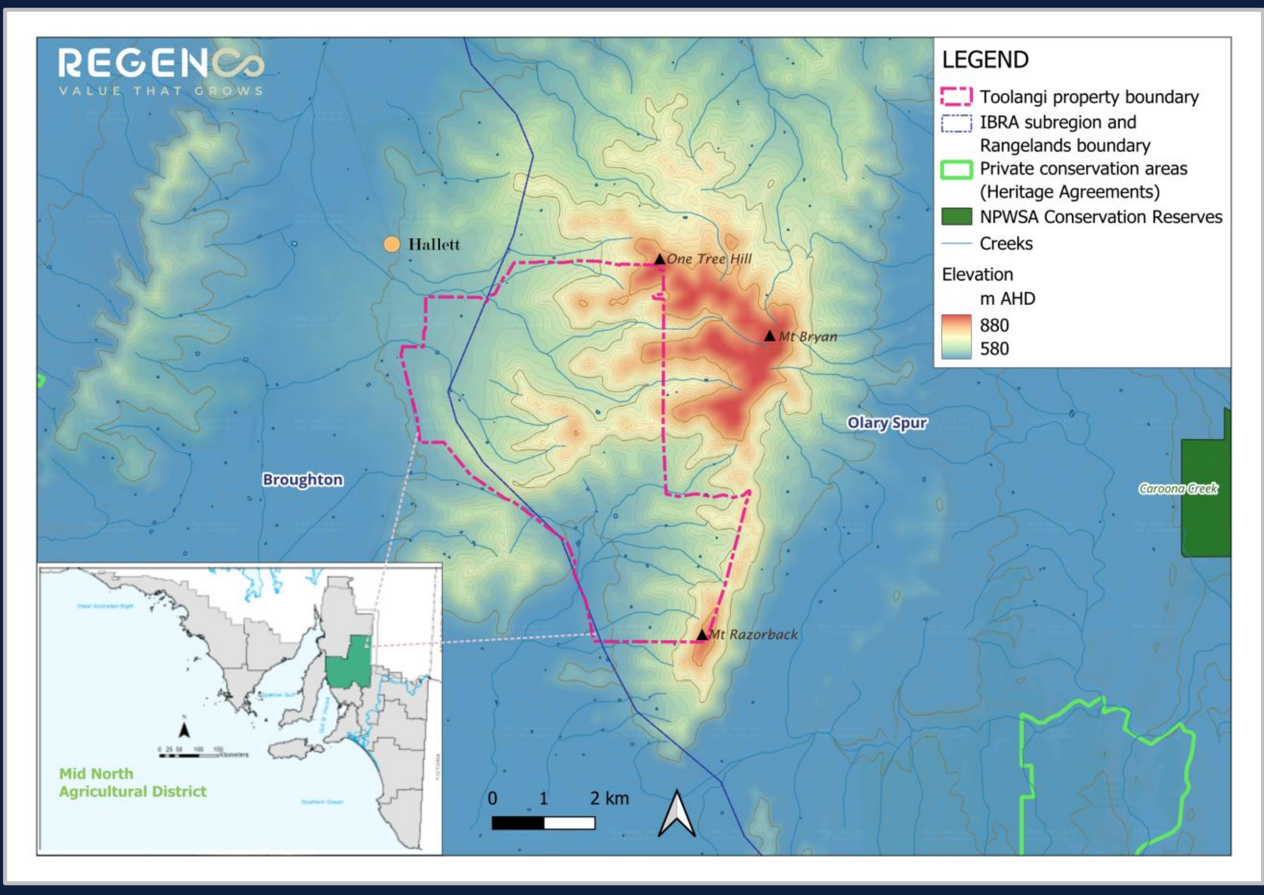
Toolangi is a 2900 ha sheep grazing property on the western side of the Northern Mount Lofty Ranges approximately 25 km north of Burra, South Australia, and just a few km south-east of the town of Hallett. Some parts in the west of the property are cropped for sheep feed, but mostly it is managed for native pasture.

From west to east, the property starts at an altitude of about 600 m AHD in the Broughton IBRA (Interim Bioregionalisation of Australia) subregion of the Flinders Lofty Block IBRA region. The western boundary experiences an annual average rainfall of about 400 mm and is near the base of the locally prominent Mt Bryan range, which is at the southern end of the Olary Spur. The property then rises with increasing steepness into the Olary Spur subregion and towards two of the highest peaks in the area - Mt Razorback (863 m altitude) in the south-east corner and One Tree Hill (890 m) in the north-east corner. At these high points, the annual average rainfall is closer to 500 mm. Slopes in the hills range from 10% to 75%. On the fans, 2 - 10% is the usual range. A number of ephemeral creeks run off the montane country in the east down to the outwash fans in the west.

The region belongs to the Mediterranean Forests, Woodlands & Scrub biome. The region supports a range of vegetation types including sclerophyll woodlands, open and grassy woodlands, and grasslands. The woodlands are dominated by different species of Eucalyptus, changing according to rainfall distribution. Clearing for agriculture has been widespread and, generally, only fragmented vegetation remains with only 9% under protection. The ecological status of this region is Critical/ Endangered, according to WWF. The relatively cool and wet environment of the regionally significant mountains around Toolangi offer a climate refuge for local biota.

The nominal boundary of the Australian Rangelands also coincides with the boundary between the Broughton and Olary Spur subregions, which passes through the property, indicating a climatic shift in this geographical area.

Due to both its bioregional topographical location, Toolangi can be regarded as occurring in ecologically important transitional country - where plant and animal diversity is often maximised - as well as agriculturally transitional country - where cropping ceases to be viable and low intensity grazing of native shrublands becomes preferred practice.



Regional physiographical context of Toolangi

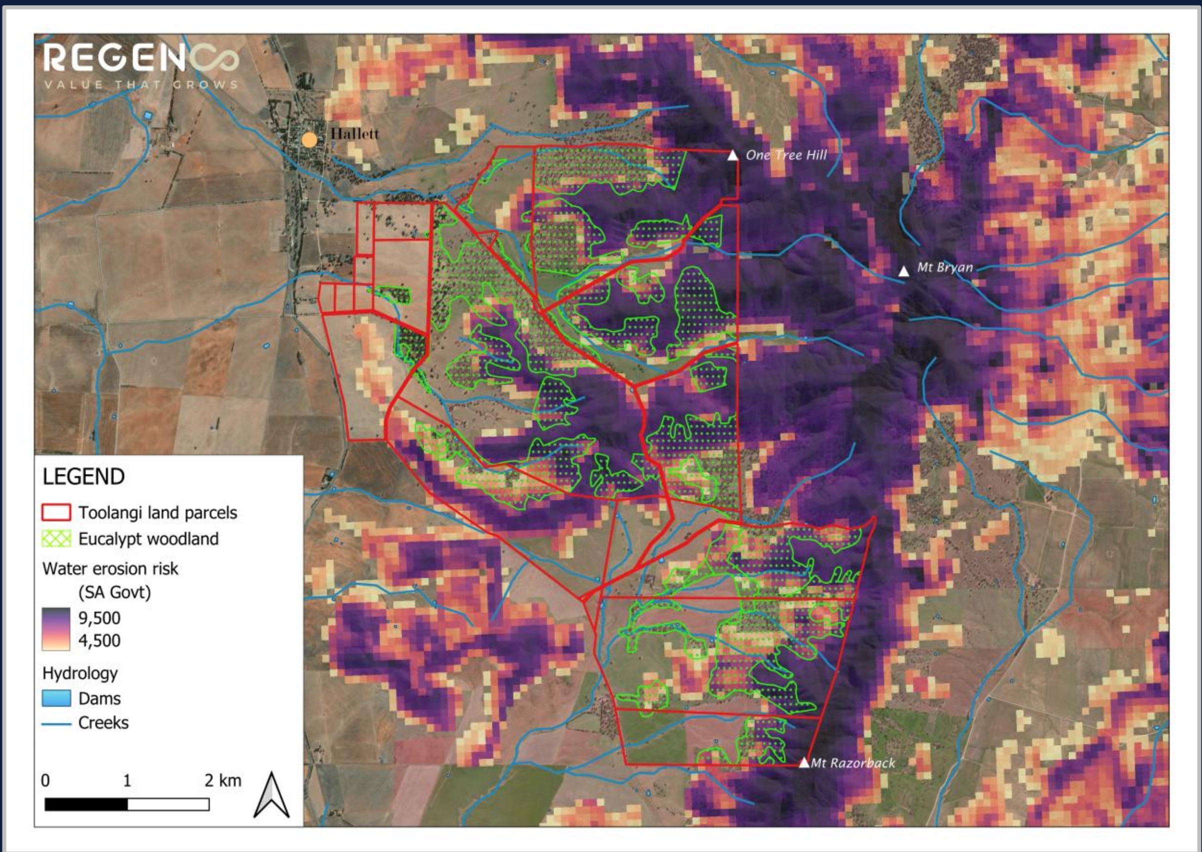
LANDSCAPE – SOILS, EROSION RISK & WOODLANDS

Over 90% of Toolangi belongs to the Razorback Land System, with just a small part in the north-west corner belonging to the Hallett Land System. Razorback soils are relatively shallow over basement rock. They include loamy soils with red clayey subsoils, shallow stony loams and calcareous loams. The SA Government describes the main features of the Razorback Land System as follows:

> *The steepness and rockiness of much of the land system limits use to rough grazing only. Because of the extreme susceptibility of the slopes to erosion, grazing management is critical to ensure sufficient protective ground cover. Water course erosion is severe in places and this can only be controlled through upslope run off reduction. Some moderate slopes are semi arable, but are characterized by rocky reefs, shallow stony soils and eroded watercourses. Cropping these areas requires skillful management. The more gently sloping outwash fans are mostly arable, the soils are deep and moderately fertile, but the erosion potential is still significant. Poor soil structure is a major limitation of soils in these areas.*

Areas of severe erosion risk are highlighted in the map below. Also shown in the map are areas of eucalypt woodland, which are mostly dominated by South Australian Blue Gum with a mostly grassy understorey. These woodlands are quite unique in the local area, both due to more complete historical clearance on other properties, and also because Toolangi receives relatively high rain and runoff at its elevated eastern end. On Toolangi, these woodland areas have mostly been left in place on the mid to lower slopes between the fertile outwash fans and the steepest and highest peaks. While these woodland areas offer protection against erosion across much of the high risk area, the highest altitude areas mostly have sparse shrubland with grassy understorey, which is unlikely to offer much mitigation of rapid runoff during intense rainfall events. It is suspected that these areas would have previously supported woodland, potentially with more palatable species (e.g. she-oak) that have been removed over time by grazing, or tree species that had some particular value that made them worthy of harvest (e.g. native pine).

The current PMP for Toolangi notes that reluctance to vary stock numbers during drought and pest herbivores, especially kangaroos, have impacted groundcover at times, which further creates conditions where soil degradation and erosion can occur. The compromised hydrological integrity of Toolangi and associated erosion is likely to create soils incapable of absorbing water leading to landscape dehydration, unless remediative action is taken.



Eucalypt woodland and erosion risk of Toolangi

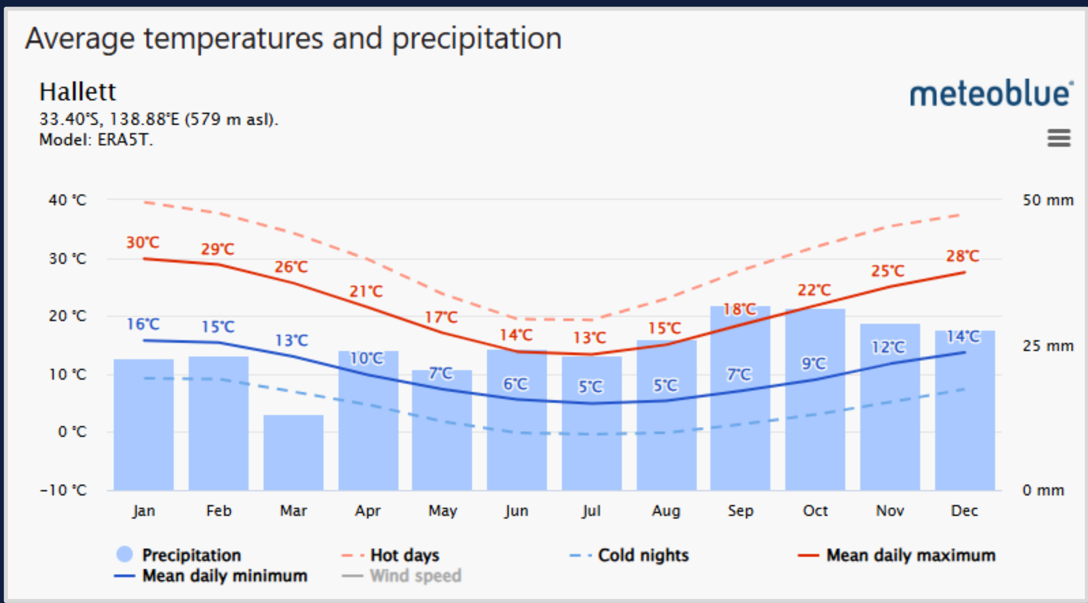
CLIMATE CONTEXT – TEMPERATURE & WATER BALANCE

The climate experienced by Toolangi, and the local region in general, is classified as Mediterranean, verging on semi-arid. Annual rainfall is generally in the range of 300-400 mm per year at the western plain, 400-500 mm per year on the peaks and ranges to the east of the property.

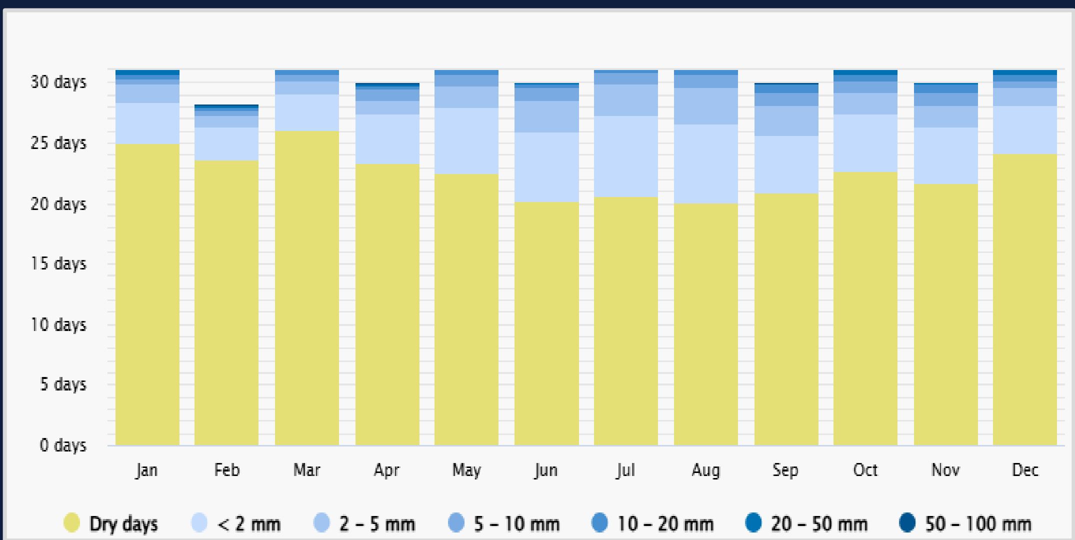
The long-term rainfall pattern slightly favours winter-spring rainfall, however this has shifted towards a heavier summer rainfall pattern and reduced winter rainfall in the past two decades, such that rainfall is now more even throughout the year. Rainfall is poorest on average in March, raising risk of feed shortage before the autumn rains arrive.

Average maximum summer season temperatures are high (high 20s to low 30s) and maximum winter temperatures are mild (low to mid teens), while overnight average minimums are 5-6C and sometimes fall below zero.

Potential annual pan evaporation volumes are well in excess of rainfall, peaking in January.



The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Hallett. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years.
Note the very high hot day maximum from November to March (over 35C), and very low cold night minimum from June to August (0C) when frosts are most likely. (Source: Meteoblue website)



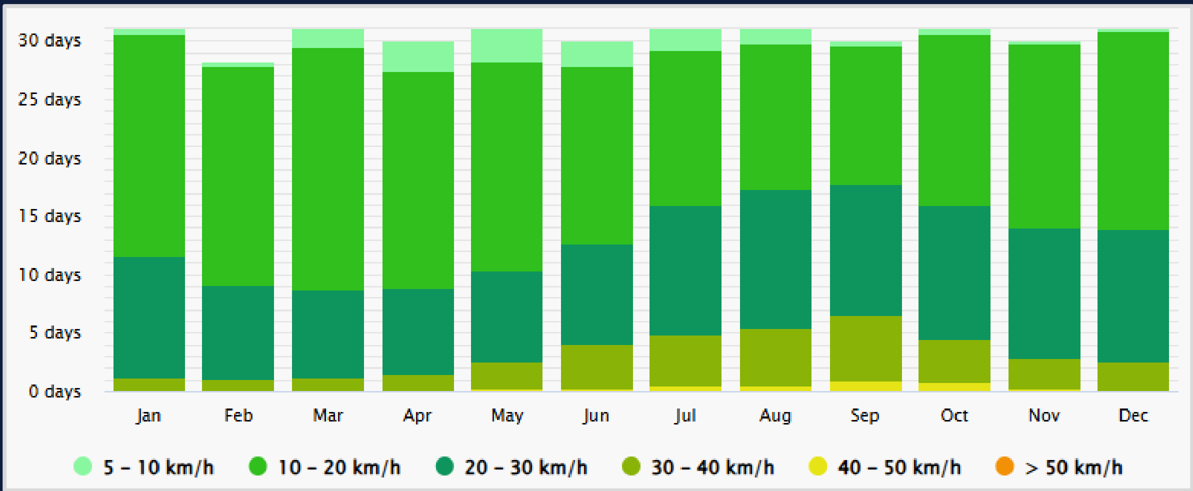
This precipitation diagram for Hallett shows on how many days per month certain precipitation amounts are reached. Note that rainfall days are lowest in late summer-early autumn, with the larger precipitation events generally occurring in spring and summer. (Source: Meteoblue website)

CLIMATE CONTEXT – WIND SPEED, DIRECTION & SEASON

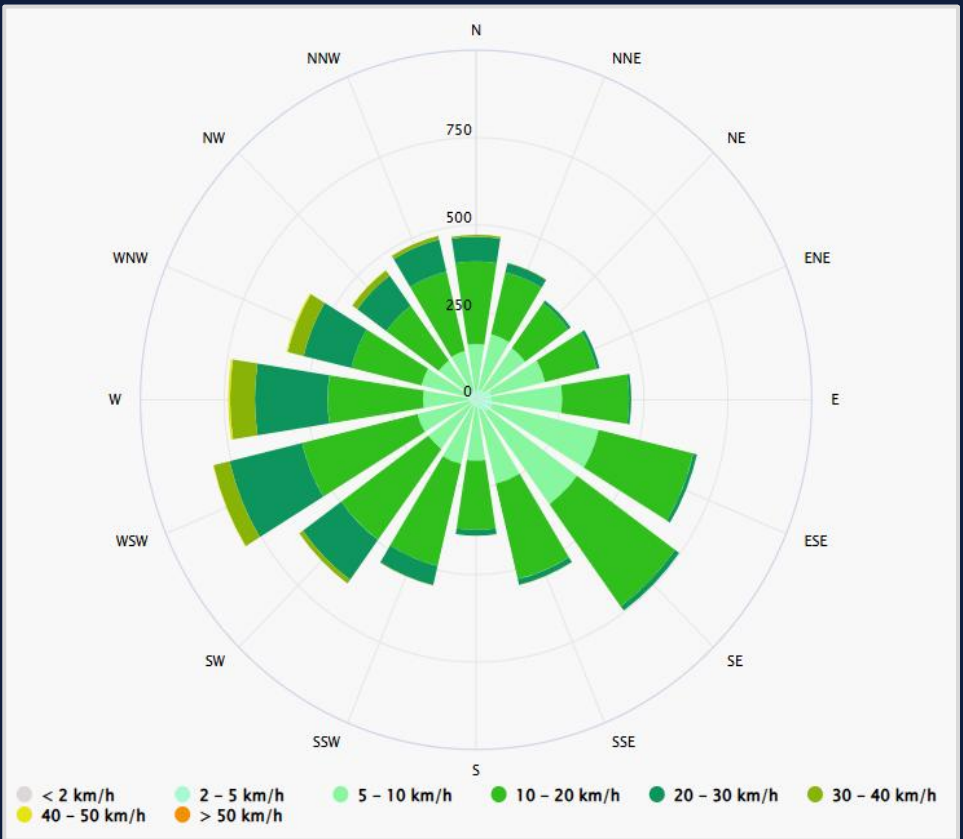
The Mid North Agricultural District of South Australia is a windy part of the state, and the area around Toolangi is no exception, with the period from July to December being a period of particularly strong winds, before easing in late summer.

September is when wind speeds generally peak, while Autumn is the time of year with most gentle winds.

Wind direction is primarily from the west/south-west, especially when winds are strong (more than 20 km/h). Although a large proportion of annual winds also blow from the south-east, these tend to be more gentle breezes. Strong hot winds (up to 40 km/h) will sometimes blow from the north-west, especially from Oct-January.



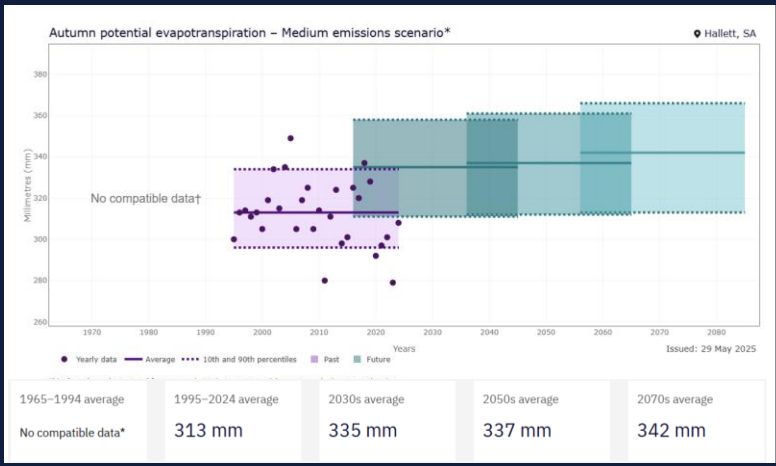
Wind Speed: The diagram shows the days per month during which the wind reaches a certain speed at Hallett. Note that the windiest time of the year coincides with the wettest time of the year (Aug-Dec) and overlaps with the coldest time of year (Jun-Aug). (Source: Meteoblue website)

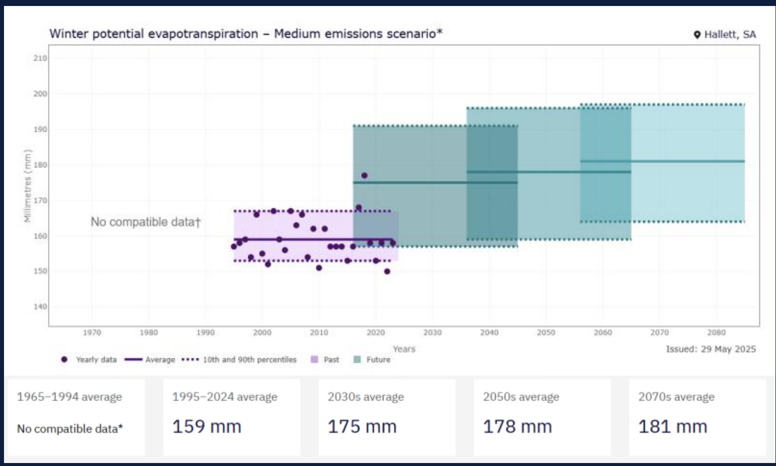


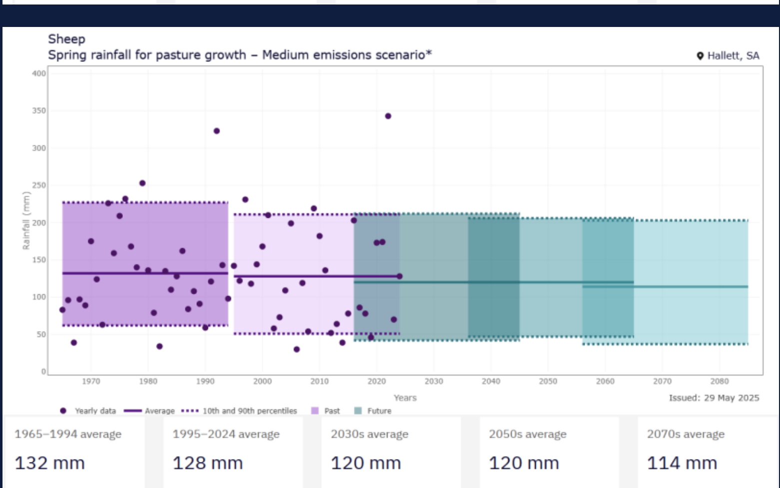
Wind Direction: The wind rose for Hallett shows how many hours per year the wind blows from the indicated direction and at what speed. Note that almost all winds greater than 20 km/h, and all winds greater than 30 km/h, blow from a westerly direction (SW to NW) (Source: Meteoblue website)

CLIMATE CONTEXT – WATER BALANCE TRENDS

The My Climate View website provides regional level climate projections under climate change scenarios for primary producers. For the Hallett region, rainfall projections suggest that winter rainfall may recover from declines seen in recent decades. However, the projected 18 mm increase in rainfall is expected to be cancelled by an equal increase in winter evapotranspiration. While summer rains are expected to remain steady, decreases are modelled for both Autumn (10 mm by 20250) and Spring (8 mm by 2050). Projections for evapotranspiration for Spring and Autumn are for an increasing trend, suggesting a worsening water deficit. Particularly noteworthy are the large increases in evapotranspiration in the next ten years or so under the influence of climate change.







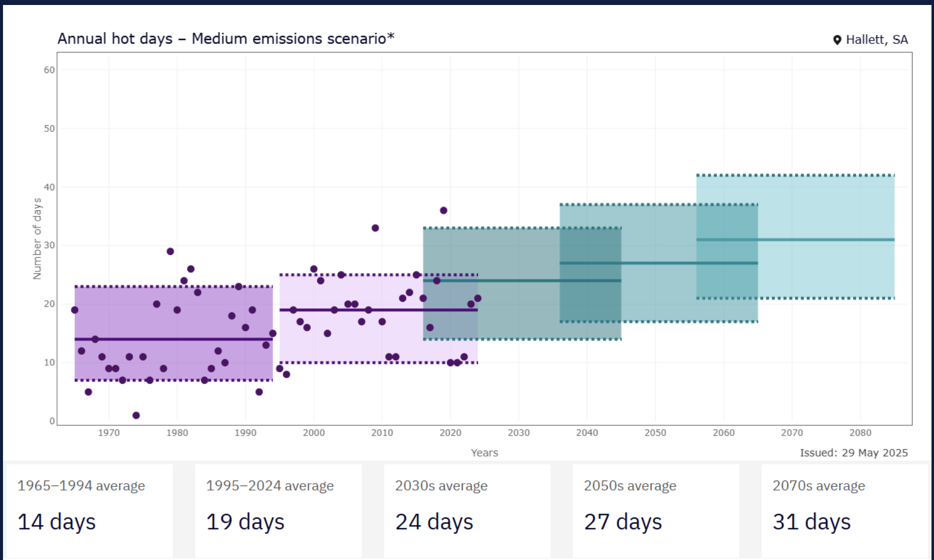
CLIMATE CONTEXT –HEAT STRESS RISK

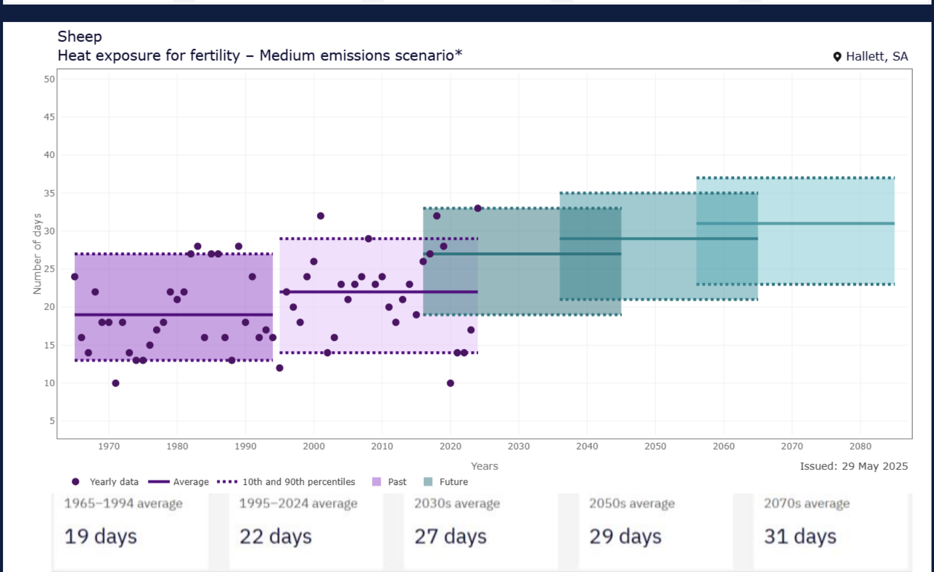
For well-fed, adult animals, the effects of higher temperatures are substantial. For example, sheep with a full fleece will often increase their respiration rate when the temperature reaches 18–21°C.

The graphs for the Hallett region below are taken from My Climate View.

The first graph indicates the number of annual hot days (more than 35C) during the 1965-1994 and 1995-2024 periods, showing that the average number of hot days has increased from 14 to 19. The graph also provides projections for annual hot days to the 2030s, 2050s and 2070s based on medium emission climate change scenarios. All projections suggest that annual hot days will continue to increase up to an average 31 days per year by 2070 – more than twice the 1965-1994 figure.

The second graph shows the number of days per year that are potentially harmful to sheep fertility due to excessive heat. The data are restricted to 15 January - 15 June each year, which is the period identified as the main lambing time around Hallett. Unsurprisingly, the current and projected trends follow much the same increasing pattern as those presented in the "Annual hot days" graph, with 7 more high risk days by 2050.





Why does it matter?

Heat stress reduces sheep fertility and lambing rates. Hot conditions can reduce the production and quality of ram semen while ewes' fertility cycle can lengthen reducing the number of opportunities to fall pregnant. Further, heat stressed ewes can have higher embryo mortality in early pregnancy and lower foetal weights. Collectively these affects can lower productivity.

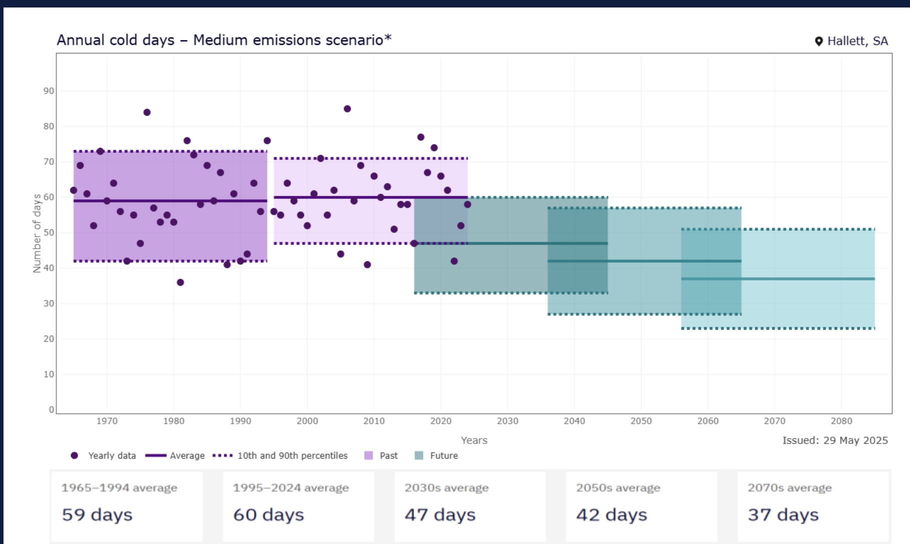
CLIMATE CONTEXT – COLD EXPOSURE RISK

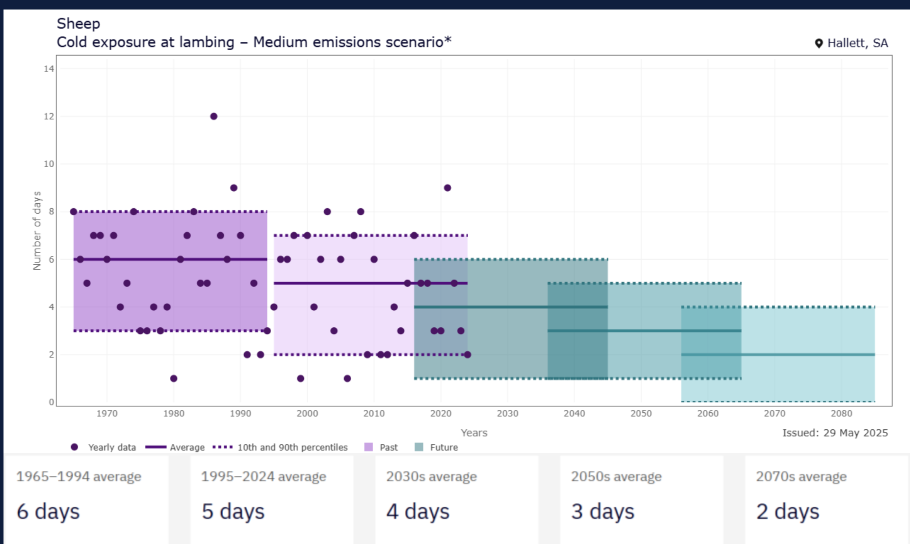
The graphs below are taken from My Climate View for the Hallett region.

The first graph indicates the number of annual cold days (with minimum less than 2C) during the 1965-1994 and 1995-2024 periods, showing that the average number of cold days has stayed pretty steady. The graph also provides projections for annual cold days to the 2030s, 2050s and 2070s based on medium emission climate change scenarios. All projections suggest that annual cold days will decrease to an average of 42 days per year by 2050 – 18 less than now.

The second graph shows the number of days per year that are potentially harmful to lamb survival due to cold exposure (minimum less than 2C and at least 1 mm of rain). The data are restricted to 1 March – 31 August each year, which is the period identified as the time when, generally, lambs are young and vulnerable in the Mid North district. The data suggest a small change, with a drop in cold exposure days from a current average of 6 to 3 days by the 2050s.

Wind chill is also a major risk when considering cold exposure. For example, a 10 km/hr wind at sheep height can lower the effective temperature from 10 to -3°C. The lack of a wind chill factor in this analysis likely causes an underestimate of the true risk of cold exposure, especially as July & August are two of the coldest, wettest and windiest months near Hallett.





Why does it matter?

Cold exposure can lead to lamb mortality, reducing productivity. Rainfall events combined with cold temperatures are used to represent potential cold exposure.

2. NATURAL CAPITAL ASSESSMENT

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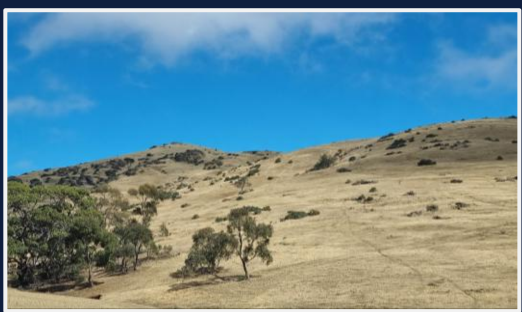
WOODY BIOMASS CARBON ASSESSMENT

- Embedded carbon and sequestration rates on Toolangi in woody vegetation biomass were assessed and estimated using the Australian Government's official carbon model – FullCAM.
- There is a large area of remnant South Australian Blue Gum (*Eucalyptus* leucoxylon) woodland on Toolangi – about 1050 ha. For modelling purposes, this area was estimated to be 80 years old. FullCAM indicates that at this age the woodland would only be sequestering at a rate of 0.15 tCO2e-/ha/yr, or 157 tCO2e-/yr across the entire woodland area. It should be noted that this annual sequestration volume cannot, at this time under rules derived from the Kyoto Protocol (1999), be used to generate carbon credits or to offset emissions in carbon footprints, due to the advanced age of the trees.
- Using the FullCAM model to calculate the current stocks of the remnant Blue Gum woodland, yields a per hectare figure of 123 tCO2e-/ha. Therefore, the embedded carbon in this woodland is estimated to currently be 123 x 1050 tCO2e- = **129,150 tCO2e-**.
- There are some scattered and mostly sparse areas of shrubland on the upper slopes, which are roughly estimated to contribute 6 tCO2e-/ha at maturity. The contribution of these areas to total embedded carbon on the property would be minor and, therefore, no attempt has been made to quantify it across the property.
- The remnant woodland and shrubland was found to be in various states of presence and condition, as described by the images and captions below. Despite a large amount of woodland on Toolangi, opportunities to increase woody biomass clearly exist.


Some areas of woodland are in good condition for long term persistence with trees of many age classes, while other areas located where there is more likely to be grazing pressure have few new recruits.




Some hill slopes and uplands are reasonably well vegetated with shrubs on the upper slopes and trees on the lower, while other hill slopes are almost devoid of perennial vegetation.


Some creeks and drainage lines are reasonably well vegetated with perennial vegetation, leaf litter & woody debris slowing flow, while others have little or no woody vegetation and are highly vulnerable to erosion.

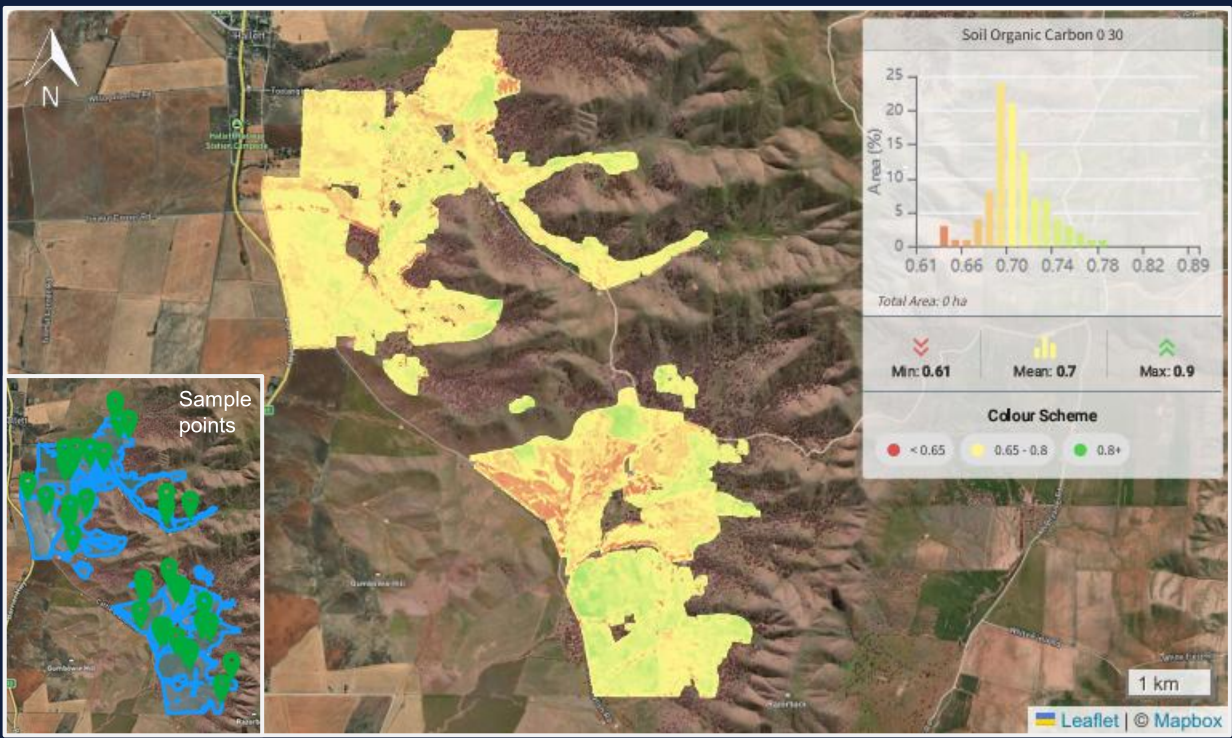
SOIL CARBON ASSESSMENT

- The soils on Toolangi are mostly a loam, which may be stony or grading to clay-loam. In the Mid North District, there is an increasing trend in surface SOC content from sand to clay loam textures, with pasture soils having higher SOC concentration than crops (Schapel et al, 2024).

Ag District SOC Benchmarks							
Texture	Count	Mean %	25%	40%	50%	60%	75%
Sand							
Loamy sand	41	0.78	0.51	0.62	0.66	0.85	1.00
Sandy loam	188	1.25	0.85	1.09	1.21	1.33	1.57
Loam	539	1.45	1.10	1.27	1.40	1.50	1.70
Clay loam	1346	1.50	1.18	1.33	1.45	1.54	1.71
Clay	1005	1.46	1.10	1.30	1.40	1.50	1.72
Weighted Mean (all texture)	3119	1.45	1.11	1.29	1.40	1.50	1.69

Table 2: Soil organic carbon benchmarks based on soil test data for the Mid North agricultural district

- The Property & Business Management Plan developed by Pinion Advisory (2024) identified better grazing management and control of soil erosion as a key goal for the property.
- In March 2024, the soils on Toolangi were sampled through FarmLab in accordance with the Emission Reduction Fund soil method, *Estimation of Soil Organic Carbon Sequestration using Measurement and Models) Methodology Determination 2021.*
- Soil Organic Carbon (SOC) was sampled at 0-30 cm and 0-100 cm depth at 52 sample points across three strata of a single CEA* (CEA area of 1,083 ha). Samples were analysed by APAL.
- Soil Organic Carbon was found to be quite consistent across the property, with an average concentration of **0.49%** at 0-30 cm depth and 0.35% across the whole 0-100 cm profile. Looking at the map below, it is apparent that SOC was lowest in areas of most intensive use for agricultural production.
- Total SOC across the whole CEA area was found to be about 26 tSOC/ha. This equates to 95 tCO_2e^-/ha or **102,885 tCO_2e-** across the whole CEA. If we extrapolate the CEA figures to the whole property, we can roughly estimate that the stock of soil carbon on Toolangi to 30 cm depth is **275,500 tCO_2e-**.
- According to work by the SA Govt., these results would put Toolangi's SOC% below the 25th percentile for soils in the Mid North District (noting that the District figures are for 0-10 cm soil depth only). This suggests that opportunities exist to increase SOC, which would most likely be realised by restoring natural hydrology and boosting organic inputs by managing grazing pressure or shifting from grazing to cropping of certain paddocks. If %SOC in the top 30 cm of the CEA was increased to reach the 25th percentile figure for sandy loam (0.85%), this would increase the amount of SOC by about 20,600 t SOC (approx. **75,000 tCO_2e^-**).

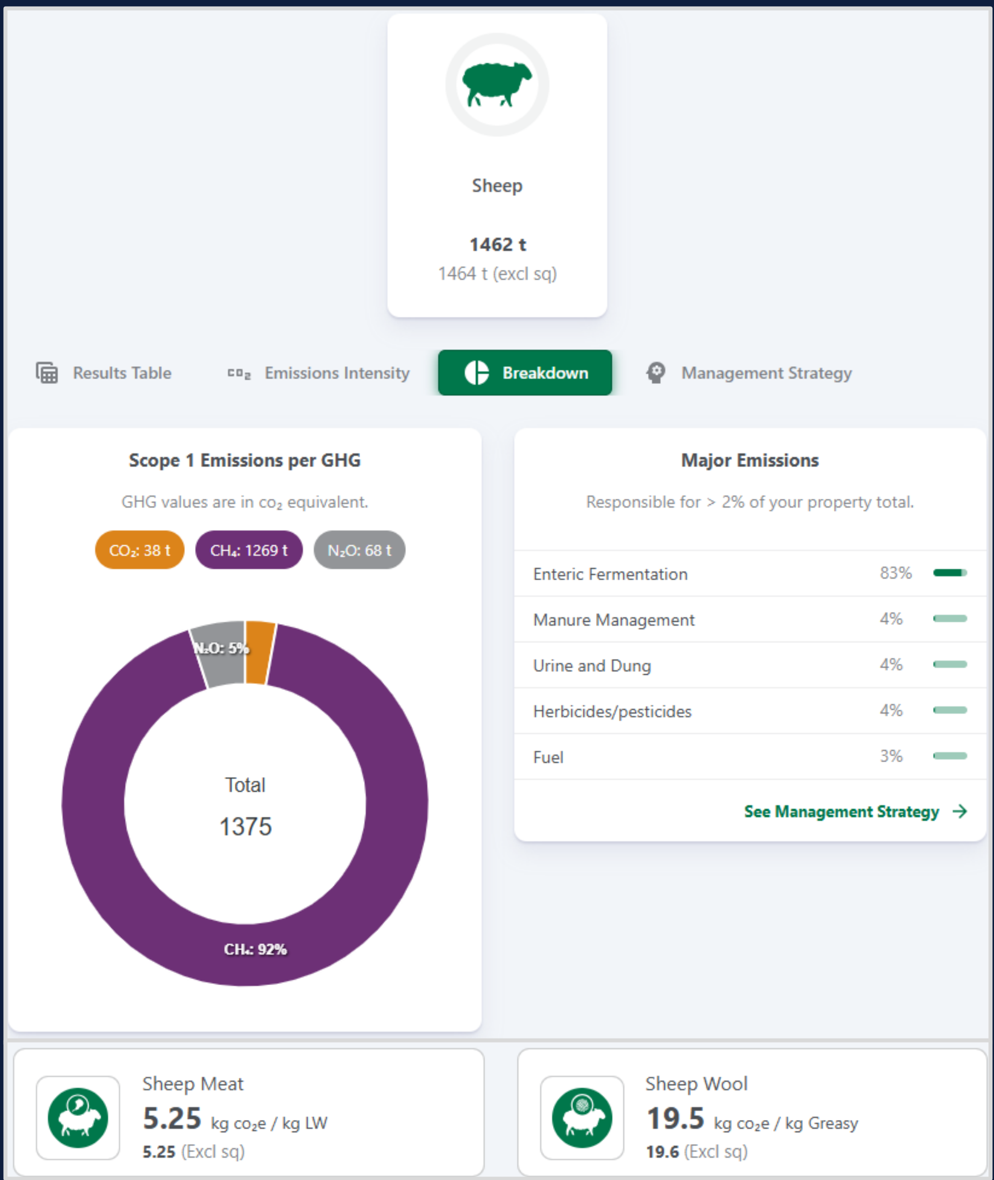


Soil sampling points, CEAs and carbon content for Toolangi

*Carbon Estimation Area

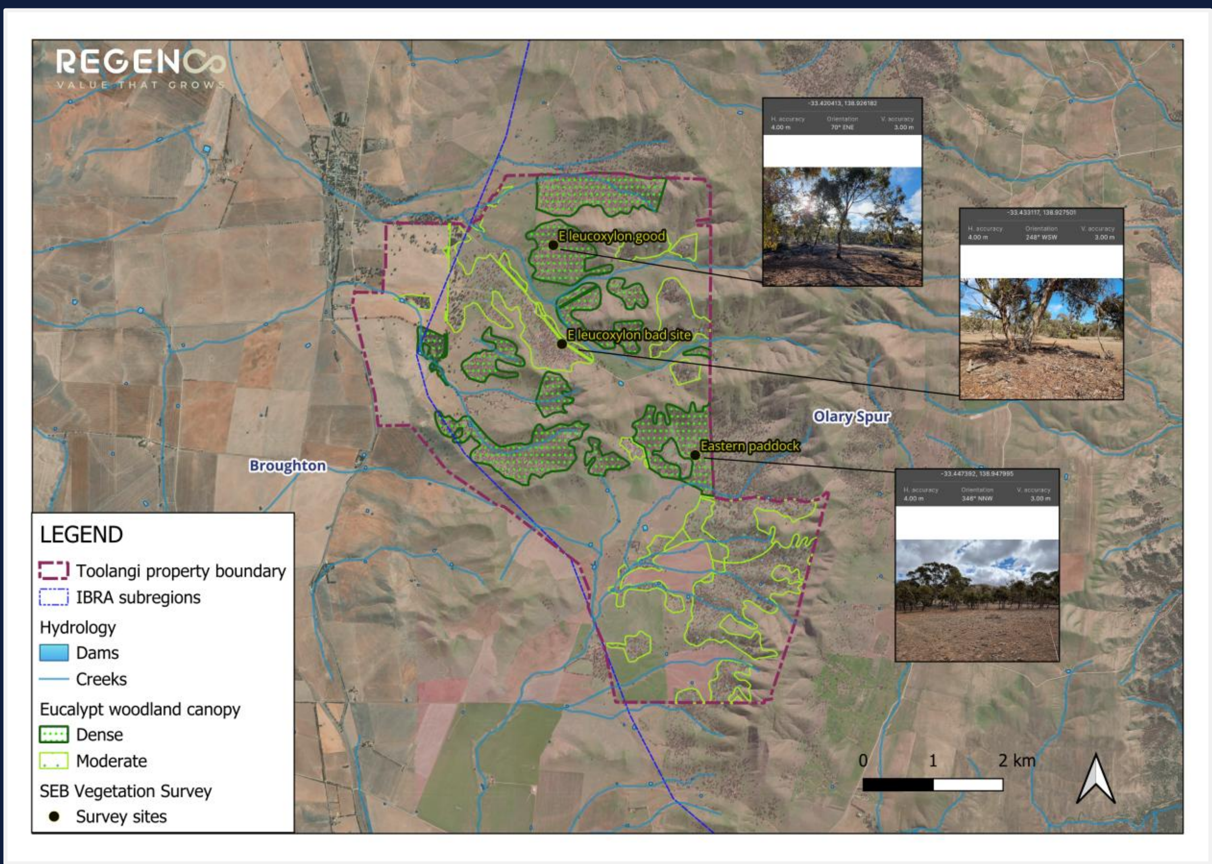
CARBON FOOTPRINT ASSESSMENT

- The carbon footprint of the Toolangi operation was assessed using the MLA Carbon Calculator. This assessment included upstream Scope 3 emissions but not downstream Scope 3 emissions (i.e. value stream emissions were accounted for until the point at which product leaves the farm gate).
- Total gross farm emissions was found to be reasonably low at **1464 tCO_2e^-/yr.** Net emissions were **1462 tCO_2e^-/yr** (i.e. after subtracting the carbon sequestered by the small area of planted trees less than 25 years old). Older vegetation is not able to be counted in carbon accounting balance sheets.
- Emissions intensity for sheep meat production was **5.25 $kgCO_2e^-$/kg liveweight** and for wool production it was **19.5 kg co_2e / kg Greasy**. This compares favourably to an Australian industry-wide benchmark for sheep meat of 6.8 $kgCO_2e^-$/kg LW and for wool of 24.4 kg co_2e / kg Greasy.
- By far the greatest source of emissions was in the form of methane from enteric fermentation and animal waste, at 92% of total CO_2e^- emitted. Only 4% of total emissions came from farm chemicals and 3% from diesel use.



VEGETATION CONDITION ASSESSMENT

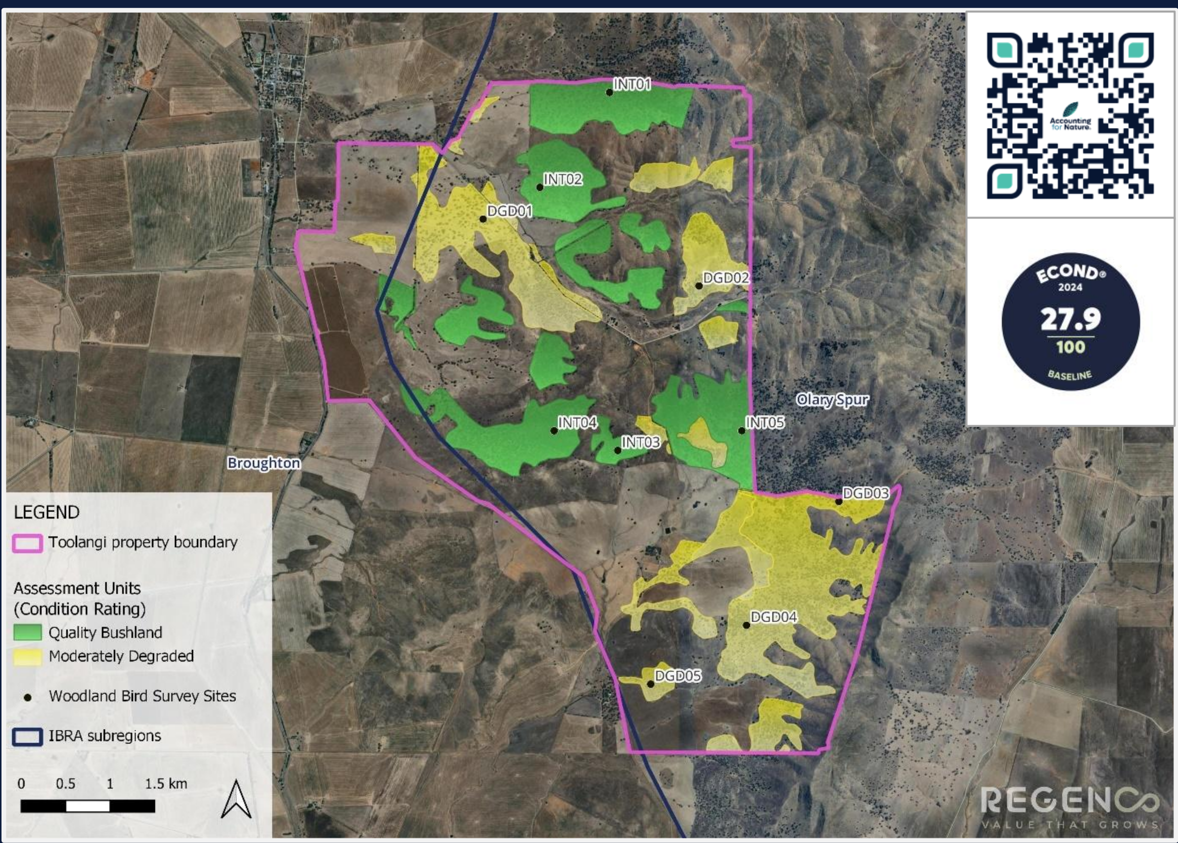
- The National Vegetation Information System (NVIS) mapping was found to be incomplete over Toolangi and nearby area. Inferred “Pre-European” government mapping suggests that patches of SA Blue Gum (*E. leucoxylon)* and Peppermint Box (*E. odorata)* woodland previously existed on the property. However, our inspection suggested that this was unlikely as we were not able to locate any Peppermint Box in the mapped patches. All patches were various categories of SA Blue Gum woodland.
- Using satellite imagery and verified on-ground, we were able to divide patches of woodland into those with dense intact canopy, and those with a less dense canopy and possibly impacted by historical management, as mapped below.
- The condition of the vegetation communities at Toolangi was assessed using the “Significant Environmental Benefit” (SEB) survey method on 4th April, 2024.
- Three survey sites were assessed across the property, all located in the Olary Spur IBRA Subregion and Terowie IBRA Association. As such, they all were given the same landscape context score. The survey sites were intended to sample locations of varying grazing pressure, while remaining easily accessible by vehicle.
- The difference between the three sites was in their vegetation condition scores. By far the highest vegetation condition score of 61.12 was achieved by the ‘E leucoxylon good’ site, leading to a Total Biodiversity Score of **78.61**. This site scored highly in all attributes of condition except regeneration. A high native to exotic understorey was a feature, with 26 native species in total.
- The ‘E leucoxylon bad’ and ‘Eastern paddock’ sites were both found to have relatively poor native plant diversity with 15 and 11 species respectively. This was reflected in their poorer biodiversity scores of **55.43** and **44.68** and implies potential overgrazing in these areas.
- The SEB framework enables a dollar value to be put on an area of vegetation. This determines what a developer must pay into a state government environmental offset fund if that area is cleared for development. The value determined for a hectare of clearance at ‘E leucoxylon good’, ‘E leucoxylon bad’ and ‘Eastern paddock’ was $27,200, $18,063, and $15,106 respectively.



Vegetation survey sites and canopy density of Eucalyptus woodland patches on Toolangi

WOODLAND BIRD ASSESSMENT

- The condition of the woodland bird community at Toolangi was assessed using the Accounting for Nature (AfN) method, *A native woodland bird assessment methodology for diverse regenerating farmlands* (AfN METHOD F-02).
- 10 survey sites were assessed across two condition-defined strata in the *E. leucoxylon* woodland of the property. Sampling density was sufficient to produce a “Moderate (80%) Accuracy” account.
- The condition (Econd®) for the Woodland Bird asset in its entirety was scored as **28/100**.
- The Econd® of the two individual assessment strata were: ‘Moderately Degraded' - 24; and ‘High Quality Bushland’ – 32.
- Econd® scores for individual survey sites ranged from 15 to 51. Site INT02 was easily the highest scoring site, with 13 species recorded, 7 of which were small-bodied natives (small-bodied species are indicative of a healthy community).
- One EPBC-listed species was observed - the Vulnerable Southern Whiteface.
- Reflecting the regional importance of the remnant SA Blue Gum woodland found at Toolangi, six regionally rare and uncommon species were recorded, including Southern Whiteface (*Aphelocephala leucopsis*), Yellow Thornbill (*Acanthiza nana*), Red-rumped Parrot (*Psephotus haematonotus*), Laughing Kookaburra (*Dacelo novaeguineae*), Grey Butcherbird (*Cracticus torqatus*), and Apostlebird (*Struthidea cinerea*).
- In total, **21 native bird species** were recorded of which 9 were small-bodied. General observations were that larger species, such as Galah, Australian Ringneck and Australian Magpie, were quite dominant on Toolangi. This likely reflects a lack of complexity in the understorey to provide safe-haven habitat niches and other resources for smaller birds.
- An ongoing environmental account for woodland birds has been registered and certified by AfN.



Woodland bird survey sites and Assessment Units based on woodland condition at Toolangi

3. KEY OPPORTUNITIES:
PRODUCTION, CLIMATE RESILIENCE & NATURAL CAPITAL BENEFITS

PROPERTY MANAGEMENT PLAN (PMP)

The current Toolangi PMP, prepared by Pinion Advisory, identifies management of total grazing pressure, both historical and current, being weaknesses of the production system. This includes both overgrazing by stock during poor seasons and the persistent unmanaged grazing impacts of large kangaroo populations. In particular, overgrazing of hilltops and steep slopes in the east, as well as road infrastructure, has created several severe erosion issues such as large gullies that would be having a dehydrating effect on the property. Improved pest and erosion control are identified as priority near-term actions. High supplementary feeding bills during poor seasons and the lack of product diversity are seen as threats to economic viability.

The Tivers' vision for the property is:

> *Continue to grow the business through land area, internal improvements and off farm investments. Aiming to create an efficient operation that leaves the property in a better state than what we started with.*

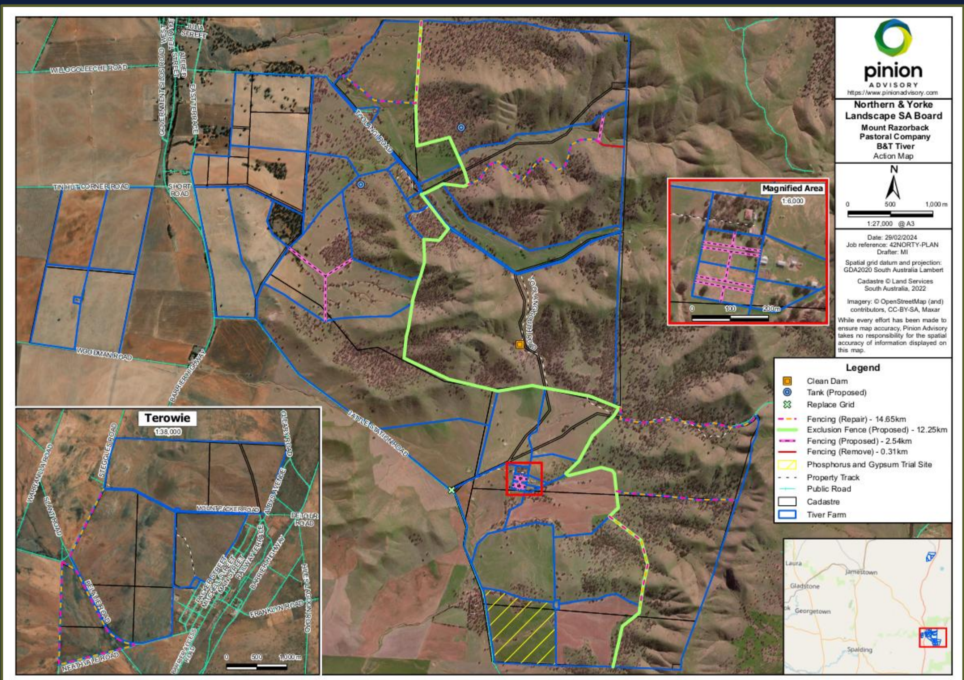
Recent actions to improve management of the natural resource base and maintain profitability through poor seasons include:

- The installation of confinement feeding pens
- Crop stubble retention
- Fencing to land class

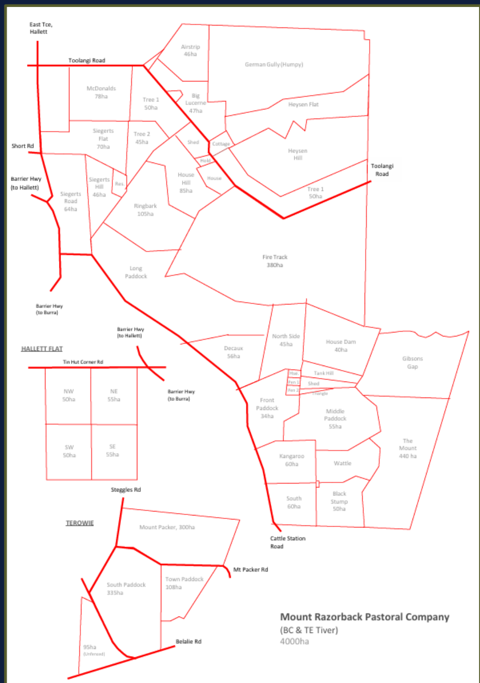
Key areas identified for improvement include:

- Increase capacity of existing confinement feeding facility to improve groundcover management, including better hay storage;
- Establish additional waterpoints;
- Improve pasture production in semi-arable areas (outwash plains of Mt Bryan range);
- Add/repair some fencing, including a significant 12 km kangaroo exclusion fence to protect the semi arable areas from the incursion by kangaroos from the hills grazing area.

The following pages of this report look at how the actions and ambitions currently underway, planned and/or identified in the PMP can support improvement of Natural Capital on Toolangi and how associated carbon and biodiversity projects may be leveraged to expand and expedite PMP delivery while enhancing farm productivity, resilience to climate change and biodiversity.



Map of Toolangi property development priorities (Pinion Advisory, 2024)



Toolangi paddock map

TREE SHELTERBELTS & BLOCK PLANTINGS

Production System Benefits

The climate information provided above shows that a major risk to the Toolangi operation is posed by climate, which is already challenging for sheep production and will only become more so under projected changes. Shelterbelts are a significant tool for mitigating these risks.

Wind chill: The information below, taken from a South Australian Government factsheet, is highly relevant to Toolangi and the opportunity presented by shelterbelts to improve weight gain and survival, particularly in late winter when rain and wind chill are a major risk.

The benefits of shelterbelts

Research has shown the beneficial effects of shelterbelts on farm productivity.

The main benefits for landholders in southern Australia are:

1. **Young lambs with shelter have a greater survival rate than those without.**
   - Shelterbelts can increase survival of young lambs in their first 48 hours from 84% to 93% for single lambs (Bird et al, 1984).
   - The increase in survival is even larger for twins, where shelterbelts have been shown to increase survival from 56% to 78% (Bird et al, 1984).
   - The bottom line $: For a flock of 2,000 ewes where half have a single lamb and half have twins, these percentages mean an extra 530 lambs surviving per year!
2. **Shelterbelts can reduce water loss in pasture plants particularly in spring and summer, which extends growing conditions.**
   - Although there can be a loss of productivity close to a shelterbelt, gains in productivity have been shown in plant production at a distance of 2-18 times the height of the shelterbelt into the paddock.
   - This positive effect is due to wind speed reduction and temperature modification resulting from the shelterbelt.

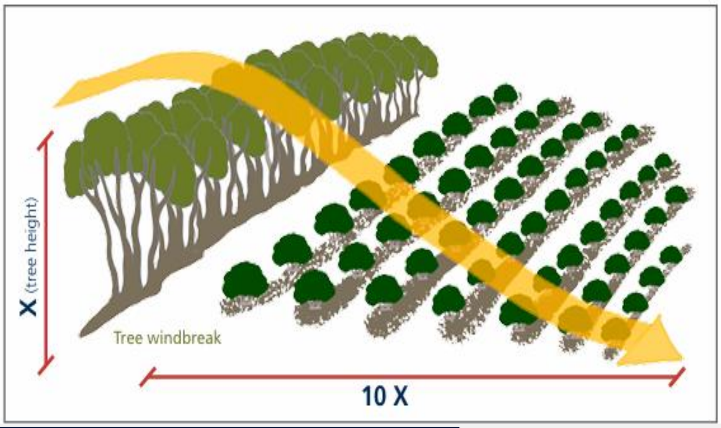


Figure 1. Protection offered by shelterbelts. *(adapted from the Goolwa to Wellington Local Action Planning Association Inc. Shelterbelt factsheet)*

Exposure can be fatal for lambs

Research on Kangaroo Island found that winds as light as 8 km per hour, in combination with 0.25-5 mm of rain per day, significantly increase mortality in Merino and Corriedale lambs. Higher winds (24-56 km per hour) combined with more than 5 mm of rain per day increased lamb mortality in Merinos by over 50% (Obst and Day, 1968).

Newborn lambs are most at risk. Further research on Kangaroo Island found that in the first six hours after birth (critical post-birth period), lamb losses were 5–10% if there was no rain and wind was less than 8 km per hour. However when wind was greater than 18 km per hour and more than 1.5 mm of rain was received in the critical post-birth period, lamb losses could exceed 70% (Obst and Ellis, 1977). In 2012, lamb deaths from exposure made the headlines, and it was estimated that up to 15 million lambs are dying within 48 hours of birth in Australia every year (The Australian, 2012). This results in large financial losses to sheep producers each and every year.

Post-shearing is a time of risk

For 14 days after shearing, adult sheep can be at risk of hypothermia if exposed to cold winds and rain. Sudden adverse weather events and unseasonal cold weather are the main cause of stock losses post-shearing. In South-West Victoria for example, unseasonal cold weather in March 1983 caused around 30,000 sheep to perish when a storm resulted in wind speeds of 32 km per hour, rainfall of 42 mm and a temperature drop to 16°C (Bird et al, 1984).

Wind affected pastures

Research indicates that high wind speeds increase water loss through transpiration in grasses and clovers leading to a reduction in growth (Radcliffe, 1983). In extreme cases, damaging winds can cause physical damage to plants through mechanical agitation (Sturrock, 1981).

Liveweight gain and heat stress: Goulburn Broken Catchment Management Authority also produced a factsheet that highlighted the value of shelterbelts to improving sheep liveweight gain, wool production and health under conditions likely to provoke heat stress, as below:

Shelter benefits:

- Ewes exposed to 32+°C after joining have a 40.7% fertilisation success
- Heat stress reduces conception rates in sheep. Refer to figures shown below

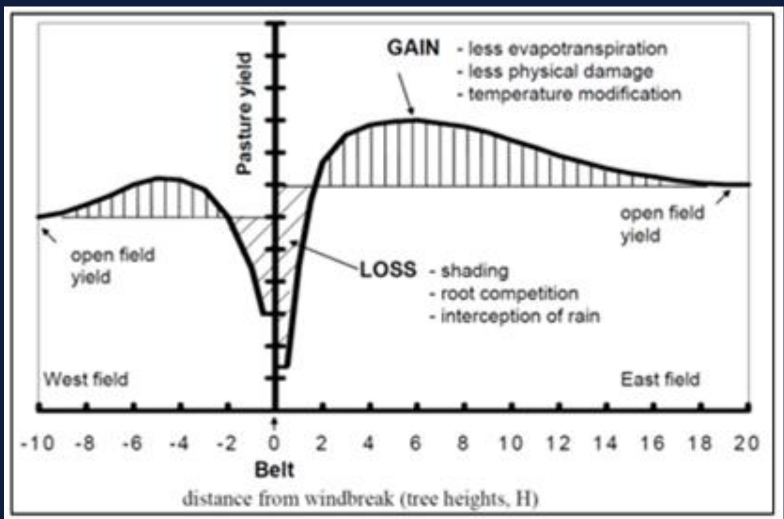
Breed	Sheltered (marked per ewe lambed)	Unsheltered (marked per ewe lambed)	Difference Extra Lambs/100 ewes
Merino	126%	102%	24
Coopworth	157%	139%	18

- ✓ Shelter increases pasture growth by 10% and sheep require 10% less pasture to maintain body heat in cold conditions when shelter is available. The combined effect of these benefits is expected to generate on average an extra $0.93/DSE per year.
- ✓ Heat load reduction on ewes at joining and lambing results in lambs with faster growth rates and more wool during their first 16 months of life. Heat stress reduces wool growth by reducing feed intake.
- ✓ Sheltered sheep showed a 31% increase in wool production and a 21% increase in live-weight in a five year trial.
- ✓ Sheltered off-shear wethers require only 1/3 the supplementary feed as unsheltered stock.
- ✓ Heat stress is detrimental to ram fertility, ovulation rate and conception in ewes and foetal development.

Production System Benefits

Pasture production: The Basalt to Bay Landcare Network collated a document titled "*The Economic Benefits of Native Shelterbelts*". This included information about the benefit of shelterbelts to pasture production, as follows:

- Shelter improves plant growth and increased pasture and crop production, by reducing moisture loss from soils and transpiration in crops and pastures.
- Sheltered pastures lose 12mm of water less than open pastures during the spring growing season.
- On one farm sheltered areas had a 20% increase in average annual pasture growth.
- Major gains in decreased animal stress and greater pasture production in winter can support an extra 1-3 sheep/ha.
- Gross value of pasture output is at its highest level when the proportion of tree area on a farm is at 34%.
- There is growing evidence that soils around trees contain elevated amounts of organic material and a higher nutrient status, thereby promoting pasture growth.
- There is no major evidence to indicate a large effect of shelter on pasture growth. Losses in the competitive zone are matched by an equivalent gain in the sheltered zone.



Estimated economic benefits: The Basalt to Bay collation also included an analysis by Patrick Bird (1996) of the estimated percentage gains and associated economic translation of several of the benefits outlined above. These benefits were estimated for two different spacings of shelterbelts – 250 m and 500 m, as below.

Table 1. Expected benefits from shelterbelts at maturity

Benefit	Belts 500 m apart	Belts 250 m apart
Wind speed reduction:	33%	50%
Improved plant growth: resulting in extra production (gross margin $ per ha)	+ 10% + $16	+ 20% + $32
Reduced maintenance energy requirement of stock: resulting in extra production (gross margin $ per ha)	+ 10% + $16	+ 17.5% + $28
Improved lamb survival (extra % units weaned): resulting in extra production (gross margin $ per ha)	+ 5% + $3	+ 5% + $3
Reduced losses of shorn sheep (ave. annual %): resulting in extra production (gross margin $ per ha)	+ 0.5% + $1.50	+ 0.5% + $1.50

Benefits from shelterbelts at maturity (Source: Bird 1996).

Note: As these estimates were devised 30 years ago for SW Vic. sheep farmers, the applicability of the economic estimates to the Upper North District in 2025 may be tenuous. Nonetheless, they provide a guide to the scale of benefits offered.

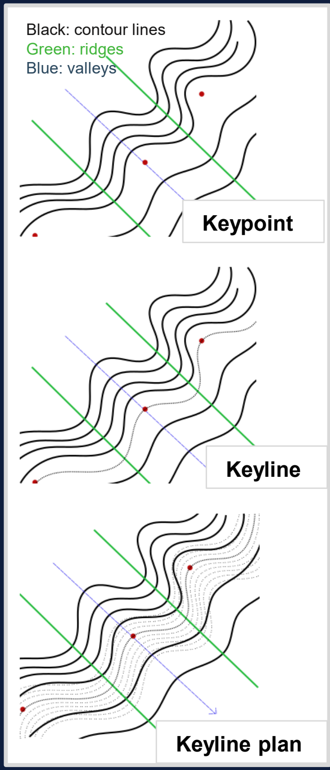
TREE SHELTERBELTS & BLOCK PLANTINGS

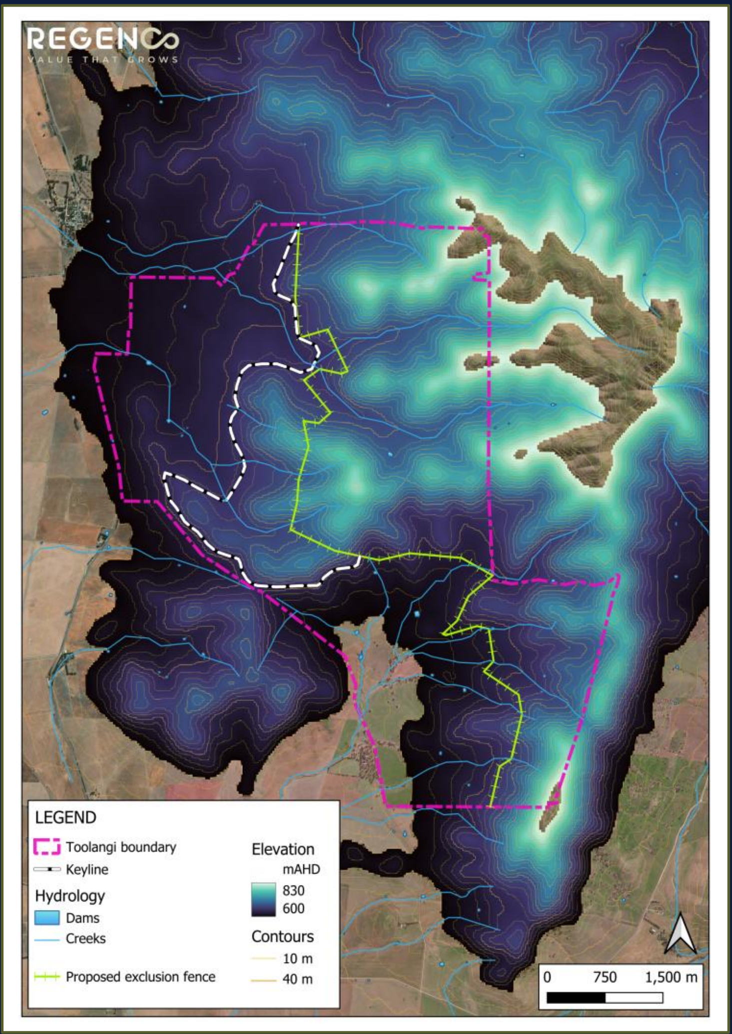
Production System Benefits

Water management: Toolangi has a significant proportion of steeper, higher rainfall country at its eastern end. The current PMP notes that there are some substantial erosion management challenges on the property with some large eroding gullies that have a dehydrating effect on the landscape.

An exclusion fence has been recommended in the PMP, as shown in the map below. The area to the west of this fence will be protected from excessive kangaroo grazing, with a higher degree of control over grazing pressure from domestic stock. The fence would generally be aligned to keep kangaroos in the steeper, less arable country to the east. However, there is a significant area of steep mountainous country outside of the proposed exclusion fence in the northern part of the property.

Strategic planting of shelterbelts, along with plowing of keyline contour furrows that hold and spread water in this area may enable rehydration of the downslope landscape and replenishment of groundwater. RegenCo believes there is potential to spread, slow and hold water in this part of the property by planting shelterbelts in locations downslope and parallel to the keyline. The map below shows an indicative keyline location for the northern portion of Toolangi.





Elevation of Toolangi and indicative keyline

Implementation is as follows (see schematic above):

1. Locate the Keypoint: The Keypoint is the key element, found slightly downhill from the valley's break-of-slope.
2. Identify the Keyline: The Keyline runs through the Keypoint, guiding the design.
3. Utilize Parallel Lines: Drawing lines above and below the Keyline on maps helps plan water and planting systems.
4. Implement Keyline Plowing: Plowing along parallel lines to the Keyline helps water move from valleys to ridges.

This rehydrates ridges and keeps water higher in the landscape for longer. The intent is to promote water infiltration which will benefit revegetation efforts and reduce erosion.

Above the keyline or between keyline shelterbelts, parallel rows of fodder shrubs interspersed with pasture could further slow and spread water flow, as well as providing a forage attraction for stock to climb into the uplands. In doing so, the sheep will cycle fertility (in their dung) back to the top of the slope, as described by Natural Sequence Farming theory.

See this animation video by the Mulloon Institute for a general idea of what the vision would be for the keyline shelterbelts, as well as in-channel options for water management.

TREE SHELTERBELTS & BLOCK PLANTINGS

Natural Capital Benefits

Although Toolangi is relatively well wooded, opportunities do exist to add planted belts of and blocks of SA Blue Gum and other mixed species native woodland to areas where historical clearing has occurred. This includes exposed slopes, uplands, creeks and fencelines. The next section of this report (4. *Project Proposal & Business Case*) presents a design and business case for a potential shelterbelt and block planting project of about 220 ha. This is intended to provide an example around which discussions can occur about matters of cost/benefit and optimal size/configuration of a tree planting project.

A planting project of this scale will improve the Natural Capital of Toolangi in a number of ways that will add to, interact with and enhance the potential production benefits described on the previous pages:

Vegetation biomass carbon – The proposed shelterbelt and block plantings are modelled to sequester carbon at an estimated average annual rate of about **1,081 tCO2e-/yr** over 25 years, accumulating about **27,047 tCO_2e^-** in that timeframe.

Soil carbon – The shelterbelts will help to increase soil carbon on Toolangi both directly, through reduced erosion and increased addition of carbon in leaf litter, and indirectly, through provision of microhabitats with lower wind and higher soil moisture allowing higher groundcover to be maintained and loss of soil carbon by exposure to be reduced.

Vegetation condition – The shelterbelts will enhance the condition of the existing native vegetation by increasing biodiversity and connecting large areas for enhanced genetic flow and self-organization. The block plantings are proposed to be established in the valleys of two creeks that run off the My Bryan range. There is also potential to experiment with planting on hill tops and include palatable species that have largely been removed from the local region, such as She-oak (casuarina), Christmas bush (Bursaria) and wattle species. Protection of these areas with the proposed exclusion fence may facilitate high-level control of grazing pressure that maximises biodiversity and health of the ground layer vegetation, helping to restore grassy woodlands.

Woodland Birds and other fauna – Restoration promotes recovery of woodland birds in agricultural landscapes (e.g. Bennett et al, 2022) and connectivity is key to this. The proposed shelterbelts will greatly enhance connectivity between large blocks of mature Blue Gum woodland, including connecting the very important refuge habitat of the high altitude areas on Toolangi with the fertile lowlands. It is proposed to make corridor plantings at least 30 m wide to enhance their habitat value. One study referred to by Basalt to Bay found that an average shelterbelt (3 rows/12m wide) can promote 12 species of woodland bird; if widened to 25m (7 rows) the number rises to 17. Bird diversity will also be enhanced by high floristic diversity and structural complexity of shelterbelts (Bonifacio et al, 2011) and by linking to the stands of existing mature vegetation (Haslem et al, 2020). By bolstering populations of woodland birds, along with other fauna such as pollinating and predatory insects, ecosystem services to adjacent crops and pastures, such as pest insect control, will be enhanced. The block plantings will be an important driver for increasing fauna biodiversity, as the bird and insect species that inhabit corridor plantings are known to be substantially different from those that inhabit large blocks of vegetation.

Water – The plantings, are located and designed to maximise survivability by taking advantage of scare water, but also to moderate hydrological processes on Toolangi to enhance property function. The keyline contour plantings, in particular, will help to keep the water that would accumulate and flow into valleys from rapidly moving into creeks and potentially causing soil erosion. Instead, the water will be spread from valleys to ridges, slowed and held longer and higher in the landscape. This will enable an improvement in soil health and soil carbon, which will in turn enhance water holding capacity of the landscape. It is anticipated that this will enable rehydration of the landscape and replenishment of groundwater and wells. It has also been shown that woodland trees enhance water infiltration in fragmented agricultural landscapes, reducing “ecosystem leakage” and potential soil erosion in intense rainfall events (Eldridge, 2005). Trees also act as ecosystem pumps that drive the small water cycle. With Toolangi’s topography rising rapidly to the east, it is possible that the plantings could create a small increase in rainfall volumes reaching the eastern parts via the additional moisture the trees would put into the atmosphere by evapotranspiration. This water will then return to the arable land in the west via runoff and creek flow.

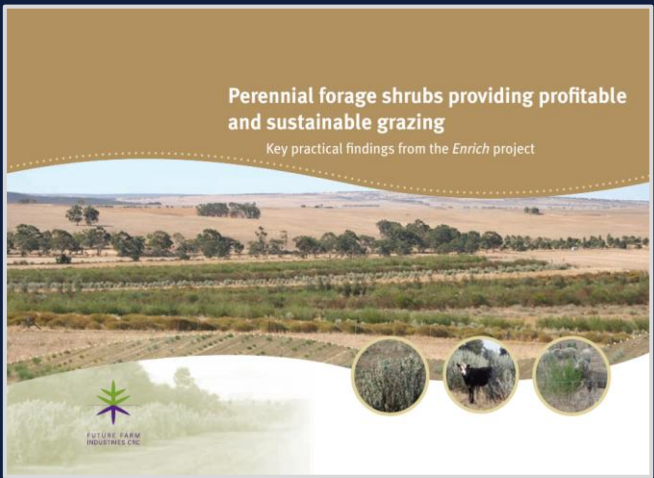
PERENNIAL FODDER SHRUBS

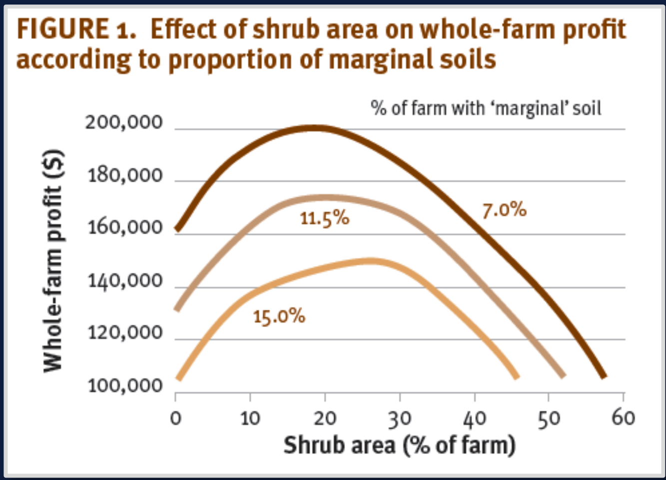
Production System Benefits

The *Enrich* research project conducted in the 300 – 350 ml rainfall zones of SA, WA and NSW (including sites in the mid/upper North of SA) was initiated due to an emerging awareness that prolonged drought and changes in rainfall patterns were making land use dominated by cropping and annual pastures unsustainable, especially in medium to low rainfall areas. These events presented an opportunity for large-scale change to livestock industries, where blending feed production from woody and herbaceous perennials with traditional pastures could become the preferred productive and less risky land use for the future.

Enrich looked at some guiding principles for incorporating forage shrubs into grazing systems, including the optimal area of a farm established to forage shrubs; grazing time for optimal use; scale and layout; plant establishment and productivity; and nutritive value traits of various species.

The headline finding was that "*For a 'typical' farm in low-medium rainfall crop-livestock zones of Southern Australia, inclusion of perennial forage shrubs at about 10-20 % of farm area can increase profit by 15-20 %*"





Toolangi's shrub layer is fairly depauperate, which implies low capacity to sustain stock on perennial vegetation when there is a dry autumn. This incurs higher costs to the production system through supplementary feeding demands, which has been identified as a system weakness by the PMP. It also creates an incentive to put stock onto annual pasture too soon after breaking rains. Therefore, the farming system could benefit from adding a variety of shrub species to the mix, some of which have likely been eliminated from the property by historical overgrazing.

The *Enrich* project examined 101 species with potential for use as forage for livestock in semi-arid Australia, not just for palatability but also:

- Edible biomass
- Plant growth over time.
- Growth form and height.
- Re-growth after grazing.
- Nutritive value (protein fibre, minerals).
- Effects on rumen fermentation (gas production to indicate digestibility).
- Bioactivity — pattern of rumen fermentation end products including methane, ammonia, volatile fatty acid composition.
- Bioactivity — anthelmintic properties.

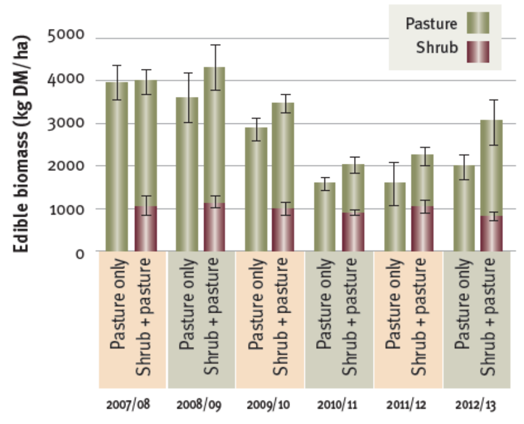
Production System Benefits

Forage production:

During six years of research under *Enrich*, greater annual productivity was achieved with the addition of forage shrubs:

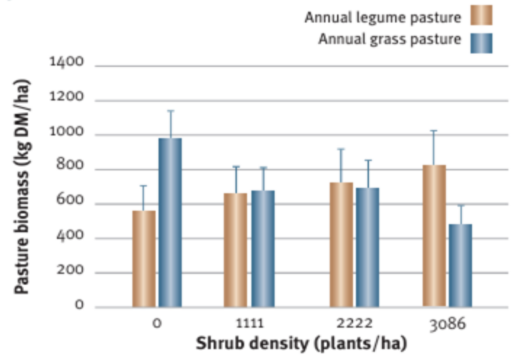
- Forage shrub production was stable from year to year and contributed around 1000 kg/ha. This 'extra' tonne in autumn is higher in crude protein and mineral content than the inter-row pasture of annual plant species, which are dead at this time of year. Animals can only utilise fibre in senesced pasture and crop stubbles if they have a source of nitrogen. Forage shrubs provide this useful dietary complement.
- Demonstrated the growth of annual pasture legumes is not compromised when grown alongside shrubs. While annual grass production is reduced with high shrub density, at moderate shrub density (for example, <1000 shrubs/ha), the loss of grass biomass is compensated by the increase in shrub edible biomass.
- Shrubs reduce supplementary feeding during summer/autumn feed gaps, and are particularly valuable forage in winter if there has been a late seasonal break and pasture growth is slow.
- Shrubs may enable deferral of grazing other paddocks at the break-of-season, allowing better winter pasture establishment.

FIGURE 2. Annual forage production measured as spring and autumn annual pasture biomass and including autumn shrub biomass for the shrub and pasture system*



* Shrubs were planted at a density of 2066 plants/ha

FIGURE 3. Effect of shrub density on inter-row pasture biomass

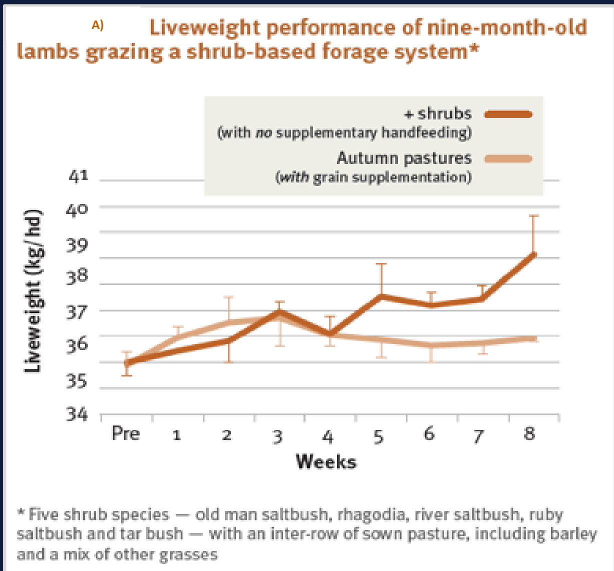


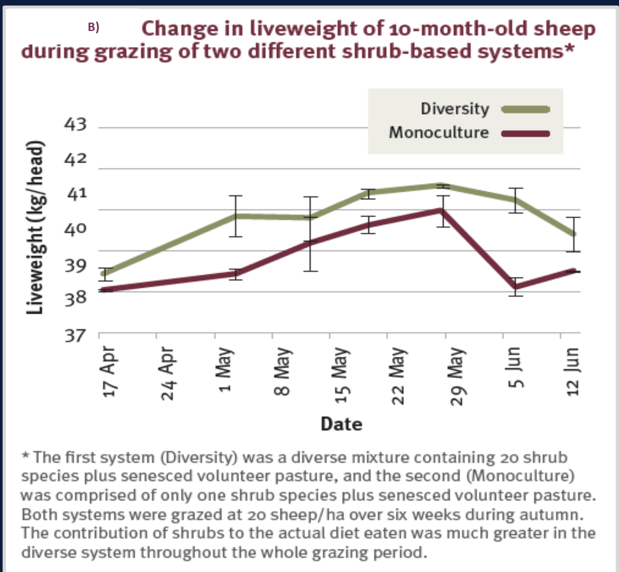
- The shade provided by shrub species can create favourable soil moisture conditions through reduced evaporation and lead to better pasture survival in conditions such as false breaks. Annual pasture species remain green for longer at the end of the cooler growing season when afforded some protection by shrubs.
- During winter, minimum temperatures are higher within shrub stands and frosts are less common.

Shelter and shade: *Enrich* found that rows of a mixture of tall and shorter species are the best way to achieve even permeability and adequate height. Using just tall species can lead to increased wind speed under trees where livestock have grazed all the lower branches. *Enrich* listed the following species as suitable for shelter provision, with species also providing good shade indicated by an asterisk. Note, the listed species are not necessarily all suitable for planting at Toolangi. Seek local botanical experts for advice.

Shorter	Medium	Tall
Atriplex nummularia (old man saltbush)	*Acacia ligulata* (sandhill wattle)	*Acacia loderi* (nelia)*
Atriplex rhagodioides (silver saltbush)	*Acacia oswaldii* (Oswald's wattle)*	*Acacia neriifolia* (oleander wattle)
Rhagodia parabolica (mealy saltbush)	*Acacia saligna* (golden wreath wattle)*	*Acacia pendula* (myall)*
Rhagodia preissii (mallee saltbush)	*Allocasuarina verticillata* (drooping sheoak)	*Geijera parviflora* (wilga)*

PERENNIAL FODDER SHRUBS





Production System Benefits

Liveweight gain:

Enrich examined and compared the liveweight gain of lambs grazing a) a shrub-based forage system vs autumn pastures with supplementary grain, and b) a diverse shrub-based system vs one with only one shrub species. The study found that weight grain was greater in a) the shrub-based forage system and b) the diverse system.

Given the wealth of information gathered by *Enrich* on a variety of shrubs, it is recommended that the landholder considers desired traits for shrubs in their forage system and incorporates a diversity of shrubs in any future plantings. Plantings of shrub rows could be made parallel to keylines, as suggested on page 23, or potentially seeded on relatively flat hilltops to spread downhill via gravity.

The booklet *Perennial forage shrubs – from principles to practice for Australian farms* provides an easily accessible resource for understanding the attributes and assisting selection of 10 of the most likely forage shrubs for semi-arid grazing systems. The detailed final project report for *Enrich* can be found here.

Restored hydrological and ecosystem processes:

The PMP for Toolangi includes a priority action to better manage erosion, which is high risk on the steep and erodible soils through track construction and overgrazing. Erosion typically occurs where perennial vegetation has been lost. Some severe active erosion gullies can be seen around the property, which are causing loss of grazable area and, most importantly, are providing a pathway by which rainfall is able to rapidly run-off, minimising infiltration and lowering soil moisture. In these locations, restoration of hydrological processes, recovery of perennial shrubs, reinstatement of intact and resilient ecosystem processes, and improved agricultural productivity go hand-in-hand.

Erosion gully in Fire Track Paddock. Note lack of perennial woody vegetation upslope

PERENNIAL FODDER SHRUBS

Natural Capital Benefits

As with the proposed tree plantings, fodder shrub plantings would support Natural Capital gains, which will, in turn, interact with and bolster farm system productivity and resilience:

Vegetation biomass carbon – A study of carbon mitigation using Old Man Saltbush plantings (Walden et al, 2017) was undertaken at six sites in southern WA, SA and NSW with similar climate to Toolangi. The study found that OMS plantings sequestered between 0.2-0.6 tC/ha/yr, which equates to 0.73-2.2 tCO_2e^-/ha/yr. The sequestration potential of other high biomass fodder shrubs is likely to fall in a similar range. The planting design on p.32 includes 70 ha of suggested area for fodder shrub plantings. Conservatively applying a sequestration rate of 1.5 0.73-2.2 tCO_2e^-/ha/yr, this area of shrubs would sequester **tCO_2e^-/yr**.

Currently there is no Australian method that enables generation of carbon credits from forage shrub plantings or shrubland regeneration, but the sequestered carbon referred to above could potentially be used to inset against farm emissions for carbon neutral claims.

Soil carbon – Establishment of fodder shrub corridors would help to increase soil carbon on Toolangi through provision of microhabitats with lower wind speeds and higher soil moisture allowing higher groundcover to be maintained and loss of soil carbon by exposure to be reduced. This is particularly the case where shrubs are planted in association with keyline ploughing. The *Enrich* project also found that nitrogen-fixing legumes tend to grow well as a companion pasture to fodder shrubs, and the presence of shrubs brings increased nutrient cycling with companion pastures having higher levels of phosphorus and potassium. Therefore, soil nutrient constraints to pasture growth many be overcome in the inter-row of a diverse fodder shrub system, resulting in greater SOC being generated.

Carbon footprint – Toolangi's carbon footprint shows that by far the largest source of its carbon emissions is enteric methane production in sheep. Fodder shrubs present an opportunity to reduce emissions from this source by including tar bush (*Eremophila glabra*) in plantings. Tar bush, a local shrub species has been shown to influence the conditions and fermentation profiles in the rumen, such as producing less methane (waste) when digested compared with other forages. Laboratory tests indicate reductions in methane production of more than 80% (Durmic et al, 2022). This would equate to an emission reduction of about **1000 tCO_2e^-/yr** at current Toolangi stocking rates. Tar bush has also been able to mitigate acidosis in sheep rumen.

Vegetation condition – Forage shrub corridors would enhance the condition of the existing native vegetation by increasing biodiversity and connecting large areas for enhanced genetic flow and self-organization. Planting a diverse range of fodder shrubs, rather than a monoculture of OMS, will further enhance this value.

Woodland birds and other fauna – The woodland bird survey at Toolangi found there to be a clear dominance of large native birds, with relatively low diversity of small-bodied birds. This is the key metric in determining the quality of the woodland bird community under the AfN method. Adding shrubs creates a new vegetation layer, resulting in increased biodiversity compared with simpler agricultural landscapes. Increased numbers of birds and reptiles are found in forage shrub plantations compared with annual pasture systems. The forage shrub species detailed in the *Enrich* booklet also host beneficial predatory insects offering potential advantages for pest management in nearby crops and pastures. A study (Collard et al, 2011) conducted in South Australia examined selected ecological indicators, including plant and bird communities, in saltbush plantings, finding that saltbush sites contained a diverse range of plants and birds, including a number of threatened bird species not found in adjacent pasture.

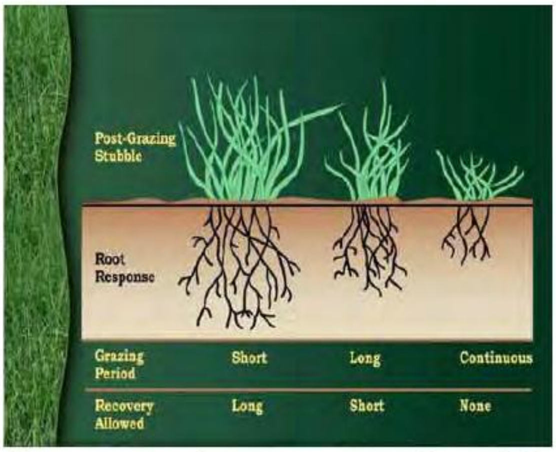
Water – At Toolangi, there tends to be a lack of perennial vegetation on hilltops, fairly well wooded mid-slopes of Blum Gum woodland, and then sometimes poor coverage of perennial vegetation on the lower slopes. Planting of shrub corridors in a parallel keyline design on the lower slopes, as suggested in the planting design on page 32, will enable water runoff to be slowed, controlling erosion and conserving soil. This will, in turn, lead to better plant growth and a positive feedback loop with water and soil to restore ecological integrity in the lower slope zone. Planting on shrubs on the flatter areas of hilltops could also be considered.

REST-BASED GRAZING SYSTEM

Production System Benefits

The PMP for Toolangi identifies grazing management as a general issue, in terms of matching stocking rate to feed on offer and recovery period after poor seasons. The further development of a confined livestock facility on the property may enable the Toolangi grazing system to allow longer rest periods for pasture recovery. In addition, if tree and forage shrub plantings are developed, as above, these areas and associated fencing may lend themselves to a more strategic division of the property to facilitate a further shift along the spectrum from continuous grazing to rotational grazing. Anecdotal and (some, but not all) experimental evidence suggests that there are a number of production benefits to transitioning from a continuous grazing system to a rotational one, including:

- Healthier root system of perennial tussock grasses, conferring a better chance of surviving long dry spells (see images below)
- Increases in perennial grass cover offering more feed towards the end of the dry season, increasing overall carrying capacity
- Improved rainfall use efficiency - *Research on long term grazing trials at Old Man Plains (OMP) research station, Alice Springs, has shown that over a ten year period, by rigorous determination of appropriate annual stocking rates and with the introduction of pasture resting, rangeland condition was improved and rainfall use efficiency improved by a factor of 2.5 in terms of kg Dry Matter (DM)/ha/yr/mm rainfall. These improvements came largely from regenerating populations of native perennial grasses.*



Plant response to grazing periods of different lengths (Colorado State University 2013).

Continuously grazed grasses will have small root systems (Australian Wool Innovation and Meat and Livestock Australia 2009).

Given projected declines in annual rainfall and increasing evapotranspiration, improved rainfall use efficiency of the pasture resource would be a critical benefit for the sustainability of the Toolangi grazing operation. Also, the return of historically overgrazed and now sparse summer-active perennial grasses would help to adapt the production system to projected relative increases in summer rainfall events. RegenCo suggests that if the Ringbark paddock is divided as suggested by the PMP, it may provide a prime opportunity to actively seed with summer-active perennial tussock grasses that were historically more prevalent in the area and to experiment with a rest-based grazing approach, only stocking during the "late summer-autumn feed gap". In good years, the paddock may be able to be rested completely.

Other reported benefits of rotational grazing include even grazing pressure; reduced herbivore selectivity and selection of most palatable species; enhanced flowering, growth and survival of plant species; improved pasture utilization; maintenance of pasture cover; increased herbage production; reduced soil erosion and improved animal production.

The length of the rest time relative to the graze time can also be influential. McDonald et al (2019) found that increasing the length of rest relative to graze time under strategic-rest grazing was associated with an increase in plant biomass, ground cover, animal weight gain and animal production per hectare when compared to continuous grazing.

Natural Capital Benefits

Continuous livestock grazing can have negative effects on biodiversity and landscape function in arid and semi-arid rangelands. Alternative grazing management practices, such as rotational grazing, may be a viable option for broad-scale biodiversity conservation and sustainable pastoral management (McDonald et al, 2019). The adoption of a more rotational grazing system at Toolangi may offer natural capital benefits as follows:

Vegetation biomass carbon – Some studies have found that rotational grazing can improve the biomass of pastures. For example, Lawrence at al (2019) found that pastures under rotational grazing management were characterised by increased cover and depth of plant litter and greater retention of pasture biomass, while McDonald (2019) found that biomass only became greater under rotational grazing when a rest:graze time greater than 6:1 was applied. Badgery (2017) found that intensive rotational grazing with a 20-paddock flexible system was able to increase pasture growth of a native pasture by 21%. Therefore, although this report does not estimate uplift of biomass carbon via rotational grazing, we can reasonably expect gains in the Toolangi pastures with this practice change, which is likely to support improved landscape function (e.g stabilize soil, provide a buffer from extreme temperatures, reduce soil erosion, improve infiltration and contribute to nutrient cycling through the decomposition and mineralization of plant material).

Soil carbon – RegenCo notes that the soil carbon map produced by FarmLab for this report indicates particularly low SOC levels around the middle of the property where the most intensive grazing and cropping occurs (House Dam, North Side, Decaux, Middle and Front paddocks). Pasture cropping presents as a good option for returning perennial native grasses to these paddocks and working them into a rotational grazing system, while building soil carbon and still being able to crop feed for the confinement feeding facility. At Winona, a property near Dubbo, soil carbon has been found to have increased by over 200% in 10 years following implementation of pasture cropping along with rotational grazing. If a similar result was achieved across the Toolangi paddocks noted above, this would equate to sequestration of about 11,300 tSOC, or **41,600 tCO_2e^-**.

McDonald et al (2023) conducted a review of research into the impacts of grazing management on SOC in Australia, finding that most studies reported no significant difference in SOC between grazing management treatments. This is despite key drivers of soil carbon sequestration being favoured by rotational gazing, including above and below-ground biomass, plant growth rate, groundcover, soil structure and soil nitrogen. Therefore, while this report makes no attempt to estimate a change in soil carbon for Toolangi under rotational grazing across the whole property, the practice change will help to create the conditions that make soil carbon sequestration more likely.

Vegetation condition – Rotational grazing can improve the condition of pasture species by reducing selective grazing and allowing recovery of preferred plants after grazing. A study by McDonald et al (2019) found few differences in plant biodiversity and ground cover between a rotationally grazed property and a nearby ungrazed nature reserve (despite differences in overall plant species composition), suggesting that rotational grazing may have potential to sustain some elements of biodiversity and ground cover on pastoral properties. It is expected that incorporating more rest into a multi-paddock grazing system, which includes fodder shrub corridors, will help recover some favoured pasture species reduced by past grazing practices, especially summer-active native perennial grasses (e.g. Ampt and Doornbos (2010)). Monitoring at Winona has found that annual weeds have gone from 60% to 5% of species in transect counts, while perennial native species have gone from 10% to 80% with rotational grazing.

Birds and other fauna – By moving towards a grazing system that incorporates longer periods of rest, ground cover vegetation at Toolangi will become more functionally diverse in composition and structure, with some areas recently grazed short with low cover and others with greater cover and biomass/height after a period of prolonged rest. This increased structural and floristic diversity in the ground-layer could potenitally add to that provided by shrub and tree plantings to greatly increase habitat heterogeneity in all vegetation strata across Toolangi. Vegetation heterogeneity has been identified as a key element in promoting bird and other biodiversity on farms, with rotational grazing being highlighted by Toombs et al (2010) as a key way to achieve this. Generally speaking, the increased standing biomass and ground litter provided under rotational grazing management will also offer superior habitat for small animals including invertebrates, birds, reptiles and small mammals.

Water – Rotational grazing offers the benefit of improved water infiltration and rainfall use efficiency. For example, a report by Ampt and Doornbos (2011) found that properties under rotational grazing management in NSW achieved results for a water infiltration indicator that was 40% higher than the continuous grazing comparison sites. Achieving a similar outcome at Toolangi will enhance pasture growth and help control erosion, particularly if implemented in concert with keyline contour plantings.

4. POTENTIAL PROJECT & BUSINESS CASE

DISCLAIMER: The information provided in this section of the report does not constitute a business offer, nor does any other part of this report. The environmental & carbon related findings and recommendations given in this section are specific to "Toolangi", however the financial information that has been used to demonstrate indicative revenue and costs is of a general nature only. RegenCo recommends that independent legal and financial advice is sought prior to entering into any commitment.

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ENVIRONMENTAL PLANTING PROJECT

Design

The map below presents a proposed configuration for an Environmental Planting project, that could potentially be registered under the Australian Carbon Credit Unit (ACCU) Scheme for the generation of ACCUs. Key features of the proposed 219 ha project are:

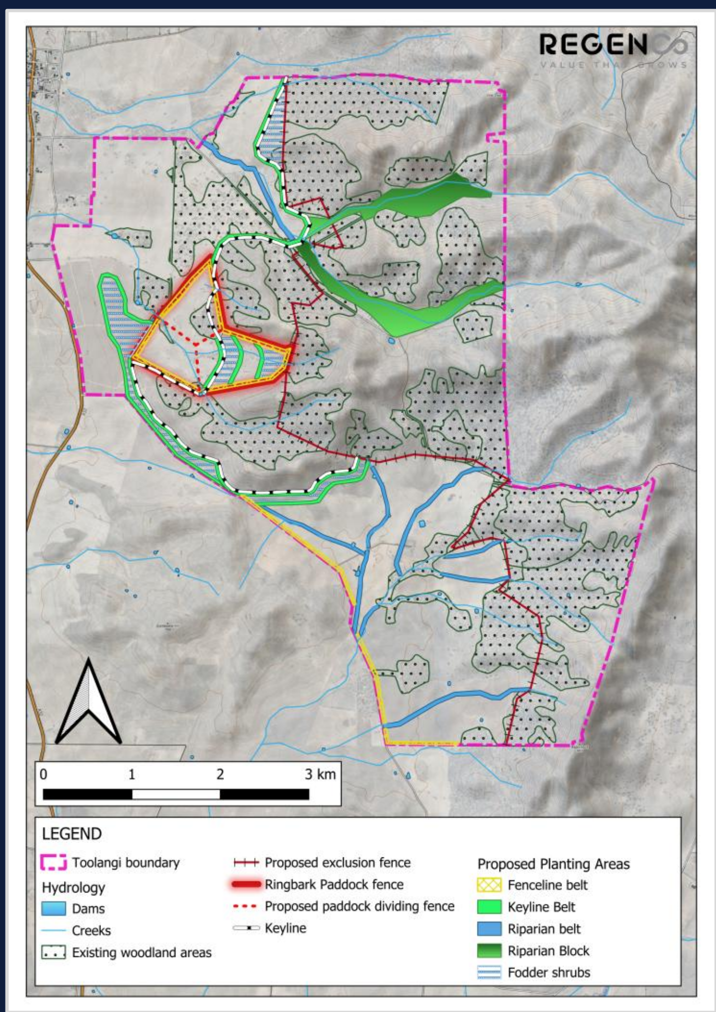
Keyline shelterbelts - The project would establish keyline shelterbelts – belts of mixed environmental plantings parallel to the upslope keyline. It is envisaged that these belt plantings would cover about 54 ha with belt width of 30-40 m to maximise ecological value and effectiveness in providing shelter and shade to stock. The design has the belts occurring in pairs in the Long Paddock, threes in the Ringbark Paddock and as a single belt further north to Airstrip Paddock. These plantings are located to provide strong ecological benefit in the form of north-south connecting habitat through the property, and also effective windbreaks to the prevailing westerly and south-westerly winds. Most importantly, these belts and their orientation parallel to keylines will both enable the plantings to take advantage of any rainfall, minimising the chances of drought failure, but also facilitate spreading and slowing of water flow when rains do come, mitigating soil erosion and facilitating infiltration. This will help to rehydrate the landscape which, in concert with the shade and wind shelter offered by the trees, will improve growing conditions for fodder shrubs and grasses between the shelterbelts. With moister soils, better groundcover and less erosion, it is highly likely that soil carbon levels will increase between the shelterbelts, which will further increase the water-holding capacity of the soils and enhance rehydration.

Fenceline shelterbelts – 30 to 40 m wide shelterbelts covering 32 ha are recommended for two locations: 1) in the south-west corner along Cattle Station Rd, and 2) around the perimeter of Ringbark Paddock. The former will offer protection to pasture and stock from prevailing south-westerly winds, while the latter will provide a very protected environment that may present as a good option for lambing, with protection from cold south-westerlies but also the drying effects and heat stress risk of hot north-westerlies. Fenceline belts along the north-west boundary could also be considered

Riparian belts - There are a number of creeks running off the range that have historically been cleared of woody perennial vegetation on the arable outwash flats. Revegetation of these with 45 ha of 40 m wide belts is recommended to slow flow through the creeks, control erosion risk, provide shelter from winds of various direction, provide shade to stock, and connecting habitat for wildlife between the plains and the slopes and uplands. Plantings on these creeks will likely have good access to water, which will increase their chances of surviving drought.

Riparian blocks – There are two significant creeks running off Mt Bryan range in the north-east of the property which have cleared valleys of 100-300 m wide. Once again, 88 ha of plantings in this area would slow the movement of water flowing through, mitigating soil erosion and facilitating infiltration. A mixed open grassy woodland would likely be the target condition to continue to facilitate grass pasture grazing. Peppermint Box grassy woodland, largely lost from this locality, may be returned to the area through this planting. Although on the eastern side of the proposed exclusion fence, additional fencing and upgrades recommended in the PMP may help to manage grazing pressure.

It is envisaged, at this stage, that most of the planting would be done by direct seeding, supplemented with some strategic planting of tubestock.



Proposed plantings for Toolangi and indicative keyline

ENVIRONMENTAL PLANTING PROJECT

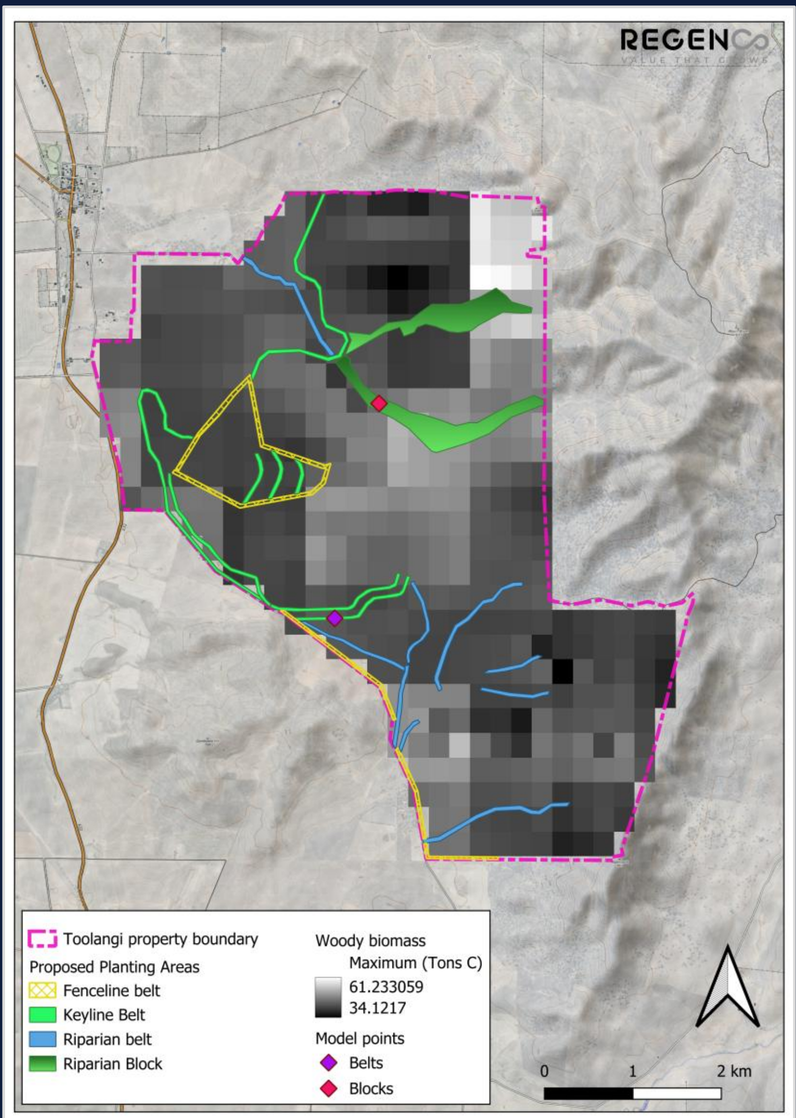
Business Case

There are three key components to a business case for a carbon project – carbon yield & revenue, start-up & ongoing costs, and co-benefits for production, resilience, biodiversity & marketing.

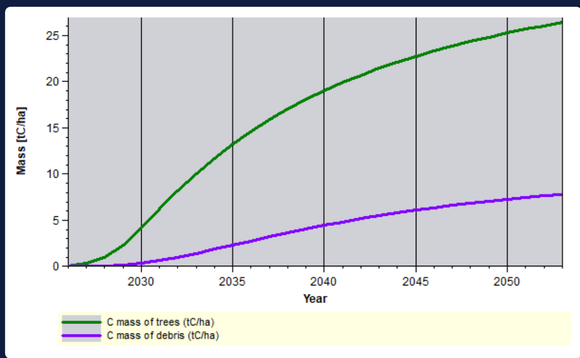
Carbon yield - The FullCAM model incorporates a spatial layer (Mbio) that represents the theoretical maximum biomass for any given location across Australia. This can be regarded as an index for carbon yield potential. The Mbio layer over Toolangi is presented in the map below, showing a modelled area of relatively high carbon yield in the vicinity of One Tree Hill in the north-east corner. Other than this area, the maximum biomass is generally quite consistent throughout the property, ranging between 40 and 50 tC/ha. The model point chosen for the belt plantings shows a maximum biomass score of 44 tSOC/ha, while the model point for the block plantings is 46 tSOC/ha. Note, RegenCo suspects this to be a model underestimate for this location, which may be worth testing in the field.

The FullCAM model was run to estimate carbon yields for the various parts of the proposed Toolangi planting.

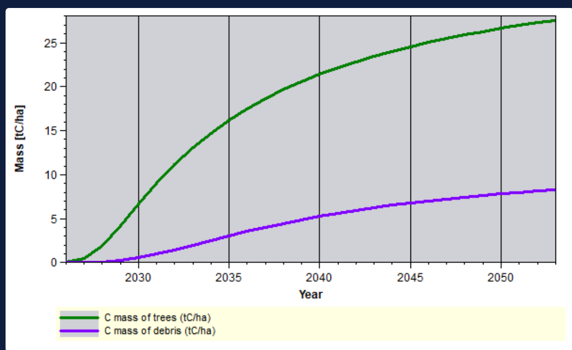
The parameters entered into the model assumed less than 1500 stems planted per hectare. The model outputs suggest the various belt plantings will sequester carbon at a rate of about 5.1 tCO_2e^-/ha /yr. The block plantings in the creek valleys will yield carbon at a rate of about 4.7 tCO_2e^-/ha/yr. On an area-weighted basis, the overall project would yield 4.9 tCO_2e^-/ha/yr. This equates to an annual average of 1,081 tCO_2e^-/yr for the entire project area and **27,047 $tCO2e^-$** for the entire 25-year crediting period.



Modelled maximum biomass carbon across Toolangi (Mbio layer)



Carbon yield curve (tC/ha) for the riparian block plantings



Carbon yield curve (tC/ha) for the various belt plantings

ENVIRONMENTAL PLANTING PROJECT

The following business case example is based purely on estimations and indicative ACCU pricing. It is for demonstration purposes only and RegenCo recommends the landholders seek independent financial advice that is specific to their business at Toolangi before deciding on any environmental initiative.

Business Case

Potential revenue - The estimated carbon yield can be converted to a gross revenue estimation, noting that the carbon market is still evolving and future value of ACCUs is unknown and hard to predict. At the time of writing, the ACCU spot price is $35.65. Environmental Planting projects may draw a premium due to their perceived higher integrity, though this not certain. Recent ACCU spot price history can be viewed here.

Therefore, to cover an indicative range of potential future ACCU values, we provide here a gross revenue estimation at $40/ACCU (approx. current value with an Environmental Planting premium), $50/ACCU (assuming future value gains), and $30/ACCU (assuming future value losses). The figures incorporate a mandatory 5% deduction of ACCUs issued by the regulator to cover the project's "risk of reversal buffer".

Est. Gross Revenue	$30/ACCU	$40/ACCU	$50/ACCU
Annual avg.	$30,833	$41,111	$51,390
Total (25 yr)	$770,845	$1,027,794	$1,284,742

Carbon project implementation costs - Costs for carbon project implementation can be categorised into:

1) initial (start-up) or ongoing costs, and
2) operational (on-farm) or ACCU Scheme program participation costs.

The table to the right presents a breakdown of estimated costs by generalised item, and potential estimated revenue projections assuming a $40/ACCU carbon credit value.

Note: These figures include costs for 15 km of fencing, including 12 km of exclusion fencing, as proposed in the PMP. This standard fencing is relatively expensive – costs were modelled at $7000/km.

It was assumed that planting would occur by tubestock at 300 stems/ha in the riparian blocks and fenceline sheleterbelts, with direct seeding being used elsewhere.

And this table (right) presents some summary statistics describing the project's basic business case, including a breakdown of potential costs over the first 5 years vs the last 20 years of the project. Not that production system benefits, as described in Section 3 of this report, are not factored into this financial model.

TOTAL COSTS and REVENUE over project lifetime	
ON-GROUND WORKS COSTS	**$412,605.00**
Fencing	$105,000.00
Tubestock planting	$183,000.00
Direct seeding	$58,905.00
Site maintenance	$65,700.00
ACCU SCHEME PARTICIPATION COSTS	**$165,000.00**
Feasibility assessment	$2,500.00
Registration	$2,500.00
Annual monitoring and reporting	$100,000.00
Auditing	$60,000.00
CARBON REVENUE	
Carbon revenue per ha per yr	**$187.72**
Carbon revenue per yr	**$41,110.68**
Total aggregated carbon revenue over 25 year crediting period	**$1,027,767.00**

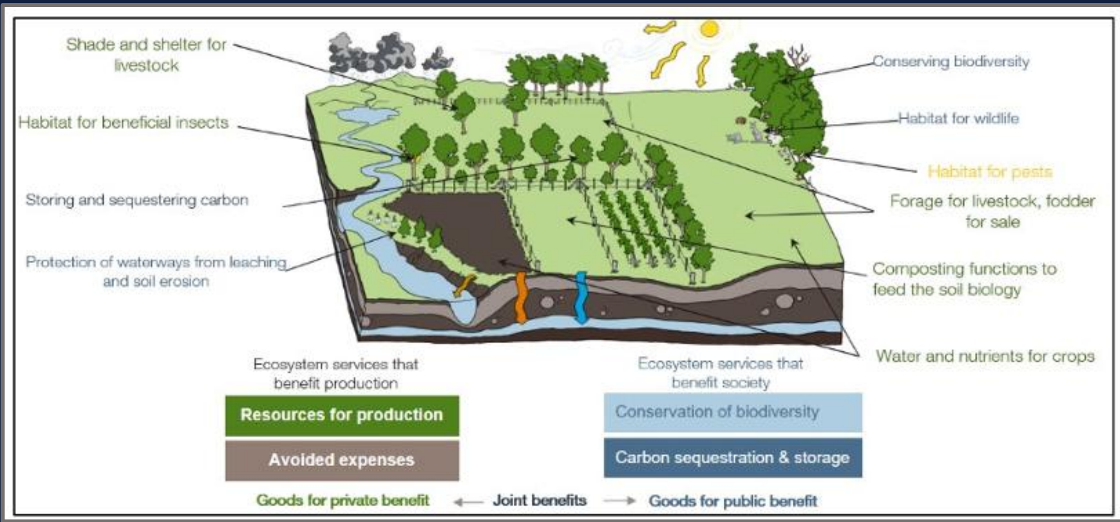
BUSINESS CASE SUMMARY STATISTICS	
Total cost	**$577,605.00**
Cost per ha	$2,637.47
Cost of production (per ton CO2e)	$21.36
Total cost in first 5 years	$477,565.000
Total cost in last 20 years	$99,980.00
Total profit (after all costs)	**$450,162.00**
Profit per ha	$2,055.53
Profit on production (per ton CO2e)	$16.64
Annualised profit over 25 years (after all costs)	$18,006.48
Annualised per ha profit over 25 years	$82.22
Cost-benefit comparison to standard reveg project costs (per ha)	**$3,939.58**

ENVIRONMENTAL PLANTING PROJECT

Business Case

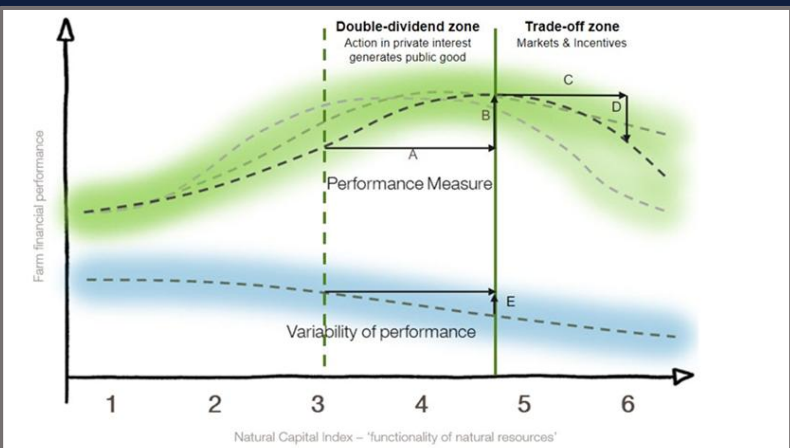
Production & Resilience - The system production and resilience co-benefits of the proposed Environmental Planting project are described in some detail in "*Section 3: Key Opportunities*" of this document. The information provided includes some financial estimates against practice change that the landholders could use to estimate potential financial benefit for their operation.

Farming for the Future is a program focusing on private production benefits associated with on-farm natural capital, including remnant native vegetation, productive pasture and croplands, riparian areas, agroforestry, environmental plantings and animals.



The pilot program report (focusing on 113 farms, mainly sheep/wool, in the Central & Tablelands region, South-eastern Australia and South-western Australia) confirmed that potential benefits like increased productivity, profitability and resilience are the most compelling motivation for producers to invest in natural capital, and that natural capital is positively correlated with production efficiency, gross margin and earnings before interest and tax (EBIT).

- Our landholder surveys show that the potential for private financial benefits is the most compelling reason for producers to invest in natural capital improvements.
- Our analysis of 113 livestock farms indicated that natural capital is positively correlated with production efficiency across a number of our natural capital indices, providing evidence of a 'double dividend zone'.
- We found different benefit pathways through which natural capital can support farm businesses, including via improving productivity, and/or by reducing input costs. These are relevant to different extents in our different study regions.
- High natural capital farms also had lower input costs across certain of the cost types examined (energy, fodder, health and labour). We suggest that natural capital may support production efficiency by replacing / substituting for some of these inputs.
- Natural capital was positively correlated with financial performance (gross margin and EBIT). Optimised natural capital levels delivered higher EBIT with median \$75 - \$175 /ha/yr higher in the Central and Tablelands region, \$20 - \$135 /ha/yr higher in the South-eastern region, and ~\$70 /ha/yr higher in the Western region, depending on the farm type. Differences in gross margin were of a similar magnitude.
- High natural capital was also associated with higher levels of resilience to both climate and market shocks. This may occur for two reasons. Natural capital may help build climate resilience by enabling higher levels of water retention in farm soils. It may help to build financial resilience and improve financial performance because natural capital inputs tend to be low-cost relative to manufactured inputs, and their 'price' is not subject to volatility of international market shocks or input supply chain disruptions.

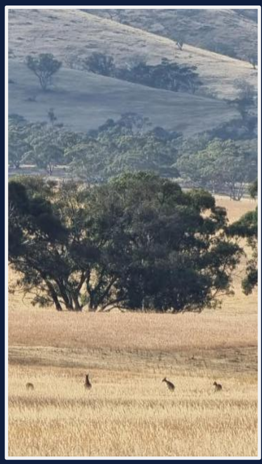


Explanation for Figure 5: The Natural Capital Index (x axis) indicates increasing levels of natural capital functionality as the scale increases from left to right. The Y axis indicates farm financial performance, and may be measured as gross margin, EBIT, productivity or any other of a range of potential measures of financial performance (or other benefits like producer wellbeing). The two curves indicate potential associations between different 'levels' of natural capital and measures of performance (green shaded curve), and performance variability (blue shaded curve).

Importantly, the research also demonstrated that natural capital can confer livestock businesses with increased levels of resilience in the face of both climate and market shocks – delivering increased stability on EBIT for livestock operations from 2017 to 2022.

ENVIRONMENTAL PLANTING PROJECT

Business Case



Finance - The proposed project would enable funding for some significant infrastructure items identified in the current PMP for Toolangi. In particular, it is envisaged that a key aspect of the project would be financing the 12 km exclusion fence, with estimated cost of around $100,000. This would significantly bolster the degree of control that the landholders have over the timing and extent of grazing pressure on the more arable parts of the property. Project revenue may also be used to fund some additional fencing, such as the dividing fence at Ringbark Paddock, and potentially some of the water management infrastructure identified in the PMP. Items such as these can provide some additional security for the survival of plantings in the early years when they are most vulnerable to grazing and drought.

The carbon revenue from the project potentially offers a pathway to pay for the cost of these management actions, already planned under the PMP, either up-front or by servicing a bank loan, depending on the selected business model. If taking out a loan to pay for on-ground works, discounted interest rates (e.g. green loans) are available from some lenders. For example, Rabobank is currently offering discounts of up to 1.15% on loans for Environmental Planting carbon projects.

Nature Repair & Biodiversity Markets – Biodiversity markets operate by putting a price on nature commodities or ecosystem services, such as woodland bird communities, with the intention of facilitating investment in conservation and restoration. At this stage biodiversity markets are in their early days and it has not yet been well established what the scale of the market for these products might be, although financial advisory, PwC, estimates that a biodiversity market could be worth $137 billion by 2050.

Mechanisms are now emerging to enable land managers to earn high-integrity products representing scientifically robust verification of positive biodiversity outcomes. Accounting for Nature, for example, are developing two products, one that is linked to nature-positive carbon projects (CarbonPlus™), and one that generates tradeable certificates independent of any carbon value (NaturePlus™).

The baseline assessment performed on the woodland bird community has placed Toolangi in a strong position to take advantage of these products and add further value to the carbon revenue earned through the planting project. The soil parameters that have been tested at Toolangi could also enable a baseline to be established under one of AfN's soil methods - *S-02: Level 3 Soil Assessment for Productive Land (Landcare)*. It should be noted that there would also be additional costs if participating in a scheme such as these (e.g. monitoring, reporting and auditing costs).

Another potential pathway is through the Australian Government's proposed Nature Repair Market. Under the scheme, which will work in alignment with the Australian Government's carbon farming scheme, nature repair projects such as the proposed Environmental Planting project can generate a tradable certificate. Biodiversity certificates will describe the biodiversity benefits from each project in a consistent way. This information will help the market users to compare and value projects. The 2024 Environmental Planting Method acknowledges the development of the nature repair market, which means registering the carbon planting for nature repair credits can be considered, once this new market comes online.

In preparation for this new market, the Australian Government ran a Carbon + Biodiversity Pilot in 2022-23 across six Natural Resource Management regions, including Northern and Yorke. The project aimed to deliver income to landholders through carbon credits while testing aspects of buying and selling biodiversity services. Under this scheme, proposed projects were graded with a modelled biodiversity benefit score. Based on the score, a biodiversity payment was calculated to cover a portion of establishment costs. Business models such as these may be worth exploring with third parties, such as NRMs and environmental not-for-profit organisations.

ENVIRONMENTAL PLANTING PROJECT

Business Case

Market access – It is widely acknowledged that there has been a shift by large wholesalers of farm products, including lamb and sheep meat, towards requiring suppliers to show their credentials in being good stewards of the environment, reducing the carbon footprint of their production systems, and being attentive to animal husbandry and humane treatment.

For example, Thomas Foods International require their suppliers to be accredited under their Thomas Family Guarantee program. This includes environmental guidelines requiring suppliers to consider actions such as planting trees and other native vegetation to encourage biodiversity, fencing creeks to deter erosion, and reducing chemical application across crops and pastures. The proposed Environmental Planting project, amongst other actions under the PMP, would enable the landholders at Toolangi to keep meeting requirements such as these to maintain market access and "stay ahead of the curve" of increasing demands on suppliers.

There are also programs in place and emerging from some large buyers of farm product that deliberately, as a marketing angle towards higher value product, look to raise the bar on "Nature Positive Farming". For example, Woolmark used the *Farming for the Future* pilot to help identify 12 core metrics for monitoring and reporting by suppliers, and awareness raising and capacity building by Woolmark to drive improvement of environmental performance.

Similarly, in order to maintain access to international markets, Sheep Producers Australia (SPA) and Wool Producers Australia (WPA) lead the Sheep Sustainability Framework. The Sheep Sustainability Framework monitors and measures industry performance against priorities aligned with four themes: animal care, the environment, economic resilience, and people and community. It is likely that reporting of performance against these themes will have the effect of raising industry expectations on suppliers over time.

Some farmers who are undertaking strong environmental stewardship actions on their farms and/or adopting more regenerative practices are leveraging the sustainable agriculture marketing angle to attract a premium price in "paddock-to-plate" business models. There is a growing product market for these kind of offerings, including in the lamb/sheep meat industry, in Australia. An example of a Mid North farm that has adopted this approach is Gilberdale farm, north of Gawler.

The above considerations around market access don't only relate to the proposed planting project but also to other matters identified in the PMP and discussed in this document, such as managing erosion, rehydrating the farm landscape, enabling a production system that allows longer rest periods for the pastoral resource, and returning a diverse group of fodder shrubs to the grazing system.

A Landscape Function Toolkit (LiFT) being developed by the Mulloon Institute may soon offer a cost-effective and accessible framework for assessing, monitoring and reporting on landscape condition and resilience improvements made through management actions such as those proposed here and in the PMP.

Acknowledgement

This project has been funded by the South Australian Government under the Growing Carbon Farming Demonstration Pilot and delivered in partnership with Upper North Farming Systems, RegenCo, FarmLab and the Northern and Yorke Landscape Board on Ngadjuri Land.

Acknowledgement and thanks goes to independent vegetation and sustainable agriculture consultant, Anne Brown, for conducting the vegetation condition assessment, and to AgEx Alliance Climate Smart Facilitator, Emma McInerney, for assisting with initial scoping.

This project was delivered on the property, and with the positive engagement, of the Toolangi landholders, Tessa & Brad Tiver. Our thanks to them for their participation.

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