NATURAL CAPITAL MANAGEMENT REPORT: "LANA"

Case Study 5: Lana, Uralla, NSW

23 February 2021

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ABSTRACT:

On-farm Natural Capital refers to the natural resources including soil, vegetation and animals that comprise an agricultural property.

Natural Capital (Environmental) Accounting can link environmental condition to economic returns and presents information about the type and condition of ecosystems. This information can be used alongside financial accounts to give a broader perspective on Farm Profit.

Environmental Accounting is an adaptation and extension of the International Accounting Standards.

This case study presents a Natural Capital Management report created from the base Natural Capital Accounts, for a commercial grazing property, Lana, in the Northern Tablelands Region of NSW

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Acknowledgement:

This project was funded by Australian Wool Innovation and represents one of a series of case studies on Natural Capital on commercial wool-growing properties. The authors would like to thank Mr Angus Ireland and Mr Sam Ropert from Australian Wool Innovation for their assistance. We would also like to acknowledge and thank Dr Steve Wiedemann, Integrity Ag and Environment, for his technical review and input.

Natural Capital Snapshot:

Natural Capital (Environmental-Economic) Accounting is a new knowledge field for Farm Business Management. This report applies a Natural Capital Accounting and Environmental Profit and Loss approach to calculate the impact of the farm's management on its Natural Capital.

This report can be positioned alongside yearly Farm Financial Management Reports, prepared by the Farm Accountant or Adviser. Having information on the change in the condition of the major business asset (Land), along with financial performance, can give a broader view of Farm Profit. Over time we hope industry benchmarks of natural capital will start to emerge.

Information for this report was compiled through a combination of field assessment by a trained ecologist, use of Farm Map4D Satellite data and farm Financial Statements provided by the farm accountant.

The report finds that while operating as a successful commercial wool growing operation Lana has:

- Using standard industry classifications, 79% of Lana can be classified as being in Very Good condition for livestock grazing, some 21% is classified as being in Good condition. This provides a strong basis for high levels of animal production.
- Over the last 13 years, ground cover remained above 90% and peaked at 100%. Industry targets suggest a minimum of 70% groundcover is required to minimise water run-off and erosion. High levels of groundcover assist in effective water and mineral cycles.
- A natural capital accounting approach to the measurement of environmental performance suggests that Lana produces negligible air pollution, water pollution or waste.
- Lana generates approximately 28.4 kg of greenhouse gas emissions per kg of greasy wool, which is 56% of greenhouse gas emissions estimated by Kering for regenerated landscapes and 30% of emissions from conventional landscapes.
- A conservative estimate of the natural value affected by Lana's commercial business operation suggests that it has impacted the ecosystem services by 26-29% and that this is not a permanent loss, compared to 80% estimated by Kering for land use impact from conventional wool production.
- Some 52 % of the landscape is regenerating towards a more diverse natural grassy woodland state, which is reflected in increases in biodiversity, greater tree canopy cover and shelter for livestock.
- Lana's natural capital is contributing free inputs to livestock grazing (forage) that are worth approximately $29/ha per year.
- The calculations undertaken indicate that the (grazing only) value of the natural capital to the farm business is approximately $299 per hectare.
- Net Carbon sequestration is 9,452 t/CO_2e per year.

Estimated Carbon Summary: Using current research information and models.
Figures calculated using a GWP of 28 for Methane (IPCC 2015 AR5)

Carbon Summaries	
Data averaged across 10 years	
Farm Name	**Lana**
Emissions	
Energy emissions (tCO_2e/year)	28.2
Sheep emissions (tCO_2e/year)	1,084.4
Cattle emissions (tCO_2e/year)	1,318.0
Fertiliser emissions (tCO_2e/year)	0.0
Pre-farm emissions (tCO_2e/year)	42.2
TOTAL emissions (tCO_2e/year)	**2,472.8**
Carbon Stocks and sequestration	
Estimated Carbon Stocks (Mg C)	220,230
Estimated Carbon Stocks per hectare (Mg C / ha)	63.5
Estimated C sequestration per ha per year (Mg C ha^{-1} $year^{-1}$) *1	-0.94
Estimated C sequestration per year (Mg C / year) *1	**-3,252.3**
Emissions balance in tCO_2e/year	
Emissions (tCO2e/year)	2,473
Estimated C sequestration (tCO2e/year) *1	-11,925
Net position for emissions (tCO2e/year) *1	**-9,452**
EP&L Factors	
Estimated extent of biomass loss	26%
Estimated extent of species richness loss	32%
GHG emissions for wool (kg CO2e / kg greasy wool)	28.4
GHG emissions for wool (kg CO2e / $ wool sold)	3.0
Normalised Stress weighted water use (litres H_2Oe / kg greasy wool) *2	2.6
Normalised Stress weighted water use (litres H_2Oe / $ wool sold)	0.3
Water Stress Index	0.0208

** **1** Note a negative number indicates a removal of CO2 from the atmosphere*
**** 2** Normalised stress weighted water use represents the use of water (L) multiplied by the Water Stress Index (WSI) for the local catchment, divided by the global average WSI (0.602).*
Further information on used for Carbon storage and sequestration calculations can be found in the Appendix (Table A6), page 25

How to use Natural Capital Management Reports:

Natural Capital (Environmental-Economic) Accounting is a new knowledge field for Farm Business Management.

This report presents a Natural Capital and Environmental Profit and Loss Management Report for Lana, a large commercial wool-growing property in the Northern Tablelands of NSW.

This report can be positioned alongside yearly Farm Management Reports, prepared by the Farm Accountant or Adviser. Having information on the change in the condition of the major business asset (Land), along with financial performance, can give a broader view of Farm Profit.

The Natural Capital Management Report can be used in the same way that Farm Financial Analysis (such as farm financial benchmarking) can be used to determine changes in key criteria over time. Changes can then be related to management decisions and the Farm Business Goals of the owners. This enables a broadening of perspectives on Farm Profit to encompass Financial and Natural Capital measurements.

Farm businesses can start to quantify contributions of management towards protecting and improving the condition of the long-term natural capital asset base, and investments in the long-term productive capacity of the business, as part of their normal yearly review of performance.

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Introduction to Lana:

Tim and Suzanne Wright own 'Lana', 22 km west of Uralla on the NSW Northern Tablelands. On their 3,470-hectare property, which comprises moderately treed granite slopes and open riparian zones adjoining two major creeks, they run Merino sheep and breeding cows. Their superfine wool is sold to Loro Piana.

Tim took over the property from his father, Peter, in 1980, who had farmed it since 1952. Various strategies of pasture improvement had been used on the property in the past, including top-dressing the property with superphosphate and seeding from the air. Oat fodder crops were under-sown with various pasture species, and this pasture improvement enabled stock numbers to be more than doubled between 1981 and 1992.

However, with the expensive inputs, the property barely broke even over a five-year cycle. In the 1981 and 1992 droughts, production records revealed that the improved paddocks had lower yields than the unimproved paddocks. The land was susceptible to drought, and profit margins were falling. Tim says it made sense to seek a change.

Concerned by the impacts of drought they changed their way of farming, motivated by two key considerations: the excessively high cost of production, especially labour; and secondly grazing management needed to better utilise our livestock on the land.

Tim started using Holistic Planned Grazing, involving establishing smaller paddocks and introducing rotational grazing at higher density, using stock for nutrient movement, enhancing soil fertility, maintaining ground cover and regenerating native grassland species.

Carrying capacity has increased from around 8000 DSE to 20,000 DSE. No hay or grain has been fed to the livestock since 1990. The only supplements that have been used are bypass protein supplement during drought and Himalayan salt for its minerals. The grazing system has proved resilient in the face of the current drought, which is the worst the property has ever experienced.

New fencing and water infrastructure were initially funded by the reduction in other costs, such as fertiliser and hay and pasture renovation. Increased production through the ability to lift stocking rates also covered the financing of the infrastructure.

Grazing management has also significantly reduced vegetable matter (VM) in their wool. VM in skirtings has reduced from 9% to 2% since 1982, increasing the main fleece lines and subsequently the overall value of the wool clip. Tim has shifted to shearing every 8-9 months. Production improvements have seen wool staple strength increasing from an average of 40 N/Ktx to 48 N/Ktx. The average fibre diameter has reduced from 17.5 microns to 16 microns. Merino lambing has increased from 80% to 90%; calving rate has also increased from 80% to 90%.

Larger mobs enable more efficient management and generally require less human input except for key periods such as lambing and shearing. Permanent labour requirements on the farm have reduced from one person per 4,000 DSE in the 1980s to one person per 16,000 DSE today. Importantly, it has also enabled the Wrights to have more time for off-farm social, community and other activities.

Natural Capital Accounting and management reporting will allow the Wrights the ability to monitor the condition of their land base alongside their Financial reports, giving a more rounded view of profit.

1. Ecosystem Services:

Highly functional Grassy Woodlands can produce a range of ecosystem services while providing grazing for food and fibre production. These areas, along with large areas planted to exotic trees for multiple uses, are the foundation of Lana Farm Business.

Ecosystem Services are the direct and indirect contributions to human wellbeing that come from an ecosystem. These services support both quality and survivability of life. They include three main services:

1. Provisioning services (food, fibre and forage production)
2. Regulating services (capacity of an ecosystem to support processes such as water purification, carbon storage and sequestration, micro-climate regulation, pollination and pest control)
3. Habitat services such as biodiversity protection and cultural services such as spiritual and aesthetic values, learning opportunities.

Diverse and highly functional Grassy Woodlands are important. They can produce a range of ecosystem services at the same time as they provide grazing for food and fibre production[1] (McIntyre et al. 2002).

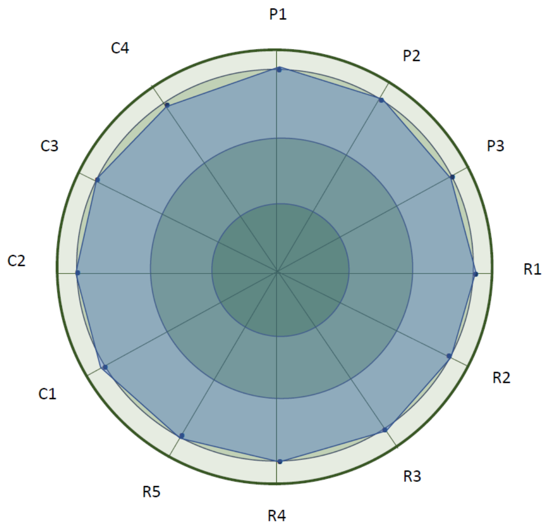
Estimates for the ecosystem services being generated by this property are developed from the Ecosystem Asset Accounts that provide a detailed record of the type of ecosystems on the property, along with the extent and condition of these areas. Estimates are based on scientific literature and are given a High 'H', medium 'M' or low 'L' core depending on the ability of the farm ecosystem to support these ecological services.

Detailed justification for the attribution of a particular score is given in the Appendix.

A summary of ecosystem services being supported by Lana is shown below:

[1] S. Lavorel et al., "Ecological Mechanisms Underpinning Climate Adaptation Services," *Global Change Biology* 21, no. 1 (2015); S. McIntyre, J. G. McIvor, and K. M. Heard, *Managing & Conserving Grassy Woodlands*, ed. S. McIntyre, J. G. McIvor, and K. M. Heard (Canberra: CSIRO Publishing, 2002).

***Figure 1**: Shows the level of ecosystem service provision on Lana. Individual services are listed. Concentric rings show whether an ecosystem service is at a high, moderate or low level (see diagram below).*

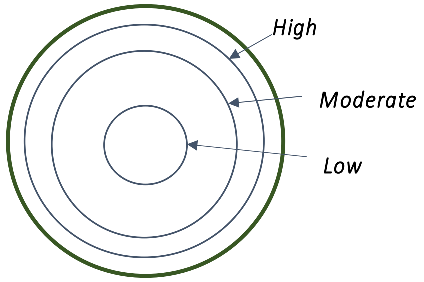


<table>
<tr><td colspan="2">List of ecosystem services in Figure 1.</td></tr>
<tr><td>

Provisioning
P1. Forage production for livestock (ten-year average)
P2. Forage for bees
P3. Timber provision, including firewood
Regulating
R1. Soil protection and nutrient retention
R2. Water quality
R3. Carbon storage
R4. Microclimate regulation
R5. Pollination and pest control services
Cultural (including habitat)
C1. Animal biodiversity
C2. Vegetation biodiversity
C3. Restoration Potential
C4. Climate change adaptation potential

</td><td>

Scoring system applied:



</td></tr>
</table>

Carbon Storage is not an ecosystem service under formal accounting standards. We have included it here because the carbon stored in landscapes is very important to society and because the high performing wool-producing landscapes may already be high in carbon and therefore not sequestering much additional carbon.

Comments:

The Ecosystem Services provided by Lana are rated as High across all criteria.

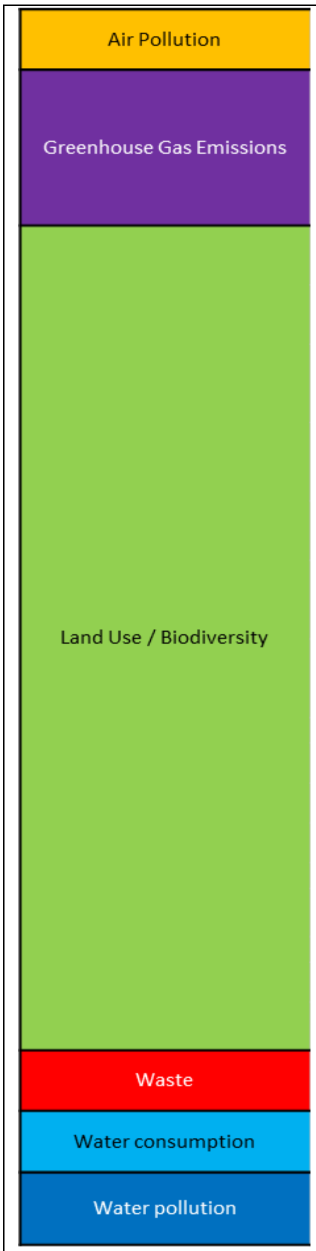
These services are produced from the diverse and highly functional grassy woodlands that occupy a large percentage of Lana.

It is important to note that a highly functional and diverse ecosystem produces a range of ecosystem services as well as providing a sound basis for the commercial wool growing business through the production of quality and diverse forage.

2. Understanding Environmental Profit and Loss:

An Environmental Profit & Loss (EP&L) account is one way of assessing the impact that a business has on the environment.

This is a new approach for individual farm businesses to take. This report has taken an E P & L approach to provide management information on the impact of Lana on the environment.



Kering developed the Environmental Profit and Loss (EP &L) methodology to help their business understand their environmental impacts and to reduce them. In the past, EP &L has been calculated for industry, using general/generic information. More information can be found here:

https://www.kering.com/en/sustainability/environmental-profit-loss/methodology/

This Natural Capital Management report uses the Kering methodology with information specific to Lana to assess the impact of wool production on the environment.

EP &L takes the concept of natural capital and applies it to business decisions. The EP&L measures the resources consumed across the supply chain, such as water and land, as well as the outputs such as water pollution, air pollution and waste Trends over time are important to monitor and can be related to management goals and decisions. Some key findings of this report are:

- A natural capital accounting approach to the measurement of environmental performance suggests that Lana produces negligible air pollution, water pollution or waste.
- Lana generates approximately 28.4kg of greenhouse gases per kg of greasy wool, which is 56% of the greenhouse gas emissions estimated by Kering for Regenerated landscapes and 30% of emissions from conventional landscapes.
- A conservative estimate of the natural value affected by Lana's operation suggests that it has impacted ecosystem services by 26-29% and that this is not a permanent loss, compared to 80% estimated by Kering for land use impact from conventional wool production.

Details of the calculations are presented in section 7 of this report (page 13).

Box 1: Inputs to an EP&L assessment were made following methods drawn from published EP&L methods and using a natural capital accounting approach.

3. Ecosystem Use:

A primary purpose for the ecosystems on this property is to provide feed for the merino sheep, which are the core of the farm business; however, the landscape is also being managed for biodiversity outcomes. Biodiversity is an important component of the owners' written management goal and an overt part of their management decision making. The impact of these management decisions on the farm's Natural Capital and EP&L can be measured over time using the Natural Capital Accounting approach.

The Ecosystem Asset – Primary Use accounts (Table 1) show that the landscape consists predominantly of Grassy Woodland (94%) and Riparian areas (4%).

Table 1: Ecosystem Asset Account (Primary Use; ha). This account organises information about the amount of each type of ecosystem on the property being used to generate economic (financial and non-financial) benefits for the business.

Ecosystem Assets @ 15th January 2018	Primary Use					
Extent-Use (ha)	**Biodiversity**	**Grazing**	**Watercourse protection**	**Farm Operations**	**Domestic**	**Total**
Cleared Native Pasture	0.0	409.0	0.0	0.0	0.0	**409.0**
Grassy Woodland	65.0	2623.0	0.0	0.0	0.0	**2688.0**
Grassy Woodland-Granite Outcrops	0.0	228.2	0.0	0.0	0.0	**228.2**
Riparian	0.0	0.0	138.7	0.0	0.0	**138.7**
Infrastructure	0.0	0.0	0.0	3.5	0.0	**3.5**
Domestic	0.0	0.0	0.0	0.0	3.1	**3.1**
Property Total	**65.0**	**3260.1**	**138.7**	**3.5**	**3.1**	**3470.4**

Comments:

Some 94% of the Ecosystem is classified as Grassy Woodland, with the dominant land use being grazing.

4. Ecosystem type:

In a Natural Capital Accounting approach, the foundation environmental account is the Ecosystem Asset Account (Table 2). This account organises information regarding the extent of different ecosystem types. In this approach, Ecosystem Asset Accounts are prepared in line with guidance from the System of Environmental-Economic Accounting (SEEA), thereby enabling farm-level accounts to be potentially aggregated to national and subnational levels. The Ecosystem Asset Accounts prepared in this project apply the guidance for spatial units as described by the expert working group for the SEEA in "Discussion paper 1.1: An ecosystem type classification for the SEEA EEA". These spatial units are used to prepare a detailed Ecological Asset Register of the different types and uses of natural capital. The summary tables presented in this report are drawn from this. To describe the amounts of different types of natural capital, the accounts apply the internationally accepted notion of ecological state and transition models. These describe the different forms that natural capital can take given its management, use and history.

This property is largely a native system located in the grassy woodland biome of NSW. While parts of the property were converted to improved pastures by previous generations, they have subsequently been managed towards native systems. Accordingly, the ecosystem accounts for this property have been prepared using state & transition models for grassy woodlands[2] Further details of the ecosystem types used in NCA for these case studies are provided in the Appendix.

While operating as a successful commercial wool growing operation, Lana has 22% of its landscape in State T2A-1A, a highly diverse Grassy Woodland. Some 29% of the landscape is in State 2A, Grassy Woodland with a diverse ground layer, 28% of the landscape is transitioning between state 2B and 2A, towards higher tree cover and diversity of native species. Further landscape types are listed below in the below Tables and Graphs. Some 52% of the landscape is transitioning to more diverse states.

Table 2: Ecosystem Asset Account (Type-Extent (ha)). This account organises information about the amount of each type of ecosystem on Lana.

Ecosystem Assets @ 15th January 2018	**State or Transition**						
Ecosystem type (ha)	**T2A-1A**	**S2A**	**T2B-2A**	**S2B**	**T3B-2B**	**NA**	**Total**
Domestic	0.0	0.0	0.0	0.0	0.0	3.1	**3.1**
Infrastructure	0.0	0.0	0.0	0.0	0.0	3.5	**3.5**
Cleared Native Pasture	0.0	0.0	0.0	409.0	0.0	0.0	**409.0**
Grassy Woodland	441.8	931.3	966.9	271.0	77.0	0.0	**2688.0**
Grassy Woodland-Granite Outcrops	183.9	44.3	0.0	0.0	0.0	0.0	**228.2**
Riparian	126.1	12.5	0.0	0.0	0.0	0.0	**138.7**
Total	**751.8**	**988.2**	**966.9**	**679.9**	**77.0**	**6.6**	**3470.4**

The information in Table 2 is represented in the graph below (Figure 2), which represents the total area (ha) in each State or Transition as a percentage of the total area of the farm. A full explanation of each Ecosystem Type is given in Table A2 and A3 in the Appendix (page 21 and 22).

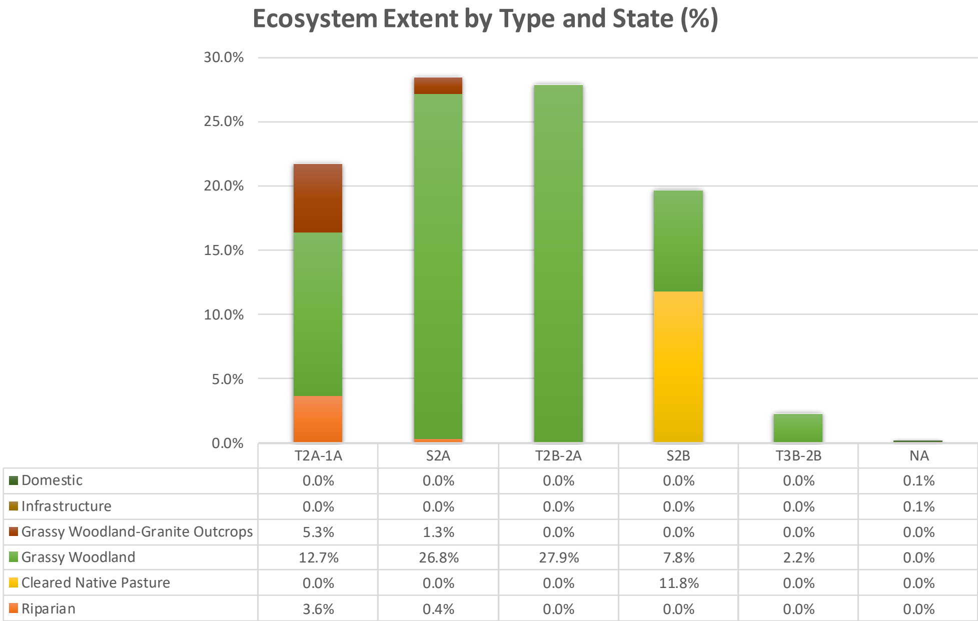


Figure 2: Chart showing the percentage of the farm that is in different grassy woodland states or transition states.

[2] P. G. Spooner and K. G. Allcock, "Using a State-and-Transition Approach to Manage Endangered Eucalyptus Albens (White Box) Woodlands," *Environmental Management* 38, no. 5 (2006); S.M. Whitten et al., "Multiple Ecological Communities Conservation Value Metric. Final Report to the Australian Government Department of the Environment, Water, Heritage and the Arts," (Canberra, Australia: CSIRO Sustainable Ecosystems, 2010).

5. Capacity of the ecosystem to support livestock grazing:

An important aspiration of environmental accounting is to gain a complete understanding of contributions that natural capital condition makes to the performance of a farm business.

In environmental-economic accounting, the forage produced by the farm ecosystems for livestock grazing are classified as provisioning services and can be thought of as farm inputs that nature provides for free to grazing enterprises. The accountings standards recommend that these are estimated in both physical and monetary terms.

Ecosystem Asset Accounts for the use of natural capital for livestock grazing can be prepared in terms of the condition of the natural capital[3] and its capacity to provide forage for livestock. The classifications used in these accounts use the approach developed for grazing management best practice[4]. The accounts (Table 3) show that using the industry-standard classifications, 79% of Lana can be classified as being in very good condition for livestock grazing, 21% in good condition with none in poor condition.

This information, coupled with the State/Transition changes evident, demonstrate the landscape on Lana is both productive and resilient from a wool-growing perspective while at the same time is providing ecological services from the diverse landscape.

Table 3: Ecosystem Asset Account showing condition for grazing and production of livestock. Very Good, Good, Fair, Poor and Very Poor capacity for grazing indicates the quality and persistence of pastures with regard to the level of groundcover and proportion of palatable, perennial and persistent species. This table provides information about the extent (ha) of land in each condition class for grazing.

Ecosystem Asset Accounts	**Grazing Condition class**						
15th Jan 2018	**Very Good**	**Good**	**Fair**	**Poor**	**Very Poor**	**NA**	**Totals**
Cleared Native Pasture	409.0	0.0	0.0	0.0	0.0	0.0	**409.0**
Grassy Woodland	2154.1	697.0	0.0	0.0	0.0	65.0	**2916.2**
Riparian	0.0	0.0	0.0	0.0	0.0	138.7	**138.7**
Domestic	0.0	0.0	0.0	0.0	0.0	3.1	**3.1**
Infrastructure	0.0	0.0	0.0	0.0	0.0	3.5	**3.5**
Property Total	**2563.1**	**697.0**	**0.0**	**0.0**	**0.0**	**210.3**	**3470.4**

The contribution the natural capital is making to the financial performance of the farm has been estimated using methods for ecosystem valuation that have been developed to be compliant with the accounting standards[5]. Table 4 presents estimates of the monetary value[6] of the annual flow of provisioning services, the net present value (NPV) of these on a per hectare and per DSE basis. Inputs to valuation incorporate a ten-year average of farm income and expenses, and NPV uses a risk-adjusted discount rate per the

[3] H. Keith et al., "Discussion Paper 2.1: Purpose and Role of Ecosystem Condition Accounts. Paper Submitted to the Seea Eea Technical Committee as Input to the Revision of the Technical Recommendations in Support of the System on Environmental-Economic Accounting. Version of 13 March 2019," in *System of Environmental Economic Accounting* (New York: UNSD, 2019); S. Ogilvy, "Developing the Ecological Balance Sheet for Agricultural Sustainability," *Sustainability Accounting, Management and Policy Journal* 6, no. 2 (2015); Sue Ogilvy et al., "Accounting for Liabilities Related to Ecosystem Degradation," *Ecosystem Health and Sustainability* 4, no. 11 (2018).

[4] Alessandra La Notte, Sara Vallecillo, and Joachim Maes, "Capacity as "Virtual Stock" in Ecosystem Services Accounting," *Ecological Indicators* 98 (2019).

[5] S. Ogilvy and M. Vail, "Standards-Compliant Accounting Valuations of Ecosystems," *Sustainability Accounting, Management and Policy Journal* 9, no. 2 (2018); UNSD, "Technical Recommendations in Support of the System of Environmental-Economic Accounting 2012-Experimental Ecosystem Accounting," (New York, USA: United Nations Committee of Experts on Environmental-Economic Accounting, 2017).

[6] Note that monetary values used in the formal accounting standards are exchange values and don't include the full societal value generated by ecosystems. Further, the values presented here are conservative in nature by only including the forage provisioning values and may underestimate other contributions of natural capital.

recommendations of the corporate accounting standards to reflect the exposure of agriculture to significant interannual and inter-decadal variation in season and market quality[7]

This indicates that by providing reliable and good quality forage, Lana's natural capital is contributing free inputs to livestock grazing (forage) that are worth approximately $29/ha per year[8]. These indicate that the (grazing only) value of the natural capital to the farm business is approximately $299 per hectare. As this is the first project (to our knowledge) to attempt to value the monetary contribution of natural capital to a farm business (separately from the real estate value of the land), we have no basis for comparison of Lana's natural capital value to that of other businesses.

Over time we hope industry benchmarks can be developed in these metrics.

Table 4: Estimates of the contribution the grazed ecosystems are making to the financial performance of the farm business.

Ecosystem Monetary Values ($) *@ 15th December 2017*	
Metric 1: Average (ten-year) annual flow of provisioning services for livestock (per ha)	29
Metric 2: Value of natural capital (grazing value only) per Ha	299

[7] IASB, "Ifrs 13: Fair Value Measurement," (International Accounting Standards Board, 2011).
[8] These estimates include expenses for activities and purchased inputs to maintain the ecosystem in good condition.

6. Estimated storage of carbon on the property

One of the benefits created by good Natural Capital Management is the maintenance of stocks of carbon stored in the landscape in vegetation and soils. Stocks of carbon represent estimates of the total carbon stored across the whole farm. A farm with high levels of stored carbon is typically in better ecological condition compared to a farm with lower carbon storage across the landscape.

These stocks can be estimated for general carbon accounting by using published 'densities' of carbon for different ecosystem types. Note that these estimates are not appropriate for trading carbon or participating in formal carbon sequestration projects. They provide an indication of the current health of the farm ecosystem, reflecting many years of management, as well as the likelihood of carbon emissions from livestock production being offset by high carbon levels across the whole farm.

Total Carbon storage for Lana (shown in Table 4) of 220 230 Tons of Carbon are likely to be high in comparison to agricultural properties in the region due to the profile of the ecosystem types and the extent of transitioning.

This Total Carbon Storage represents 63 t/ha of Carbon averaged across the whole farm. However, published benchmarks are currently difficult to find.

Table 4: Carbon (biocarbon) stocks on the property by ecosystem type. These estimates are prepared from published densities of carbon for different ecosystem types.

	State or Transition						
Carbon stocks by Type / State (Mg C)	**T2A-1A**	**S2A**	**T2B-2A**	**S2B**	**T3B-2B**	**NA**	**Total**
Cleared Native Pasture	0	0	0	19358	0	0	**19358**
Grassy Woodland	52561	66628	53873	12826	3526	0	**189413**
Riparian	10596	856	0	0	0	0	**11453**
Domestic	0	0	0	0	0	3	**3**
Infrastructure	0	0	0	0	0	3	**3**
Total	**63157**	**67484**	**53873**	**32184**	**3526**	**7**	**220230**

Comments:

While published benchmarks are difficult to find, the level of 220 230 Tons of Carbon (63 t/ha) stored over the whole farm is considered a high level due to the profile of the Ecosystem type.

Over time it is hoped industry benchmarks will become available for Carbon Stocks.

Carbon estimates, and references, for each type of ecosystem are shown in the Appendix, Table A6.

7. Detailed Environmental Profit and Loss:

NOTE: The units used to report some of the metrics in this section differ from those used in the summary tables presented in the Natural Capital Snapshot section (pages 2 and 3). The summary table figures (page 3) are reported using industry-standard units, whereas the figures in this section are reported in units according to the Kering EP&L methodology. In particular, the metrics below are reported per kg of clean wool instead of per kg of greasy wool used earlier in the report. Furthermore, water use is reported in absolute terms (m^3/kg clean wool) rather than as a normalised water stress unit (litres H_2O -e/ kg greasy wool). Whilst the figures reported below are in reported per kg of clean wool; the figures exclude emissions and resource use associated with the scouring process of the wool. The figures represent emissions and resource use for the production process of the wool at the farm gate.

Air Pollution	Dust, particulate matter, SO_2 and NO_x produced from farm operations (typically from the burning of fossil fuels). Calculated per kg of clean wool produced. Proportionally allocated based on other animal products from the farm (cattle, lamb sales)		
Metric 1	Dust generated through farm operations	0.0	kg / kg Clean Wool
Metric 2	Particulate matter generated	0.0	kg / kg Clean Wool

Comments:

Negligible dust emissions due to consistent ground cover. Unable to calculate NO_x and SO_2 particulates due to use of fossil fuels given the insignificant volume of use and the lack of methodologies to derive the values.

Greenhouse Gas Emissions	Calculated as per Australian Government Department of Environment and Energy: National Inventory Report 2018 Volume 1. This includes direct Scope 1 emissions from the burning of fossil fuels, indirect Scope 3 emissions from the production / transport of fuels, and the indirect emissions from electricity generation assuming no renewable energy use. This also includes animal based emissions of enteric (CH4), manure (CH4), dung and urine (N2O) and atmospheric deposition (N2O).		
Metric 1	Fossil Fuel emissions	0.36	kg CO_2e / kg Clean Wool
Metric 2	Livestock emissions (IPCC 2014 AR5 factors)	37.33	kg CO_2e / kg Clean Wool
Metric 3	Fertiliser emissions	0.00	kg CO_2e / kg Clean Wool
Metric 5	Pre-farm emissions	0.22	kg CO_2e / kg Clean Wool

Comments:

The GHG emissions have been calculated separately for fossil fuel use vs animal emissions, as these emissions have a very different impact pathway on the biosphere. Emissions from fossil fuel use have a significant impact on the climate due to the fact that it is releasing carbon into that atmosphere that has taken billions of years to be stored in stable carbon in the ground.

In comparison, the emissions due to livestock are part of a relatively short carbon cycle – CO_2 is sequestered in grass through photosynthesis, livestock eat grass, livestock emit carbon in the form of CO_2 (respiration) and CH_4 (respiration, manure, urine). Whilst CH_4 does have a higher global warming potential than CO_2, it is short-lived, and the cycle is not introducing any additional Carbon into the atmosphere (Ref: Eckard et al., 2016).

The pre-farm emissions relate to the emissions generate during the production of products purchased such as fertilisers, superphosphate and externally sourced grain and fodder, as well as emissions related to purchased livestock.

Land Use / Biodiversity	Natural land areas provide essential services to society which regulate our environment, provide goods and services and support livelihoods. The conversion and degradation of natural areas results in a reduction of these services. The figures below represent a proportional loss of the capacity of the property to generate each ecosystem service compared to an ecosystem in pristine (reference) condition.		
Metric 1	Area attributed to wool production	534	Hectares
Metric 2	Wool produced	14567	kg
Metric 3	Food from natural/semi-natural ecosystems	29%	Extent of service loss (weighted average across area based on state of ecosystem relative to reference condition)
Metric 4	Fibre, other raw materials	29%	
Metric 5	Domestic and industrial water	26%	
Metric 6	Bio-prospecting & medicinal plants	29%	
Metric 7	Ornamental products	29%	
Metric 8	Air purification	26%	
Metric 9	Recreation	29%	
Metric 10	Spiritual and aesthetic	29%	
Metric 11	Cognitive and learning opportunities	29%	
Metric 12	Stable climate	26%	
Metric 13	Pollution control and waste assimilation	29%	
Metric 14	Erosion control	26%	
Metric 15	Disease and pest control	29%	
Metric 16	Flood control and protection from extreme events	26%	

The metrics demonstrate that whilst some function or capacity to deliver ecosystem services has been lost over time; the farm still provides a significant amount of capacity for these services. The figures are not direct measures of each ecosystem service but rather have been calculated based on a proxy of biomass loss and/or species richness loss. They represent a very conservative estimate of the capacity to deliver these services.

A conservative estimate of the natural value affected by Lana's operation suggests that it has impacted the ecosystem services by around 26-29%, compared to 80% estimated by Kering for land use impact from Regenerated operations in their E P and L. This impact is not permanent and may reduce over time.

Waste	Hard waste generated from inputs to the grazing operation. Calculated based on packaging from fodder. Calculated per kg of clean fleece produced. Proportionally allocated based on other animal products from the farm (cattle, lamb sales)		
Metric 1	Non-biodegradable waste	0.001	kg / kg Clean Wool

Comments:

Low levels of fodder purchased, so low levels of non-biodegradable waste generated for wool production.

Water consumption	Stock consumption of water, and water used for irrigation. Calculated per kg of clean fleece generated from the greasy wool produced. Proportional allocation based on biophysical allocation of wool as a proportion of all sheep products.		
Metric 1	Stock water consumption including evaporation	0.102	m^3 / kg Clean Wool
Metric 2	Water consumption for irrigation of fodder	0.000	m^3 / kg Clean Wool
Metric 3	Normalised Stress weighted TOTAL water consumption including evaporation	3.5	litres H_2O-e / kg Clean Wool
Metric 4	Water Stress Index (Pfister et al 2009)	0.0208	

Note: The Water Stress Index is a measure of scarcity of fresh water in the region. Normalised stress weighted water use represents the absolute water use figure multiplied by the localised Water Stress Index, divided by the global average WSI (0.602 - (Ridoutt & Pfister 2013)).

Comments:

As there is no irrigation to produce fodder on the property, the figures provided represent the water consumed by the stock. The water use has been shown as absolute values (metrics 1 and 2), as well as a normalised stress weighted water use (metric 3).

The total water use for wool production (0.102 m^3/kg clean wool) is lower than Kering's estimate of water use for wool produced from conventional production (0.366 m^3/kg clean wool) and is significantly lower than the comparable water rating for the production of other fibres such as cotton (5.03 m^3/kg conventional cotton) (Kering 2018).

Water Pollution	Water pollution created as a result of the use of agricultural chemicals (eg. fertilisers and pesticides) that are then leached from the ecosystem and runoff into surrounding waterways. Calculated as kg of pollutant per kg clean fleece produced.		
Metric 1	Nitrogen leaching into the waterways	0.000	kg / kg Clean Wool
Metric 2	Phosphorus leaching into the waterways	Not calculated	kg / kg Clean Wool

Comments:

No fertiliser was used. Functioning grasslands ensure that negligible leaching and run-off from manure deposited in grasslands by stock. Riparian areas in good condition also provide increased filtering services to mitigate any pollutants released by leaching.

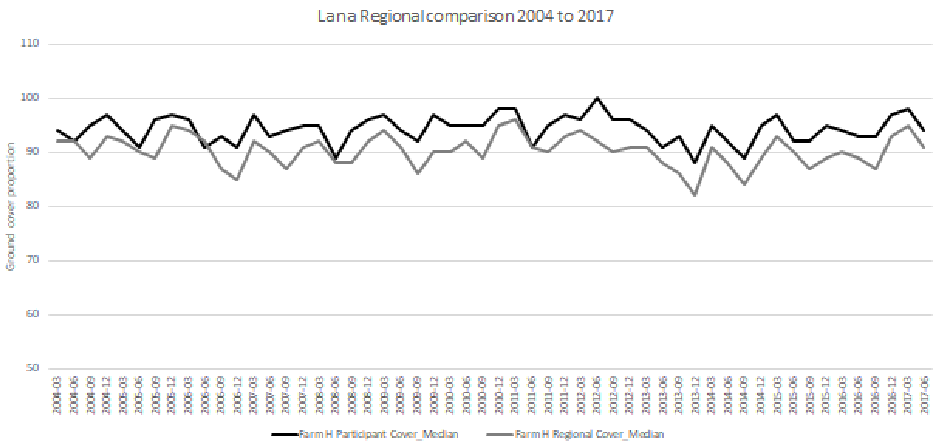
8. Groundcover assessment:

FarmMap4D is a commercially available GIS information system available in an on-line format. It allows customised and easy to use mapping, reporting and analysis tools to analyse the condition of land over time.

A feature of the program is the ability to track historical changes in groundcover and to create local and regional comparisons.

Managing pastures to maintain adequate levels of groundcover is an effective way to minimise rainfall run-off and soil loss. By reducing rainfall run-off, more water is made available for plant growth. By reducing erosion, soil, nutrients and organic matter are retained in place and siltation problems are minimised. In addition, groundcover is important for soil health and assists in weed control (Lang 2005). Groundcover provides an important role in the establishment of perennial native grass seeds and hence the regeneration process (AgVic).

Lana ground-cover comparison – properties within 5km



Comments:

The graph above uses FarmMap4D to analyse groundcover on Lana and compares this with properties within a 10km radius for the period 2004 – 2017 (13 years). It is evident that in every year the ground cover of Lana is above that of properties within a 5 km radius. Ground cover remained above 90% and peaked at 100%. Industry targets suggest a minimum of 70% groundcover is required to reduce run-off and erosion (Lang 2005). A high level of ground cover is an important component of an effective water cycle, mineral cycle, weed control and in providing conditions for native plant recruitment.

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Appendix:

1. Descriptions of 'condition for grazing' categories

Categories describing condition for grazing are adapted from the MLA EDGE framework (MLA 2016) to be relevant to temperate pastures. Where areas of a farm were borderline for land condition between these two categories we also applied an important principle relating to the sustainability of grassy woodlands (McIntyre et al 2002) that relates to the potential to slow water flow across the landscape and thus contribute to landscape rehydration as well as efficient use of nutrients.

The categories applied in Table 3 in the report are described in Table A1.

Table A1. *Categories of 'condition for grazing'.*

Category	Description
A (very good)	Very good land condition that has high levels of groundcover, including tussocky perennial species and litter that contribute to landscape functioning, a diverse mix of perennial, palatable and persistent species. a good amount of biomass is retained (>1500 kg/ha). Few weeds are present and soil erosion is absent.
B (good)	Similar to A with good land condition that has high levels of groundcover (<90%). There is a slight decline in perennial, palatable and persistent species and larger tussocky species that contribute to ongoing high levels of landscape functioning are not common. Reasonable biomass is retained and there may be some signs of previous erosion as well as potential for current erosion in some areas. Likely to be a minor presence of weeds.
C (fair)	There are reasonable levels of groundcover (>70%), a moderate diversity of palatable and perennial species but persistent native species that protect soil assets in poor times are missing. Weeds (annual or invasive perennial) are present and noticeable. Bare ground may be significant (>50%) in some years and there are obvious signs of erosion with current susceptibility to erosion high.
D (poor)	A fair proportion of bare ground (>30%), low biomass most of the time and (likely to very low in extended dry times), dominated by unpalatable perennials and annual weedy species.
E (very poor)	Few perennial species are present and a severe and hostile environment for plant growth (i.e. scalding, salinity, severe and continuing gullying in susceptible areas. Potential and likelihood of weed invasion is high.

2. Information on 'identity' classifications:

To determine the condition of an area on a farm it is necessary to assign a category that summarises characteristics of the particular area of land. The condition of this area can then be considered in the context of the purpose for which that area of land is managed. Purposes may include livestock grazing, timber production, honey production or conservation. An area of land may have dual, or multiple, purposes. For example: scattered trees among native grasslands have livestock production, conservation of biodiversity, carbon storage and honey production potential; a timber plantation where plantings are less dense can be used for livestock grazing, shelter, timber production and carbon storage.

Identity states are well established for native ecosystems in Australia. These identity 'states', and the transitions between states, are referred to as 'State and Transition' models. Generally, in areas modified for agriculture, there has been a general move towards lower tree cover and conversion of the ground layer vegetation from native species to exotic improved pastures.

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

As the case studies in this project are situated within the temperate grassy woodland biome, we use published 'state' and 'transition' identity classes for that biome as outlined in Whitten et al (2010). We apply these identity states to areas on a farm that retain general characteristics of the original native ecosystem such as remnant trees and some native herbaceous species. In the context of this project, determining the 'state' or 'transition' identity of an area enables a determination of the potential for provision of a range of ecosystem services. The categories for each 'State' in the recognised State and Transition models are outlined in Table A2. Transitions refer to whether an area of interest is transitioning between these recognised states.

Each 'state' or 'transition' identity implies no value judgement. A value judgement only exists once management and production goals are considered. For example, a management goal for wool production may be to have persistent and palatable forage as well as areas for stock to shelter. These ecosystem services can be provided by a less modified native ecosystem (State 2A/B 3A/B) or by an area forested with exotic or native timber if the canopy is open enough to allow good forage as well as timber production.

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

Table A2. Descriptions of the 'identity' states referred to in Table 2.

Identity states are in relation to the natural ecosystem present in the grass woodland biome in reference condition. Transitions are also occurring between these states.

It is possible through planned management decisions to restore characteristics of the original native ecosystem where there has been modification for agricultural production. The degree to which this is possible will depend on the level of modification of an area through past practices. 'Transitioning' to an identity state that more closely resembles the original native ecosystem is likely to impart greater resilience to a farm. The end goal will depend on the goals of the landowners, whether the primary use for an area is for grazing production or for conservation.

Title/code for 'state'	Description	Detailed description
1A	Grassy woodland with a diverse native ground-layer	Tree (canopy) cover >15% and the ground-layer has a high diversity and cover of native species (< 30 species and >70% groundcover of native species). Never fertilised or fertiliser use ceased 3–4 decades previously).
1B	Derived native grassland with a diverse native ground-layer	There is low tree-cover, but the ground-layer has a high diversity and cover of native species (< 30 species and >70% groundcover of native species). Never fertilised or fertiliser use ceased 3–4 decades previously).
2A	Grassy woodland with a diverse native ground-layer	Tree-cover is slightly lower (10–14%) than 1A and the ground-layer has a slightly lower diversity and cover of native species compared to 1A (16–29 species and 50–69% groundcover of native species). Rarely fertilised or fertiliser use ceased 2–3 decades previously).
2B	Derived native grassland with a diverse native ground-layer	There is low tree-cover, but the ground-layer has a high diversity and cover of native species (16–29 species and 50–69% groundcover of native species). Rarely fertilised or fertiliser use ceased 2–3 decades previously).
3A	Some mature trees present and a moderately diverse, mainly native, ground-layer	Mature eucalypts present (but with no tree regeneration). The ground-layer has a moderate diversity of native species (8-15 species) and 30–49% native-ness of the ground-layer. Historically low-moderate fertiliser application.
3B	A moderately diverse and mainly native grassland with few trees	Few mature eucalypts present (but with no tree regeneration). The ground-layer has a moderate diversity of native species (8-15 species) and 30–49% native-ness of the ground-layer. Historically low-moderate fertiliser application.
4	Grassland with a mix of native and exotic species and occasional scattered trees	Grassland with 4–7 native species and <30% cover of native species and the occasional scattered tree with no natural tree regeneration. There has been frequent fertiliser application until present day.
5 (includes improved pastures)	Predominantly exotic grassland with a few native species. No remnant trees present.	No trees remaining and no natural tree regeneration. Pastures are predominantly exotic with <3 native species and <10% cover of native species. There has been frequent fertiliser application until present day.

Commonly, farms in the temperate zone of Australia are a mosaic of more and less modified areas. Where areas have been significantly modified from the original native state through cropping, and/or forestry, we have created alternative 'identity' states to describe the core characteristics of an ecosystem and enable an understanding of the potential to provide a range of ecosystem services. Due to the new ground this project is exploring, these alternative states may require further consideration.

These modified identity categories are outlined in Tables A3 and A4.

Table A3. Modified states

State abbreviation or code	Description	Detailed description
FREDM	Fully Replaced Exotic Dense Mature	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are dense (<50% canopy cover) with mature aged trees.
FREDI	Fully Replaced Exotic Dense Intermediate	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are dense (projected to be >50% canopy cover) with intermediate aged trees.
FREDY	Fully Replaced Exotic Dense Young	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are dense (projected to be >50% canopy cover) with intermediate aged trees.
FRESM	Fully Replaced Exotic Sparse Mature	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are sparse (>50% canopy cover) with mature aged trees.
FRESI	Fully Replaced Exotic Sparse Intermediate	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are sparse (<50% canopy cover) with mature aged trees.
FRESY	Fully Replaced Exotic Sparse Young	The original native community has been fully replaced with alternative vegetation that is introduced/exotic. Plantings are sparse (<50% canopy cover) with young trees.

Table A4. Native plantings

State abbreviation or code	Description	Detailed description
FRNDM	Fully Replaced Native Dense Mature	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are dense (>50% canopy cover) with mature aged trees.
FRNDI	Fully Replaced Native Dense Intermediate	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are dense (projected to be >50% canopy cover) with intermediate aged trees.
FRNDY	Fully Replaced Native Dense Young	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are dense (projected to be >50% canopy cover) with young trees.
FRNSM	Fully Replaced Native Sparse Mature	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are sparse (projected to be <50% canopy cover) with mature aged trees.
FRNSI	Fully Replaced Native Sparse Intermediate	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are sparse (projected to be <50% canopy cover) with intermediate aged trees.
FRNSY	Fully Replaced Native Sparse Young	The original native community has been fully replaced with alternative vegetation that is native to Australia. Plantings are sparse (projected to be >50% canopy cover) with young trees.

Table A5 explains the allocation of the potential for Ecosystem service provision in Figure 1.

Type of ecosystem service	***ID***	***Score***	***Reasoning***
Production			
Provisioning for livestock (across 10 years i.e., stability of production)	P1	H	Consistency of livestock production across years based on land condition (MLA reference; McIntyre et al 2002; Chapman et al 2006; Dunin and Passioura, 2006; Simpson and Langford, 1996) as well as stock/financial records
Forage for pollinators including bees	P2	H	Extensive areas of eucalypt woodland along with mid and under-story species diversity (Leech 2012).
Firewood/timber resources	P3	M	Abundant trees in the landscape, abundant natural regeneration, knowledge of ongoing income from firewood collection (Brown et al 2009)
Regulating			
Soil protection/nutrient retention	R1	H	High levels of perennial groundcover allow ongoing protection of soils and retain nutrients (Greenwood and McKenzie 2001; Eldridge and Freudenberger, 2005; McIntyre and Tongway, 2005; Tongway and Hindley, 2005).
Water quality	R2	H	High levels of groundcover and retained biomass ensure nutrient and sediment run-off is negligible (Dunin and Passiour, 2006; Tongway and Hindley, 2005)
Carbon storage	R3	H	Large amounts of carbon are stored on this farm due to healthy, perennial grasslands and abundant tree cover (Young et al 2005).
Micro-climate regulation	R4	H	High levels of groundcover, abundant areas with scattered, and sometimes denser, tree cover, abundant taller grasses and well-vegetated riparian areas (Cleugh et al 2002; Bird et al 2007; Bennell and Verbyla, 2008)
Pollination and pest predation services	R5	H	High levels of insect diversity likely due to abundant habitat suitable for pollinators (grasslands and woodlands) present throughout property
Cultural (including habitat)			
Biodiversity - animal	C1	M	Fencing infrastructure across the property, combined with significant areas of a more cleared landscape. Nb. Very few farms with a primary purpose of production would score 'high' for wildlife biodiversity due to the restrictions for movement for larger animals
Biodiversity – non-animal	C2	H	High – most of the farm is in an identity state that supports high levels of plant diversity. (Whitten et al 2010).
Restoration potential (Threatened ecosystem)	C3	H	Most of landscape is in an identity state that is close to high conservation value (Whitten et al 2010). Lack of fertiliser application for past few decades means that native diversity is likely to continue increasing. If allowed (i.e., fitted with management goals), tree cover could also increase.
Climate change adaption.	C4	H	Grassy woodlands in good – and regenerating – condition across most of the property confers significant climate change adaptation potential (Lavorel et al 2015).

Table* A6 *Details for carbon calculations –

Carbon storage and sequestration calculations for this project do not account for the possibility that regeneratively managed soils may be sequestering significant amounts of soil carbon. We chose to be conservative in our approach with this and applied either a figure for soil carbon under healthy perennial grasslands (native and/or introduced species; 37 T/ha - with a range of 25–50 T/ha) or a lower figure where pastures had a significant number of annual species and lower ground cover (19 T/ha - with a range of 12–30 T/ha). The figures applied are based on an average value across peer-reviewed literature and relate to soil in the top 30cm of the profile. Figures and approach were also peer-reviewed by experts in the field. Thus, the figures may not reflect carbon gains in the soil from regenerative grazing practices. The reason for not including this is that, to our knowledge, data is not currently available in the peer-reviewed literature to support potential gains in soil carbon from regenerative grazing practices.

***Table* A6.** Amounts of carbon stored in each structural layer of the woodland or grassland ecosystem. e.g., carbon stored in grasslands cleared pastures will comprise of soil (0-30cm) and grassland vegetation; carbon stored in a mature woodland will consist of the overstorey, coarse woody debris, ground-layer vegetation and carbon in the soil. The coarse woody debris component will not be included in a cleared pasture with few trees or a cleared pasture in the early stages of regeneration to a woodland.

Structural element	*Characteristics*	*Range (T/ha)*	*Average value (T/ha)*
Denser eucalypt woodland overstorey	Mature woodland with significant cover of eucalypt canopy > 50%	32-52	46
Moderately open eucalypt woodland overstorey	Moderate canopy cover between 35-100 trees/ha.	16–44	30
Coarse woody debris	Significant amounts of fallen timber (diameter > 10cm) in woodland areas - similar what would be present in a natural, mature woodland	9.5-14.5	12
Eucalypt woodland overstorey - State 2B)	A moderately low density of mature/old trees (between 5–10% canopy cover)	not available	19
Scattered eucalypt woodland overstorey	Sparse (3.5% canopy cover calculated from median canopy cover State 2B and 3B Whitten et al 2010)	not available	9
Agroforestry (Above ground biomass)	For dense plantings taken as same figure for dense eucalypt woodland above. For open plantings taken as the same figure for moderately open eucalypt woodland overstorey	32-52 (dense) 16–44 (moderately open)	46 (dense) 30 (open)
Perennial grassland (above-ground biomass)	Carbon held in above ground biomass of ground-layer vegetation	2–4.8	3
Soils (to 30cm), perennial grassland (incl. woodlands)	Carbon held in top 30cm of healthy, perennial grasslands	25–50	37
Soils (to 30cm) annual, exotic grassland	Carbon held in top 30cm of soils under pastures dominated by annual species	12–30	19

Table A7. Reference details for carbon sequestration and storage data

Structural element	***Reference details***
Denser eucalypt woodland overstorey	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215. Montagnini, F. & Nair, P. 2004. Carbon sequestration: an underexploited environmental benefit of agroforestry systems. New Vistas in Agroforestry. Springer.
Open eucalypt woodland overstorey	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215. Young, R., Wilson, B. R., McLeod, M. & Alston, C. 2005. Carbon storage in the soils and vegetation of contrasting land uses in northern New South Wales, Australia. Soil Research, 43, 21–31.
Agroforestry (Above ground biomass)	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215. Montagnini, F. & Nair, P. 2004. Carbon sequestration: an underexploited environmental benefit of agroforestry systems. New Vistas in Agroforestry. Springer. Fernández-núñez, E., Rigueiro-rodríguez, A. & Mosquera-losada, M. 2010. Carbon allocation dynamics one decade after afforestation with Pinus radiata D. Don and Betula alba L. under two stand densities in NW Spain. Ecological engineering, 36, 876-890.
Coarse woody debris	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215.
Perennial grassland (above-ground biomass)	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215. Wheeler, M. M., Dipman, M. M., Adams, T. A., Ruina, A. V., Robins, C. R. & Meyer III, W. M. 2016. Carbon and nitrogen storage in California sage scrub and non-native grassland habitats. Journal of Arid Environments, 129, 119–125.
Soils (to 30cm), perennial grassland (incl. woodlands)	MacDonald, B., Gillen, J., Tuomi, S., Newport, J., Barton, P. & Manning, A. 2015. Can coarse woody debris be used for carbon storage in open grazed woodlands? Journal of Environmental Quality, 44, 1210–1215. Young, R., Wilson, B. R., McLeod, M. & Alston, C. 2005. Carbon storage in the soils and vegetation of contrasting land uses in northern New South Wales, Australia. Soil Research, 43, 21–31. Orgill, S. E., Condon, J., Conyers, M., Greene, R., Morris, S. & Murphy, B. W. 2014. Sensitivity of soil carbon to management and environmental factors within Australian perennial pasture systems. Geoderma, 214, 70–79.

Structural element	***Reference details***
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