Final report

Farming for the Future
An impact focussed research and change program for Australian producers

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Traditional lands where this work took place

- Pyemmairrener
- Djabwurung
- Wiradjuri
- Nganyaywana
- Ngarabal
- Yuat
- Minang
- Tyerrernotepanner
- Jardadjali
- Ngunnawal
- Biripi
- Wailwan
- Balardung
- Lairmairrener
- Djadjawurung
- Gundungurra
- Dainggatti
- Kamilaroi
- Nyaki-Nkaki
- Gunditjmara
- Taungurong
- Dharug
- Gumbainggir
- Badimaya
- Wiilman

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Abstract

Farming for the Future is a public good research and change activation program that has been established as a response to the increasing urgency for agriculture to play an active role as a nature-based solution to climate and biodiversity loss for Australia whilst continuing to produce high quality food and fibre. *Farming for the Future* aims to quantify relationships between on-farm natural capital and the productivity, profitability and resilience of Australian producers to ensure that the Australian agriculture sector can factor natural capital more effectively into their business planning processes.

Farming for the Future collected data from 130 livestock businesses in selected regions of NSW, Victoria, Tasmania and Western Australia. We collected fine scale natural capital information, alongside detailed financial and production data, via remote sensing, field surveys and producer interviews. The resulting dataset contained 113 farms with full data considered appropriate for analysis, and is the largest dataset of its kind in the world.

Our analysis of 113 livestock farms indicated that natural capital is positively correlated with production efficiency, gross margin, earnings before interest and tax (EBIT) and resilience to both climate and market shocks. We suggest that natural capital may support production efficiency by substituting for more expensive, and more volatile, inputs like energy, fodder, animal health costs and labour.

We analysed natural capital – livestock enterprise relationships separately for three different 'types' of farms that were evident in our dataset. This allowed us to isolate the effect of natural capital because it ensured that all other things like farm size, stocking rates etc. were approximately equal.

Each individual farm type showed a positive association with natural capital across some or all of the range of natural capital scores measured. Given that our farm sample was representative of farms present in the broader study area, this suggests most farms could improve one (or usually more) elements of natural capital whilst also achieving improvement in livestock production efficiency, although we note that larger sample sizes and additional analyses are necessary to establish causal relationships. We also saw evidence of a 'trade-off zone' for some elements of natural capital. This suggests there may be a role for natural capital markets or incentives in a limited set of circumstances.

Our research confirmed that potential benefits like increased productivity, profitability and resilience are the most compelling motivation for producers to invest in natural capital. By demonstrating these private benefits, *Farming for the Future* can accelerate large-scale industry adoption of improved natural capital management and help build a financially prosperous, climate-resilient agriculture sector for Australia.

Executive summary

Background

Farming for the Future is a public good research and change activation program that has been established as a response to the increasing urgency for agriculture to play an active role as a nature-based solution to climate and biodiversity loss for Australia whilst continuing to produce high quality food and fibre. The program has a bold vision to transform Australia's agriculture sector into one that empowers producers to evolve their farm businesses in ways that maintain and enhance their natural capital to build resilience and improve profitability.

Farming for the Future believes that the financial contribution of natural capital to core farm production is large relative to the economic opportunity presented by alternative natural capital income streams like carbon and biodiversity markets. We believe that increasing producers' knowledge about the nature of benefits that natural capital can deliver to core farm production will help to drive large-scale industry adoption of improved natural capital management practices and enable the agriculture sector to play an active role as a nature-based solution to climate and biodiversity loss for Australia.

Farming for the Future envisages a near future where all levels of the agricultural sector, from producers, to the financial services sector and retail brands, understand, and can quantify, the benefits on-farm natural capital delivers to their businesses. We aim to create the conditions where members of the agricultural value and supply chains will collectively deliver outcomes that serve their private commercial interests, whilst also delivering public benefits.

Objectives

Farming for the Future is building the first national-scale evidence base that documents on-farm natural capital and its relationship to business performance on Australian farms. We aim to embed natural capital in mainstream farm valuation and management practices by providing producers with the data, practical support, and tools needed to measure their on-farm natural capital and manage it in ways that help build more productive, profitable, and climate-resilient businesses.

Specifically, *Farming for the Future* seeks to:

- Understand and quantify natural capital - farm business performance relationships.
- Uncover any benefit pathways through which natural capital can provide benefits to farm businesses and farming families.
- Design, build and test a natural capital benchmarking module to support farm business decision making by providing insights about how on-farm natural capital can be managed to optimise benefits to producers and their families.
- Activate the system of supply chain, financial services, and government organisations to support producers to measure, manage and invest in natural capital as a factor of production.
- Act as a catalyst for systems change, building diverse and effective networks across industry, government, philanthropy and academia to accelerate adoption of natural capital opportunities and help build a more profitable and climate-resilient agricultural sector for current and future generations.

Methodology

Farming for the Future's Livestock Pilot Program has focussed its research activities on livestock operations in selected agricultural regions of NSW, Victoria, Tasmania and the south of Western Australia. It has collected data from 130 livestock businesses whose operations are representative of the range of natural capital types, and enterprise size in these regions.

Farming for the Future captured and recorded high quality, fine scale natural capital data, alongside detailed financial and production data, using a combination of remote sensing technology, field surveys, and producer interviews. We used statistical analysis and benchmarking approaches to quantify relationships between natural capital and farm business performance, and to identify benefit pathways and associated management actions that can improve both natural capital and farm performance across a range of spatial settings.

We also led a range of landholder, farm advisor and industry information and co-design sessions to identify and deliver effective tools and outputs that can help catalyse industry adoption of natural capital measurement and management.

Results/key findings

The *Farming for the Future* Livestock Pilot Program has provided the first large scale evidence of a positive relationship between natural capital and farm performance. Key findings are summarised below:

- 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.
- We analysed natural capital – livestock enterprise relationships separately for three different 'types' of farms that were evident in our dataset, rather than making comparisons between

modes (i.e. where conventional farms are compared to 'regenerative practice'). Each individual farm type showed a positive association with natural capital across some or all of the range of natural capital scores measured. Given that our farm sample was representative of farms present in the broader study area, this suggests that that most farms could improve one (or usually more) elements of natural capital to improve livestock production efficiency (although we note that larger sample sizes and additional analyses are necessary to establish causal relationships).

- We also saw evidence of a 'trade-off zone' for some elements of natural capital in some farm types (Ecological Condition and Vegetation Aggregation for productivity benefits; Ground Cover and Connectivity for profitability benefits), suggesting a role for natural capital markets or incentives in a limited set of circumstances.

Benefits to industry

Farming for the Future is providing the measurement protocols, evidence base, tools, and resources for producers to manage their natural capital in a way that builds more profitable and climate-resilient farm businesses. These outputs also provide producers with the capacity to report natural capital baselines and associated improvements through time to supply chains, industry bodies and other relevant parties and associated market opportunities.

Farming for the Future engages the farm advisory/accounting industry as its key pathway for sharing information and insights and collaborates with a diverse network of industry partners. By building capacity across all relevant stakeholders, *Farming for the Future* is catalysing large scale adoption of beneficial land management practices, and helping to build a more financially prosperous, climate-resilient, and environmentally positive agriculture sector for Australia.

We provide a range of deliverables (farm-scale natural capital and benchmarking reports) so that the potential for natural capital management interventions to improve business performance can be explored on a case-by-case basis by farm advisors with their clients, combining information from our benchmarking dataset with their own expertise and local knowledge.

Delivering insights into natural capital-farm business relationships across a broader range of focus regions and enterprise types could help to drive large-scale industry adoption of improved natural capital management (+38% of farms beyond forecast baseline levels).

Future research and recommendations

Data analysis for this Livestock Pilot focussed on trends in business performance associated with increasing levels of natural capital <u>within</u> different farm types. This allowed us to investigate whether and how producers might benefit from improved natural capital, irrespective of their current production mode or starting point. Additional industry-level insights may be gained by comparing performance <u>across</u> different farm types. This is a much larger question with important implications for production trade-offs (for example between farm size, stocking rates and production efficiency) at the industry-scale. Future analyses based on larger sample sizes will aim to address these important issues.

In its next research phase (2024-2026), *Farming for the Future* proposes to expand its reach to include approximately 270 new farms, and two new focus regions (one in Queensland and one yet to be determined). This larger sample size will enable us to deliver insights into natural capital farm business performance relationships with the desired degree of statistical confidence (95%). Accordingly, our next research phase will include sampling an additional 170 farms in our existing focus regions.

Over the next 5 years, *Farming for the Future* sees the need to continue to expand our research activities to include 1,500 livestock, cropping and mixed cropping-grazing farm enterprises across all Australian states and territories to achieve these aims. This will enable us to create a dataset that is representative of the breadth of operation types and farm types, sizes, and locations across the Australian agricultural sector. In doing so it will help build a financially prosperous, climate-resilient and decarbonising agriculture sector for Australia.

Farming for the Future will continue to strengthen its network of contributors, collaborators and delivery partners across all future stages of our program.

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Natural Capital in agriculture is defined as

"the natural resources that producers manage for the benefit of their businesses, their families and for future generations of producers. Agricultural Natural Capital includes soils, water, pasturelands and croplands, riparian areas, remnant native vegetation, agroforestry and environmental plantings and animals."

1. Background

1.1 Farming for the Future program overview

Farming for the Future is a public good research and change activation program that has been established as a response to the increasing urgency for agriculture to play an active role as a nature-based solution to climate and biodiversity loss for Australia, whilst continuing to produce high quality food and fibre. The program has a bold vision to transform Australia's agriculture sector into one that empowers producers to evolve their farm businesses in ways that maintain and enhance their natural capital to build resilience and improve profitability.

A key constraint facing producers and farm advice networks is an inability to access relevant, robust and reliable information about the economic value of natural capital in farm business performance (England *et al* 2020). This has resulted in a substantial under-investment in this important factor of production.

Producers currently rely on direct observations of specific aspects of their own business, based mainly on their own direct experience, to make decisions about investment in on-farm natural capital (Paxton 2019). This strategy is necessary because relevant information about the natural capital stock on farms and its relation to farm performance has, to date, been unavailable. As a result, farm managers and farm advisory services have been seeking to manage performance in a scenario where the full set of information related to farm performance is unavailable. This clearly limits the development of effective strategies for determining optimal practice - especially in a future of unknown climate and market conditions.

Beyond farm-level concerns, the incorporation of natural capital into agricultural enterprises is needed as a matter of urgency to meet increasing market demand for the inclusion of measurable investment in environmental sustainability. Increasing awareness of the importance of natural capital as a key input into agricultural production has stimulated interest and activity in measuring natural capital in agriculture (e.g., Accounting for Nature, Land to Market, La Trobe Farm-scale Natural Capital Accounting project).

Farming for the Future differs from other natural capital programs in a number of important ways:

- First and foremost, *Farming for the Future* focuses on the private production benefits associated with on-farm natural capital. Our engagement with producers, farm advisors and key industry partners indicates that large-scale adoption of natural capital improvement in Australian farming landscapes will be driven by a desire to improve farm production, rather than access to payments via carbon credit markets or other financial incentives.
- Second, *Farming for the Future* engages with producers via the farm advisory industry. This leverages the considerable experience around farm performance improvement already existing within the industry, and develops important influence pathways to ensure adoption of our research findings.
- Third, *Farming for the Future* builds a broad network of collaborators across industry, government, academia and philanthropy. It ensures relevance through continual co-design of its research, outputs and engagement activities. In doing so it builds natural capital literacy and capacity to ensure that the Australian agriculture sector is ready to take advantage of current and emerging natural capital opportunities.

Figure 1: Farming for the Future: Building large-scale evidence for informed natural capital management.

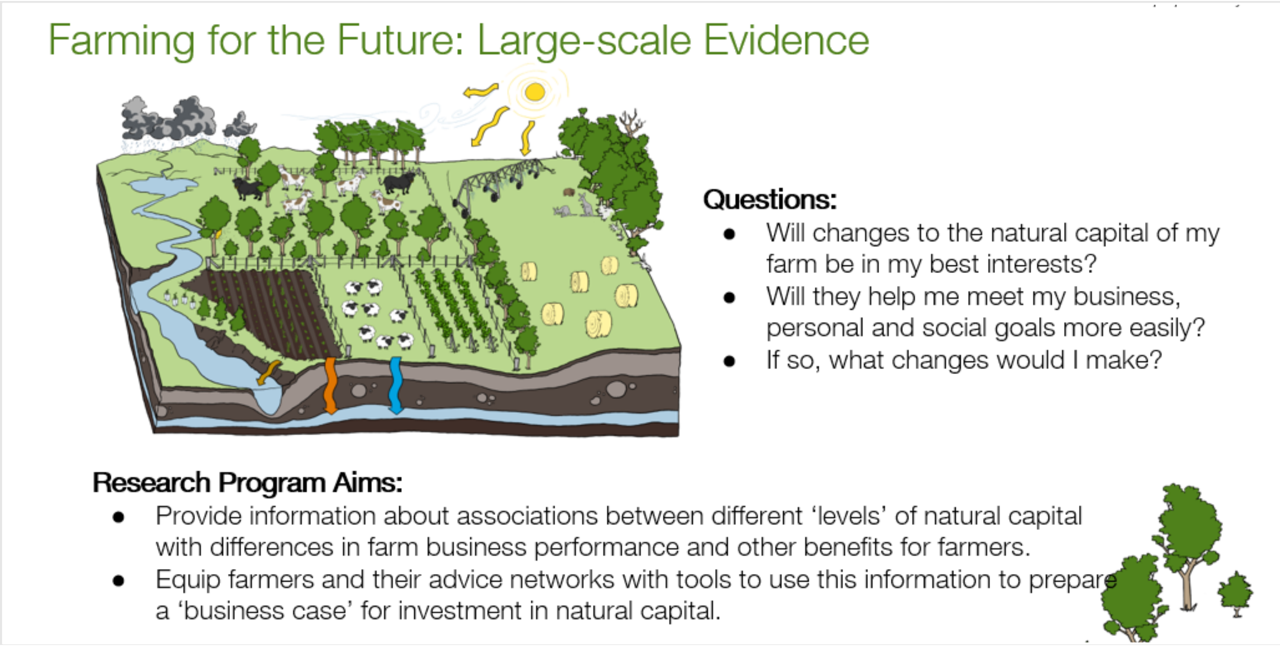
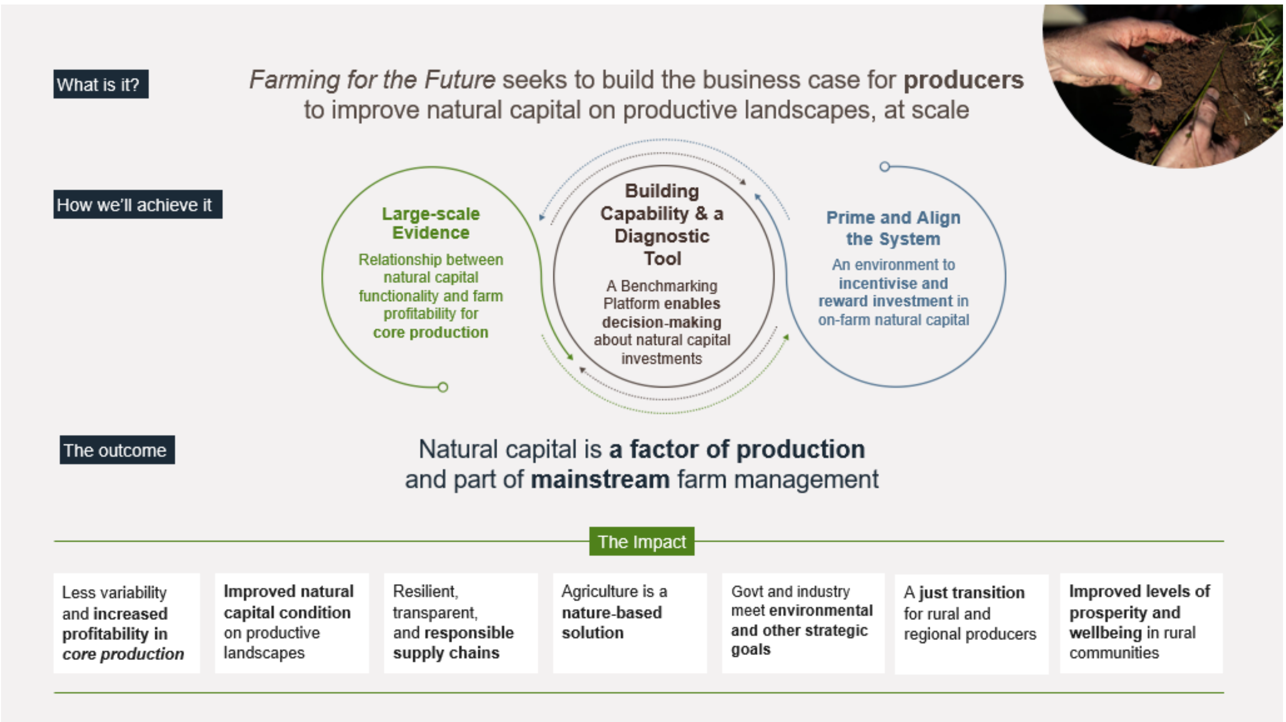


Figure 2: Farming for the Future: Enabling systems change.



1.2 A vision for Australian livestock producers

Agriculture occupies approximately 55% of the Australian land mass and contributed $93 billion in gross value and around 2.4% of Australia's GDP in 2021-22 (ABARES 2023). *Farming for the Future* seeks to provide a way for the agricultural industry to make the most of natural capital as a productive asset generating financial and other benefits for producers.

Farming for the Future believes that the financial contribution of natural capital to core farm production is large relative to the economic opportunity presented by alternative natural capital income streams like carbon and biodiversity markets (Figure 3). We believe that increasing producers' knowledge about the nature of benefits that natural capital can deliver to core farm production will help to drive large-scale industry adoption of improved natural capital management practices and enable the agriculture sector to play an active role as a nature-based solution to climate and biodiversity loss for Australia.

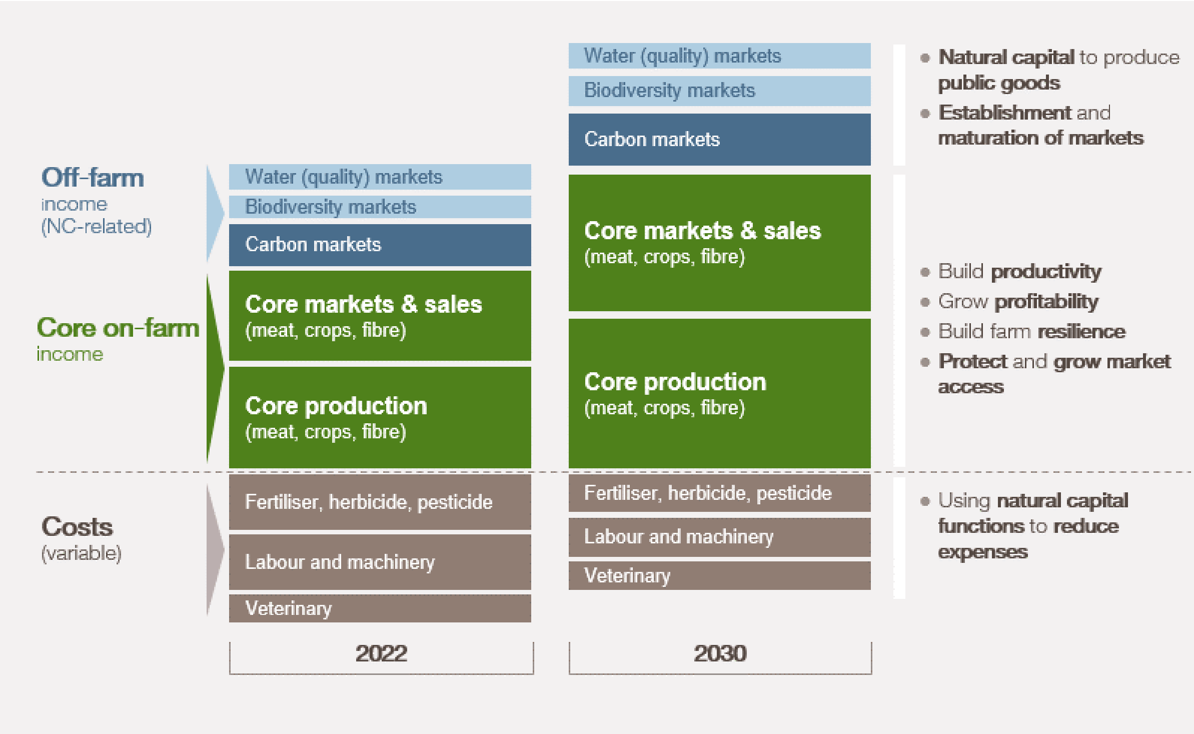
Producers already know that good management of their farm's natural resources – such as soil, water, plants and animals – is critical to the long-term viability of their operations. Yet knowledge about 'how much', 'how to', 'where', and 'when' remains largely unknown, and a more detailed understanding of the impact of increasing natural capital levels on farm enterprise performance is required. *Farming for the Future* seeks to fill this gap and to build capacity around the treatment of natural capital as an important farm asset amongst the farm advisory industry.

Farming for the Future aims to build a future where:

- Australian producers are confident of the benefits they can obtain from management of natural capital and are empowered to incorporate natural capital into everyday farm management and longer-term strategic farm planning activities.
- Australian producers are enabled, incentivised and rewarded by food and fibre companies, retailers, the financial services sector and policymakers with markets, products and contracts that help to optimise environmental and economic outcomes for farm businesses and farming families.
- Australian producers and associated supply chains can manage and mitigate drought and other climate or market risks through targeted natural capital management.
- Policymakers recognise and incentivise farm management strategies that promote biodiversity, and address climate change whilst also enabling productivity and profitability of the agricultural sector to be maintained.

Farming for the Future is helping to future-proof Australian agriculture by delivering a natural capital benchmarking module that will enable Australian farms to adapt more quickly, and more successfully, to changing climate and market conditions. Our benchmarking module will enhance peer-to-peer learning by allowing producers to access robust information about farm performance outcomes from a broader range of natural capital investment and management strategies than they would otherwise have access to.

Figure 3: Farming for the Future's vision for Australian agriculture 2030 showing the relative size of economic advantages associated with productive benefits versus other natural capital income streams.



2. Objectives

Farming for the Future is building the first national-scale evidence base that documents on-farm natural capital and its relationship to business performance on Australian farms.

We aim to embed natural capital in mainstream farm valuation and management practices by providing producers with the data, practical support, and tools needed to measure their on-farm natural capital and to manage it in ways that help build more productive, profitable, and climate-resilient businesses.

Farming for the Future seeks to:

- Understand and quantify natural capital - farm business performance relationships.
- Uncover any benefit pathways through which natural capital can provide benefits to farm businesses and farming families.
- Design, build and test a natural capital benchmarking module to support farm business decision making by providing insights about how on-farm natural capital can be managed to optimise benefits to producers and their families.
- Activate the system of supply chain, financial services, and government organisations to support producers to measure, manage and invest in natural capital as a factor of production.
- Act as a catalyst for systems change, building diverse and effective networks across industry, government, philanthropy and academia to accelerate adoption of natural capital opportunities and help build a more profitable and climate-resilient agricultural sector for current and future generations.

Table 1 summarises the project objectives and achievements. Further detail is provided in the body of the report. See Appendix 6 for a reconciliation of planned Monitoring Evaluation and Reporting (MER) activities and completion status.

Table 1: summary of project objectives and achievements.

Project objectives and outputs	Comment
1. To design, build and test processes that underpin Natural Capital Farm Benefits Benchmarking approaches as a 'toolset' of methods, concepts, and approaches to engagement/knowledge sharing around the;	
• Measurement of natural capital on farms	**Achieved:** Methods and protocols for quantifying the natural capital of farms have been developed. These are at a scale appropriate to farm management decisions and have a level of rigour appropriate to the research.
• Generation of natural capital indices that reflect the performance of farms inclusive of natural capital as a factor of production	**Achieved:** Methods for preparing natural capital indices were successfully demonstrated to enable natural capital to be analysed as a factor of production and to provide useful information about the qualities of farm natural capital.
• Approaches to enable red meat producers to seek to achieve their own objectives through investment in, and use of, natural capital.	**Achieved:** The analysis methods and presentation of outputs provide information that enables red meat producers to apply natural capital-related pathways to achieving their business and personal goals.
This toolset is expected to include documents describing data collection methods, benchmarking processes, statistical routines for analysis with the details to be revealed by the methods.	**Achieved:** Methods documentation, benchmarking processes, and statistical routines have all been developed and peer-reviewed over the course of this program. They are available on the program website and/or via farm advisors.
2. Gain support for the toolset and underpinning processes by involving farm businesses, advisors and stakeholders from the supply chain, financial services industry and state and federal government in design and development. This will be assessed by analysis of consultations in workshops and pre and post participation surveys.	**Achieved:** Expressions of support for the toolset along with useful feedback and suggestions were captured via semi-structured workshops and meetings with these stakeholders. 79% of Farm Advisors reported that they are 'certain' to participate in future phases of *Farming for the Future*. 93% of farm Advisors are 'certain' or 'almost certain' to participate in future phases.
• We expect >70% of direct participants to wish to continue contributing data to benchmarking approaches into the future	We have not surveyed farmer willingness to continue to provide data to ongoing benchmarking directly but have good indication that willingness to continue in the program is high, as reported by farm advisors, and evidenced through high response rates (>80%) to the wellbeing survey conducted as the final data collection process late in 2023.
• We aim for incorporation of additional producers into the program through leveraging other projects and stakeholders in agricultural industries in Australia	**Achieved:** More than 250 producers have lodged Expressions of Interest to the *Farming for the Future* program (in addition to those who were surveyed as part of our Livestock Pilot Program). We are also leveraging our collaborations with NRMs, grower groups and universities to access additional participants.
3. Develop and demonstrate data collection standards, protocols and tools for enabling simple and cost-effective collection of natural capital and business performance data so farm businesses can contribute to the platform and use the results. The effectiveness of these will be tested by feedback from users and by observing any data collection	**Achieved:** data collection standards, protocols and tools were successful in supporting data collection and compilation. Improvements for further efficiencies have been identified (reported separately).

Project objectives and outputs	Comment
errors that emerge as a result of issues with documentation.	
• Feedback data will be collected using follow-up short interviews with key participants and through discussions with agricultural consultants associated with data collection	**Achieved:** Feedback has been collected periodically throughout the program internally (by team members and externally (by independent consultants). Data has been collated and continues to be tracked as part of our program monitoring and evaluation process.
4. Produce initial evidence of relationships between natural capital and farm business performance using data contributed by 120 to 150 farm businesses as initial users. These will be used to test, with users and other beneficiaries of the platform its ability to demonstrate its potential to quantify natural capital benefits that are representative of grazing and mixed cropping grazing and of enterprises of different sizes. Evaluation will involve a combination of workshop and survey consultation.	**Achieved:** the initial evidence for these relationships is reported in Section 4 Results. Details on benchmarking outputs, and associated feedback from stakeholders, are provided in Section 4.3.1 and Appendix 4.
5. Produce reports or case studies on perceptions regarding principles underpinning the toolset by initial users and other stakeholders engaged in the project and by potential users and stakeholders not engaged in the project.	**Achieved:** The perceptions of stakeholders were collected via semi-structured survey mechanisms complemented by interviews and one to one feedback. Refer to Section 4.3 Project Impact. We also prepared 3 specific case studies, available in Supplementary Document H: *Farming for the Future* Case Studies.
• These data will be collected through an online survey with project participants, interviews with other stakeholders and ongoing discussions/interviews/feedback throughout the project	**Achieved:** we have conducted two types of online surveys with our participants – workshop-based surveys that collect individual feedback and also allow for group discussion, and detailed individual surveys / interviews. Data is collated and continues to be tracked as part of our program monitoring and evaluation process.
6. Pursue strategies to secure funding, project and delivery partners based on a business case for incorporation of the toolset methods into a larger scale and larger scope benchmarking program.	**Achieved:** Strategies to secure further funding are in progress. Strong support for involvement in later phases has been confirmed for farm businesses, Farm Advisory and Accountancy firms, NRM and Landcare groups, Future Drought Fund Hubs, members of the financial services industry and supply chain, and ABS.
7. Develop a description of a pathway to a long-term independent and trusted 'owner' and funding structure for a benchmarking program to continually provide producers and the broader ecosystem with insights into changes to natural capital and farm performance as these adjust to climate change and market opportunities.	**Achieved:** A commercialisation plan has been developed and is available upon request.

3. Methodology

Farming for the Future has implemented a broad range of research and change activation activities, including:

- Collection of natural capital information and farm financial information for farms across a wide range of ecological zones.
- Robust statistical analysis to quantify the relationship between natural capital and farm business performance.
- Co-design activities with farm advisors to identify and deliver information, tools and insights that can integrate with their existing products and services.
- Production of a natural capital benchmarking module to achieve adoption of new insights relating to on-farm natural capital. In its current format, this module is a clickable prototype that serves as an example of how benchmarking results could be presented to users. This module has formed the basis of ongoing co-design activities aiming to develop the specifications for a future operational benchmarking module. See Appendix 4 for additional details.
- Strengthening of networks across the philanthropic, industry, government, and academic sectors to achieve systemic and lasting change.

3.1 Conceptual Frameworks

3.1.1 What is natural capital?

Farming for the Future defines natural capital as:

"the natural resources that producers manage for the benefit of their businesses, their families and for future generations of producers. Agricultural Natural Capital includes soil, water, pasturelands and croplands, riparian areas, remnant native vegetation, agroforestry and environmental plantings and animals."

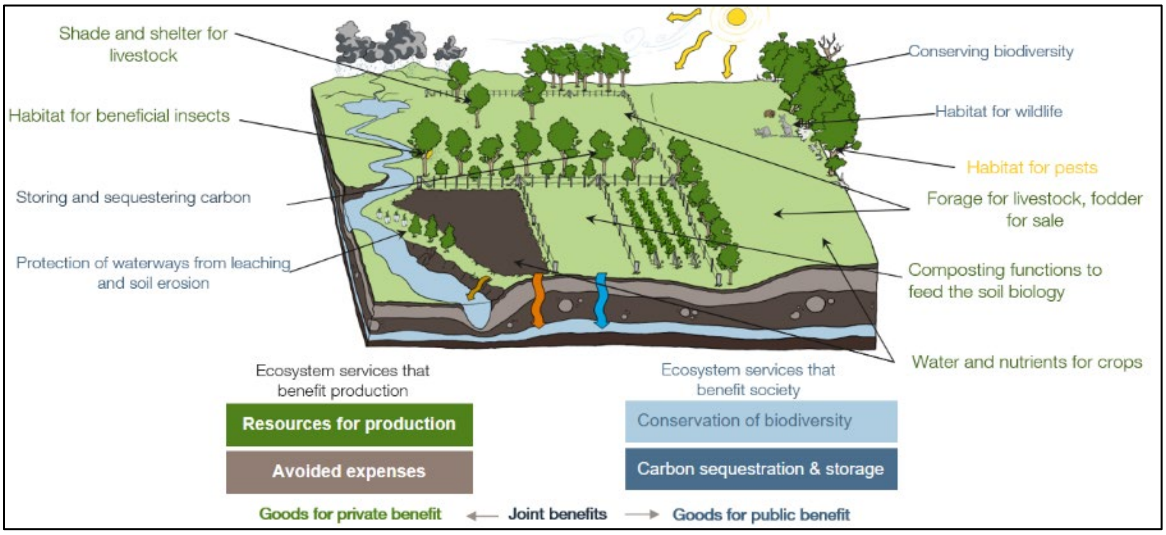
This definition does not necessarily equate natural capital explicitly or exclusively with 'nativeness' or 'distance from reference condition'. Rather, it includes all the ecosystems and ecosystem elements present on a farm, including remnant native vegetation, intensively managed croplands and pasturelands, soils, native and naturalised pastures, water resources, livestock and native fauna (Ogilvy 2015, Radford and Ogilvy 2021, Ogilvy et al. 2022, O'Brien et al. 2023).

On-farm natural capital can provide a variety of ecosystem services. These include:

- Provisioning services, for example timber, forage, and crops for harvest.
- Regulating services, for example shade and shelter for livestock and crops, regulation (regeneration) of soil and pasture quality, avoidance of soil erosion.
- Cultural services, for example landscape amenity, contribution to knowledge, preservation of culturally important species.

Some ecosystem services deliver benefits for society (e.g., carbon sequestration, biodiversity), while other services produce economic benefits for individuals or companies. *Farming for the Future* is concerned primarily with the latter group of benefits – the benefits that on-farm natural capital delivers to producers through improved productivity, profitability and / or income stability.

Figure 4: Natural capital: Inflows (and outflows) of economic benefit.



3.1.2 Natural capital – farm business performance relationships

There is broad acceptance that natural capital provides essential inputs to farming systems. Producers know that good management of their farm's natural resources – such as soil, water, plants and animals – is critical to the long-term viability of their operations. Increasingly, the scientific literature also supports the view that the extent and condition of natural resources can be related to farm performance (Mallawaarachchi and Szakiel 2007, Aisbett and Kragt 2010, Sandhu et al. 2010, O'Reagain et al. 2014, Lavorel et al. 2015, Gregg and Rolfe 2016, LaCanne and Lundgren 2018, Sherren and Carlisle 2019, Fenster et al. 2021).

Natural capital and its associated ecosystem services can provide private production benefits to producers in three ways:

- By increasing output – this implies a direct link between ecosystem processes and private benefits that arise through biophysical processes that support core farm production (e.g. pollination, improved soil water retention and/or pasture vigour or palatability, sun and wind protection, etc.)
- By reducing farm input costs – these are replaced with increased reliance on natural capital as 'free' (or lower cost) inputs from nature. (e.g. reduced need for regular pasture renewal, lower stock water requirements, reduced insect pests can reduce chemical needs, improved soil health can reduce fertiliser needs, etc.).
- By increasing resilience – Experimental investigations, case studies and applied demonstrations (e.g. England et al. 2020; Cong et al. 2014; Maseyk et al. 2022) indicate that natural capital practices, including the use of persistent, perennial, palatable forages, adaptive grazing management, cover-cropping and tree establishment, can increase drought resilience for production. Reduced reliance on volatile input markets (like those for chemical fertilisers) may also help to confer economic resilience.

However, outside of experimental settings and small studies (e.g. Star et al. 2013, Barbi et al. 2015, Rolfe and Gregg 2015, Gosnell et al. 2019, Rolfe and Star 2019) the form of the relationship between natural capital and farm performance remains unknown. Case studies related to this issue have tended to use basic indicators of natural capital, rather than comprehensive measures across a range of natural capital types (soil, water, vegetation etc.), limiting their relevance for whole-of-farm planning processes

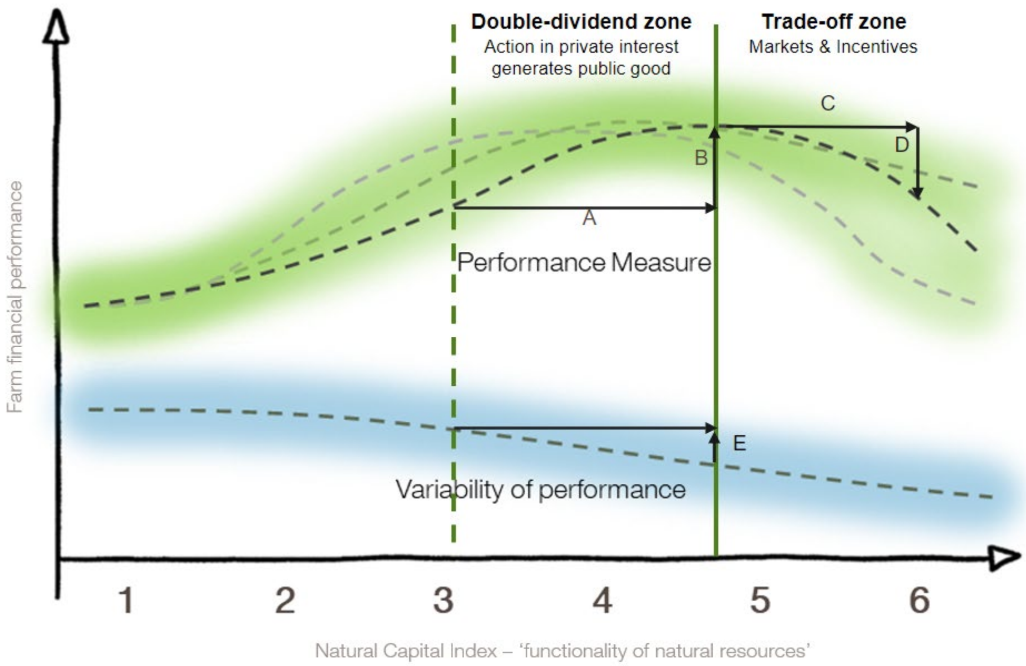
Limitations in the literature to date mean that farm managers continue to face uncertainties over target levels of natural capital, as well as the natural capital metrics and measures they should be using. Heterogeneity amongst Australian farms also means that experimental and/or case study research has limited applicability to the majority of farms in Australia – emphasising the need for research that is both 'deep' (uses detailed measures) and 'broad' (provides large-scale and targeted/relevant coverage for a large range of producers).

*Farming for the Future'*s core objective is to robustly quantify the relationship between natural capital and farm performance.

Figure 5 identifies two specific zones that represent different potential relationships between natural capital and farm business performance:

- The "double-dividend zone" – where producers can improve their on-farm natural capital (represented by Interval A) whilst also improving the financial performance of their farm business (Interval B).
- The "trade-off zone" – where improvements to on-farm natural capital (represented by Interval C) are associated with a decline in the financial performance of the farm business (Interval D).

Figure 5: An illustrative vision of the relationship between natural capital and farm business performance.



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).

Identifying the "double dividend" and "trade-off" zones is crucial for enabling:

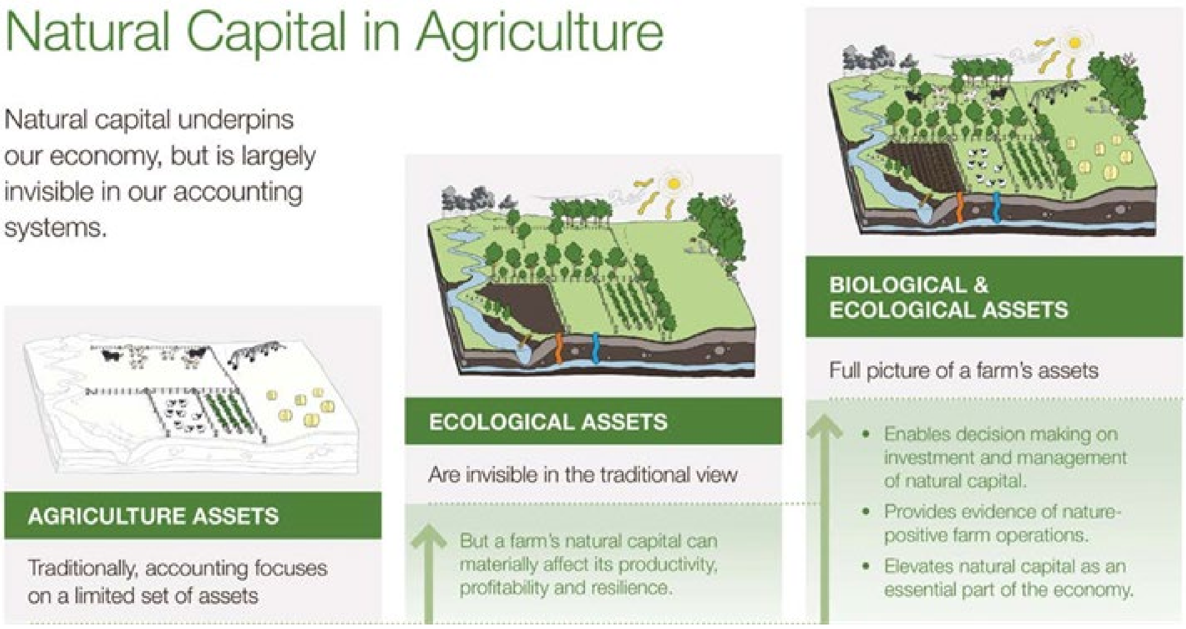
- Producers to make informed decisions about whether and how they might invest in on-farm natural capital to improve their farm performance.
- Supply chains to understand the extent to which new environmental standards might impact producers' capacity to maintain product supply and associated business outcomes.
- Banks to assess lending risk based on the natural capital condition of their agricultural portfolio, and to assist farms in mitigating climate and market related risk.
- Governments to understand the balance between the public and private benefits likely to arise from any proposed improvement to on farm natural capital, and to develop appropriate, efficient and cost-effective policy (See Section 4.3.3).

We also explore the relationship between natural capital and variability in farm financial performance – a key concern for ensuring stability of farm income and stability of supply of agricultural commodities. Insights gained will help inform the Australian agriculture sector to transition to a climate- and market- resilient future.

3.1.3 Natural capital as a factor of production

Under the United Nations System of Environmental Economic Accounting (UN SEEA) framework, it is acknowledged that ecosystem services and human factors (including labour, infrastructure and other inputs) work together to generate benefits to producers and farm businesses (O'Reagain et al. 2014, Ogilvy 2015, Gregg and Rolfe 2016, Sevenster et al. 2020, Ogilvy et al. 2022). But despite this understanding, natural capital is often treated differently to other forms of capital and is omitted from decisions about farm management and investment (Figure 6).

Figure 6: A limited versus holistic view of assets in agriculture and natural capital as a factor of production.



The history of performance management, being based on the ability to measure factors of production (and outputs/revenues), means that it has tended to focus on factors that are easy to measure: labour inputs, capital stocks, material (intermediate) inputs, revenues, land area, etc. Over time these performance models have become more complete through the inclusion of factors that are more complex to measure, often related to weather and management choices such as: rainfall levels, livestock weight, different types of labour input, growing season rainfall, and more.

However, natural capital remains a glaring omission in the consideration of farm production and farm performance. As the essential capital stock underpinning almost any land-based activity, including agriculture, it is likely that natural capital is a critical factor in agricultural production and that higher levels of natural capital may support improved farm performance. While it is possible that 'low' levels of natural capital will be optimal in supporting agricultural productivity, existing evidence suggests that this is unlikely (e.g., Mallawaarachchi & Szakiel 2007; Sandu, Wratten & Cullen 2010; Aisbett & Kragt 2010; Gregg & Rolfe 2011; O'Reagain et al. 2014; Ogilvy et al. 2018; Sherren & Calisle 2019; Gregg & Rolfe 2016; Gregg & Rolfe 2018; Fensteret al. 2021).

Decision-making in the absence of full consideration of all the factors that contribute to productivity is almost certain to lead to sub-optimal investment at both farm- and industry-scales. The omission of any important input from optimisation and/or strategic decisions will tend to lead to its overuse, because the costs of its use are not taken into account. Omission of important 'factors of production' will tend to result in:

1. The omission of natural capital from farm performance assessment is likely to result in a substantial over-estimation of farm business performance, and to incorrectly indicate inefficient farms as being efficient.
2. The omission of natural capital from farm performance assessment increases the risk of degradation of natural capital below optimal levels for long-term farm performance outcomes.
3. The omission of natural capital from farm performance assessment is likely to lead to incorrect inferences on performance improvement pathways leading to worsening actual performance over time relative to what could be achieved (and relative to countries/industries that do successfully incorporate natural capital measurement frameworks).
4. The omission of natural capital from farm performance assessment is likely to lead to lower sustainability of farm production in the medium to longer term and to greater variability (lower resilience) in farm production outcomes (see Clark 2010 and Gregg and Rolfe 2018 for a review of the dynamics of renewable resource management).

3.1.4 Benchmarking farm performance

Performance measurement is highly valued in agricultural industries. It has a long history and is associated with substantial investment and differentiation amongst advisory organisations and businesses. During 2021, Macdoch Foundation funded work to test the need for a natural capital benchmarking module to provide the evidence needed by producers, and by industry to address the issues identified above. An initial engagement program was undertaken in September 2021 via two workshops. Attendees, including farm managers, farm advisors, RDC's and other industry bodies confirmed there was substantial demand for the program and support for the approach. A summary of feedback from this engagement process is provided in Supplementary Document A: Needs analysis.

There are important differences between industry-standard performance approaches that use Key Performance Indicators (KPIs) and benchmarking methods. Both approaches have benefits and disadvantages meaning that it is important to understand the limitations and applicability of each in order to use both to their best advantage. In this program we seek to integrate formal benchmarking approaches into the farm advisory landscape, and to outline their complementarity with commonly applied KPI approaches.

3.1.4.1 Why is benchmarking important?

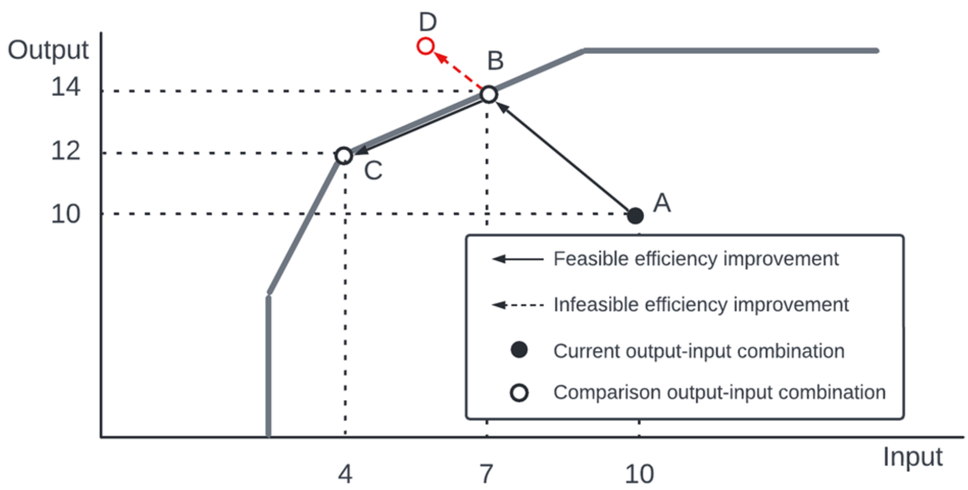
Existing agricultural performance metrics use a range of KPIs and targets to assess performance. However, these KPI approaches often require substantial contextual knowledge, and a large number of KPI assessments to generate a comprehensive assessment of enterprise performance. They also are typically not transferable between different performance assessment organisations/approaches making it difficult to benchmark farm performance at large scales.

Knowing the level of performance of a business, in terms of a score against a KPI, is, in itself, not informative. For example, knowing that a profitable business, call it 'Business A', produces 10 units of output from 10 units of input (a productivity ratio of 1) does not tell us whether this is 'good' or not: the business might be currently profitable (or not), but if its competitors are doing much better, then it is unlikely to be performing well.

The essence of benchmarking is that it compares a business's pattern of production against a relevant alternative in order to provide a comparative assessment of performance. Imagine there was a second business ('Business B') that was a similar size to business A and used the same production system. If Business B could produce 14 units of output with 7 units of input, it would have a productivity ratio of 2. The productivity ratios calculated in this example allow us to compare the relative performance of two businesses. We can conclude that Business B is twice as efficient as Business A because business B gets twice as many outputs per unit of input as business B.

Productivity scores are rated between 0 and 1. If Business B was unable to increase its output without also increasing inputs (or to decrease input without also decreasing output) we could say that B was 'Technically Efficient'. It would be assigned an efficiency score of 1. Business A's efficiency score would then be 0.5 (or 50%). This suggests that, with management changes, Business A could become twice as efficient as it currently is. These patterns are shown in Figure 7.

Figure 7: Feasible and infeasible efficiency improvements and scale efficiency changes.



As described above, benchmarking can measure business efficiency against a set of relevant peer (similar) enterprises. But we also want to know why an enterprise might be more or less efficient compared to its peers. Benchmarking seeks to provide these insights by identifying and describing pathways to improving performance based on observation of the approaches of better-performing peer enterprises. Moving back to our example, we could say that if Business A were to increase output and reduce inputs to the point B shown in Figure 7 it would be fully Technically Efficient under its current production system.

Benchmarking can also be used to investigate the relative merits of changing business size or production mode. For example, even though Business B has a score of 1 for its Technical Efficiency, it could still improve its performance – for example, by changing its scale of production. By moving to point C in Figure 7, Business B will experience a reduction in inputs of 3 units, which is greater than the reduction in associated outputs (2 units). It will then have a productivity ratio of 3). In this example, both ‘B’ and ‘C’ are Technically Efficient. Point C is also ‘Scale Efficient’ because it has optimised the scale of its operations. This latter point also shows that businesses may perform better with lower intensity or scale of operation – a point that is often overlooked in agricultural performance discussions.

Benchmarking can be used to measure and compare different types of efficiency. These include:

- Technical efficiency: A technically efficient enterprise is one that cannot reduce inputs without also reducing output or that cannot increase output without also needing to increase inputs. Technically inefficient firms can do one or both of these. Technical efficiency is measured on a percentage scale – we can state whether an enterprise is 100% efficient or how inefficient it is in percentage terms. This percentage measure of inefficiency is a direct reflection of either how much percent that enterprise can reduce inputs or, alternatively, increase outputs.
- Allocative efficiency: An allocatively efficient enterprise is one that has the ‘mix’ of inputs and/or outputs best organised to reduce costs and/or maximise revenue. Compared to technical efficiency, allocative efficiency uses price information to reflect on whether an enterprise is minimising cost/maximising revenue, regardless of whether they are technically efficient.
- Scale efficiency: A scale efficient enterprise has the appropriate ‘size’ to maximise their overall productivity. Scale-efficient enterprises are also technically efficient but achieve greater overall productivity compared to scale inefficient enterprises through making better use of the overall combination of inputs they use.

3.1.4.2 What is Data Envelopment Analysis (DEA) Benchmarking?

DEA Benchmarking is the most common method of benchmarking. Originating in both the economic and organisational management research disciplines, DEA benchmarking has provided a basis for robust performance comparisons and associated insights for over four decades. It remains the core method for performance analysis at organisational (i.e. farm business), regional (e.g. state or region), industry (e.g. livestock) and national levels.

DEA benchmarking is highly technical but as it is such a well-established long-standing methodology, it has a substantial body of methods, tools, and insights that are easily applied to deliver performance insights, even for those who do not seek to understand its full technical detail.

3.1.4.3 Communicating performance levels from DEA

DEA benchmarking outputs are complementary to commonly used farm KPIs for several reasons. Some key benefits of DEA benchmarking methods compared to KPIs include:

1. They provide for a natural and robust performance comparison basis that is comprehensive. This compares to KPIs that typically differ across the industry and that target specific parts of the business. So, where KPIs provide insights into specific parts of the enterprise, DEA benchmarking approaches provide an overview of the full enterprise performance outcomes.
2. Properly-specified DEA benchmarking analyses are unbiased and do not rely on contextual knowledge. This compares to KPIs that, due their partial focus, tend to be biased and so rely on the substantial contextual knowledge of industry experts in order to act as appropriate tools for improving management. This means DEA benchmarking methods can add value to KPI approaches as overall measures of farm performance and as mechanisms to 'calibrate' KPIs into the future.
3. DEA benchmarking methods provide for a clear ranking of enterprises in terms of their efficiency scores, and efficiency scores provide a quantitative measure of potential for improvement. This compares to KPI measures that rely on the choices and expertise of industry experts in order to generate farm performance rankings and to move from performance measures to potential improvement outcome measures. This means DEA benchmarking methods can act as key 'yardstick' measures of the potential outcomes of enterprise performance improvements in ways that are easily understood and can be incorporated into investment/business analysis tools.

This natural interpretation of DEA performance measures means that it is highly useful as a communication tool. For example, a farm business that is shown to be 80% technically efficient has the potential to increase output by 20% without increasing any inputs or, alternatively, to decrease inputs by 20% without decreasing output through better management. In contrast, a 100% technically efficient farm business is performing as well as any other that it is compared against. Similarly, a farm business that has 90% allocative efficiency can improve farm profits by 10% by simply changing their mix of inputs or outputs. These types of comparison are obvious, intuitive, and are based on a comprehensive measure of farm performance, one that is inclusive of all relevant inputs/outputs (at least the ones we know about). Even though these efficiency scores are simple, as shown above, DEA benchmarking has the potential to dive deeply into the sources of enterprise inefficiency, and into potential pathways to improved performance.

Table 2: Key insights provided by DEA efficiency and benchmarking methods.

Key insight	Description
Performance is measured as efficiency	DEA benchmarking analyses produce a performance score that can be interpreted as efficiency/inefficiency. For Technical Efficiency measures, the efficiency score has a direct interpretation as the percentage reduction in all inputs that can be achieved while keeping outputs at the current levels, or the percentage increase in outputs that can be achieved while keeping inputs at the current levels.
Efficiency is measured relative to comparisons against peers	Performance in DEA benchmarking is measured against similar 'decision making units' (DMUs). DMUs are the focal point of management performance – they can be whole farm businesses, basic farm enterprises (e.g. the livestock enterprise or the cropping enterprise) or even regions/industries when comparisons are being made at a larger scale. This means that comparisons are 'real' in nature and do not rely on hypothetical comparisons against modelled expectations or pre-specified targets. Similar DMUs are designated as 'peers' and act as yardsticks for performance – i.e. a DMU acts as a peer when they provide information on how another DMU can improve performance.
Peers are other 'similar' organisations	Comparisons against 'peers' means that DEA benchmarking analysis is meant to provide for comparisons between similar DMUs. Specifically, it means that DEA benchmarking analysis should be used for different DMUs that can achieve similar outcomes given the current state of their business/organisation. Comparisons against these 'peers' means that efficiency calculations are 'fair' in the sense that each enterprise ranked in an analysis would have the chance to operate at a fully technically efficient level if they were to change the inputs/outputs that they have control over.
Efficiency is traditionally a ratio measure	As with many KPIs, DEA benchmarking efficiency measures use a ratio measure to depict performance. This can be most easily understood as the aggregate amount of output produced divided by the aggregate inputs used to produce that output. This level of 'productivity' is then compared to other enterprises in the sample and scaled accordingly to a value between 0 (completely inefficient) to 1 (fully technically efficient, cost efficient or scale efficient depending on the focus).
Different metrics are possible	The ratio measure of efficiency means that we consider productivity instead of production, and profitability instead of profit. However, with some methods of DEA benchmarking we can refer to the amount that profit itself can be increased from increased efficiency achievements. For example, DEA may be used to measure efficiency in terms of gross margin, EBIT or other financial performance metrics.
Efficiency focuses on factors that are under the control of management	The focus of DEA benchmarking is on defining performance with respect to factors under the control of the DMU. Environmental and other variables are characteristics that are not under the control of management are often called 'fixed' factors because they are unable to be changed by the DMU. Rainfall is an important fixed factor in DEA that compares farm performance.

Key insight	Description
	‘Fixed’ factors can be dealt with in two ways. They can be used to define different groups of producers (sets of peers). There are also types of DEA analyses that account for the influence of these fixed factors as covariates during their comparison of DMUs.
Organisations/ enterprises are given the best possible efficiency score for their performance relative to similar others	In the vast majority of DEA analyses DEA, benchmarking gives a ‘benefit of the doubt’ view of organisation efficiency – it seeks to provide the best possible efficiency score for each organisation given the other firms in the sample. “This means that the inefficiencies noted would tend to understate the actual inefficiencies that may be present. [...] This bias makes this a tool that managers can use with confidence. When a DEA analysis is determined to be complete in terms of using appropriate inputs and outputs, it offers paths to achieve real improvements in performance. The amount of the improvements that are technically available would be at least as great as the amount identified with DEA”. Sherman and Zhu (2006, p66)
DEA can compare outcomes from different modes of production	There are approaches in which we conduct multiple DEA benchmarking analyses that allow us to compare the performance between groups. These approaches provide for peer comparisons whilst also allowing considering of how different systems of production perform relative to others.

More details on the *Farming for the Future* benchmarking methods please see Supplementary Document B: *DRAFT FftF_Nat-Cap-Productivity_Working-Paper_Aug2023*. A complete list of supplementary documents is provided in Appendix 5.

3.1.5 Creating systems change

Farming for the Future’s research consortium comprises a robust network of producers, farm advisors, NRM professionals, academics and industry professionals. All are leaders in their field, and collectively they span the breadth of roles that are required to build the evidence-base for natural capital practices and achieve systemic and lasting change.

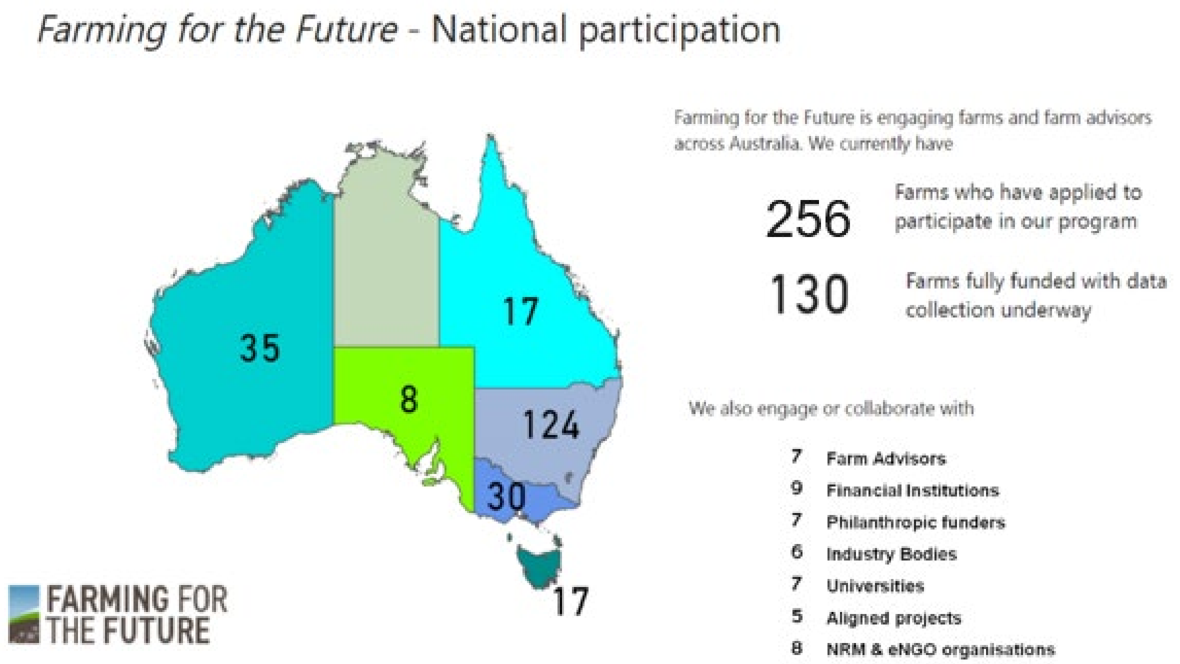
Our research consortium was purposefully designed to deliver meaningful and lasting behaviour change via the ADKAR – (Awareness, Desire, Knowledge, Ability, Reinforcement) model: a change management model applied by organisational leaders and change management professionals worldwide (Prosci 2019):

1. **Awareness / Desire:** Eight farm advisory services deliver engagement activities. Advisors incorporate natural capital into their existing drought-planning, training, investment and other advisory services to increase *awareness* of how natural capital can support farm performance. A focus on the economic benefits natural capital delivers to farm businesses helps build *desire and motivation* for change.
2. **Knowledge / Ability:** In addition to the advisory businesses, our broad network includes Bush Heritage Australia and other NRMs with expertise across the country so advice can be tailored

to the relevant local context to ensure producers have the *knowledge* and *ability* to improve on-farm natural capital.

3. **Reinforcement:** *Farming for the Future* is supported by academics (La Trobe University, CSIRO) and key industry bodies (National Farmers Federation, Meat & Livestock Australia and Australian Wool Innovation). This will *reinforce* the ongoing benefits of change via high-level communications that help shift industry norms.

Figure 8: Engaging for systems change.



3.2 Data collection

3.2.1 Farm selection

To achieve the goals of the research program, *Farming for the Future* sought to establish sample populations of farms that were:

- Reasonably alike (matched) in operational aspects (size, operation type) and in the same agri-ecological zone (climate, soil type, elevation etc).
- Different (separated) in 'natural capital' characteristics, particularly in the 'amounts' of natural capital present on the farm.

To ensure farms were reasonably alike, we set the following farm selection criteria:

- Farms must be 600 – 5000 ha in size.
- Farms must have at least 50% livestock production by size.
- Livestock production should be sheep and/or cattle operations.

We limited sampling to 13 sampling areas, which were subsequently pooled into three regions ("Central and Tablelands", "South-east" and "Western") based on underlying similarity in rainfall, temperature and soil type variables (as indicated by Koppen Class classifications). Summary statistics for each of these regions is provided in Appendix 1.

We sought to include a variety of farms that range from intensively managed, more heavily modified farms that have fewer trees remaining, to lower intensity farms that have been less modified and have more tree cover and native vegetation remaining (Figure 9). We did not include any financial performance criteria in our farm selection process, as this was hypothesised to be an outcome arising from farm management and associated natural capital condition (i.e. the dependent variable in our statistical analyses). Approximately half of our surveyed farms were identified via *Farming for the Future*'s network of farm advisors, and half were identified via our online expression of interest process (see EOI link here). Descriptive statistics for our farm sample are presented, by region, in Table 3.

This farm selection approach was based on statistical requirements. It helped minimise the risk of identifying spurious (non-causal) correlations when comparing farm business performance across farms with different levels of natural capital, whilst also ensuring that our sample was representative of the range of farm businesses present within the Australian livestock sector (within our focus regions) so that the results of our study can be robustly and reliably scaled up to investigate industry-scale trends and outcomes from natural capital management. The extent to which our farms are representative of the full population farms in each of our focus regions is explored further in the Supplementary Document C: *FftF sample balance_M1 report 04072023-final*.

Figure 9: Overview of sampling strategy. Farms were selected on the basis that they are in the same agri-ecological zone, they have a similar operational type, and are in the farm size range, but have different amounts of natural capital when measured on the 'Natural Capital Grid' that considers input intensification and tree cover.

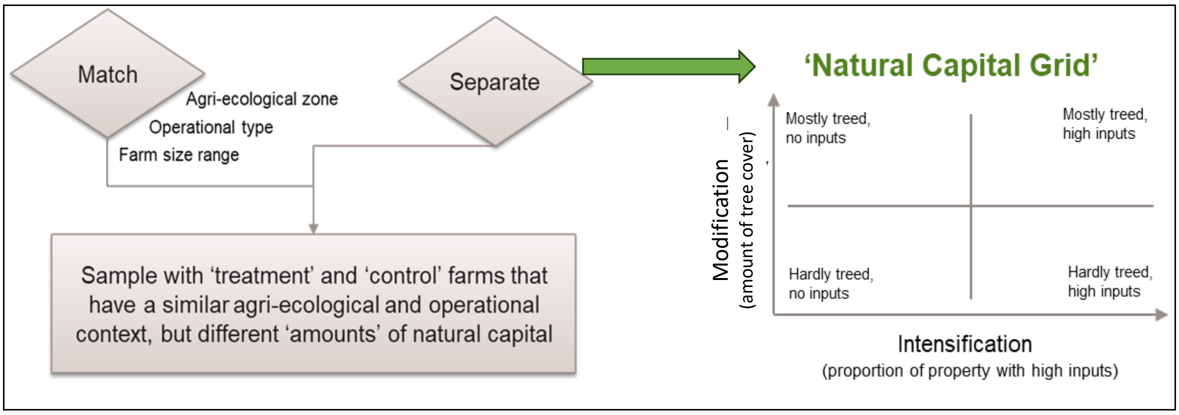


Figure 10: Map showing Farming for the Future focus regions. Our 13 sample regions have been consolidated into 3 agri-climatic regions for ease of analysis and interpretation.

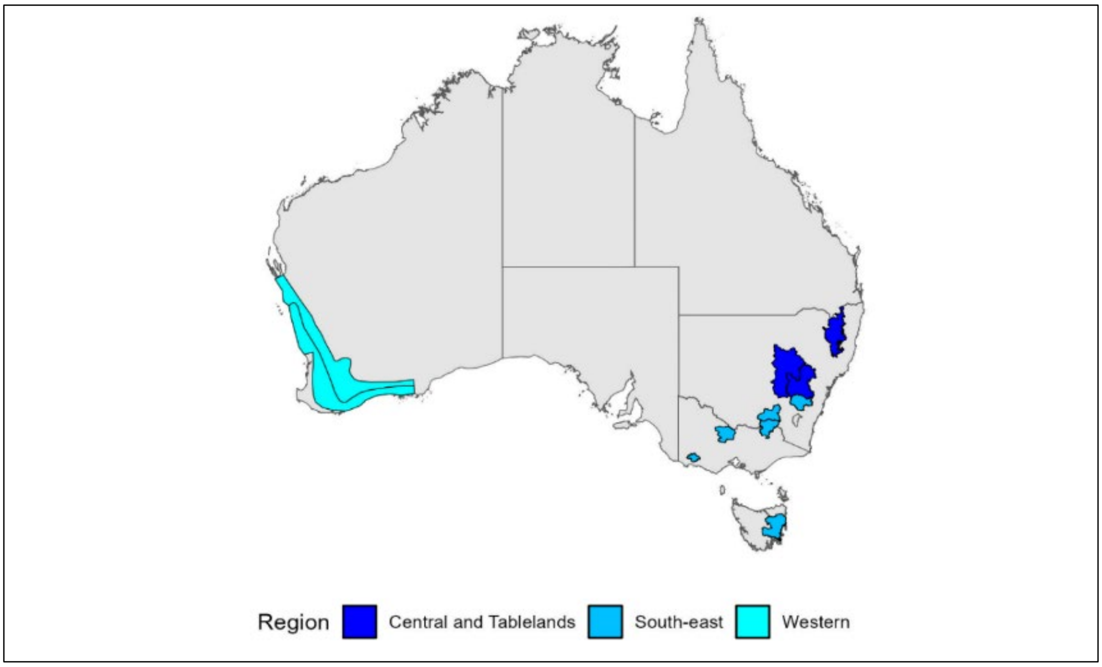


Table 3: Descriptive statistics of our farm sample, by study region

		Central and Tablelands			South East region			Western region		
Variable	**Units**	**mean**	**median**	**sd**	**mean**	**median**	**sd**	**mean**	**median**	**sd**
Farm area	Ha	2046	1761	1189	1921	1824	1177	2749	2699	1548
Livestock area	Ha	1812	1595	1113	1553	1246	977	1426	1303	1027
Cropping area	Ha	134	0	347	195	0	416	945	478	1081
Av. annual rainfall	mm	702	713	139	619	588	114	388	369	91
Days 5 – 30 degrees	no	310	313	32	322	328	25	276	258	33
days >30 degrees	no	53	49	34	40	35	27	90	108	33
Average min. temp	deg C	6	5	1	4	5	2	8	8	1
Average max. temp	deg C	25	25	2	23	24	2	29	29	2
Stock	DSE	7640	6750	4129	11084	9614	7756	5300	4308	3467
Stocking rate	DSE/ha	4.9	4.8	2.7	7.3	6.2	4.0	5.0	3.5	3.5
Sheep stock	DSE	3521	3170	3570	7474	5482	6317	3206	2332	3682
Sheep stocking rate	DSE/ha	3.1	2.9	2.7	6.0	5.2	3.8	5.0	3.2	4.1
Cattle stock	DSE	4119	3518	3948	3610	1056	6018	2094	0	3334
Cattle stocking rate	DSE/ha	2.9	2.3	2.4	2.4	1.0	2.9	3.0	2.2	2.5

3.2.2 Measuring natural capital

Farming for the Future captured and recorded high quality, fine scale natural capital data from 130 farms using a combination of remote sensing technology and field data gathered by expert field ecologists. The overarching data collection process is summarised below. Full details are provided on the *Farming for the Future* website at Natural Capital Methods Paper – Farming for the Future.

1. *Mapping and Remote Assessment:*
   - Participating producers provided farm boundary information, which was converted to a digital map using GIS software. All paddock fences were digitised[33] to generate farm management units (paddocks).
   - Each management unit was assigned an ‘ecosystem type’ classification based on remotely sensed information relating to canopy cover, 5-year minimum ground cover metrics and historic vegetation class.
   - Management data was provided by producers for each paddock including any tree plantings, current crop rotations, fertiliser history, and areas excluded from production (e.g., riparian areas).
   - The farm was divided into ecosystem units (EU) based on similarity in underlying ecosystem type data and farm management information.

2. *Field observations:*
   - A representative stratified sampling strategy using approximately 30 representative assessment points across all the different types of ecosystem states was prepared.
   - A qualified ecologist performed field observations at each of 30 farm assessment points applying the detailed data collection protocol provided.

- Data collection included parameters relating to vegetation extent, type and configuration, as well as ground cover. Data and photographs were curated in iAuditor for compilation into a State & Transition (S&T) model and forage condition classifications used for the project.

3. Compile asset register

- The farm stratification and the site assessment scores were used to impute (assign by inference) both the Ecological condition and Forage condition scores to the remainder of the farm's EU to compile the Ecosystem Asset Register (EAR).

4. *Generate indices and summary tables*

- The EAR, compiled with the combination of remotely sensed information and field observations, was used to generate Ecological Condition and Forage Condition and summary tables of the extent of each type of ecosystem at each condition classification in the S&T model and of each forage condition category. Other natural capital indices were generated using remotely sensed information.

The high-level process for the natural capital data collection process is shown in Figure 11 and Figure 12. Additional details of the data collection process, including State & Transition models, are provided in the Supplementary Document D: *Natural Capital Data Collection Methods Master DRAFT v0.2.*

Figure 11: High-level process for collection and compilation of natural capital data for the Farming for the Future program.

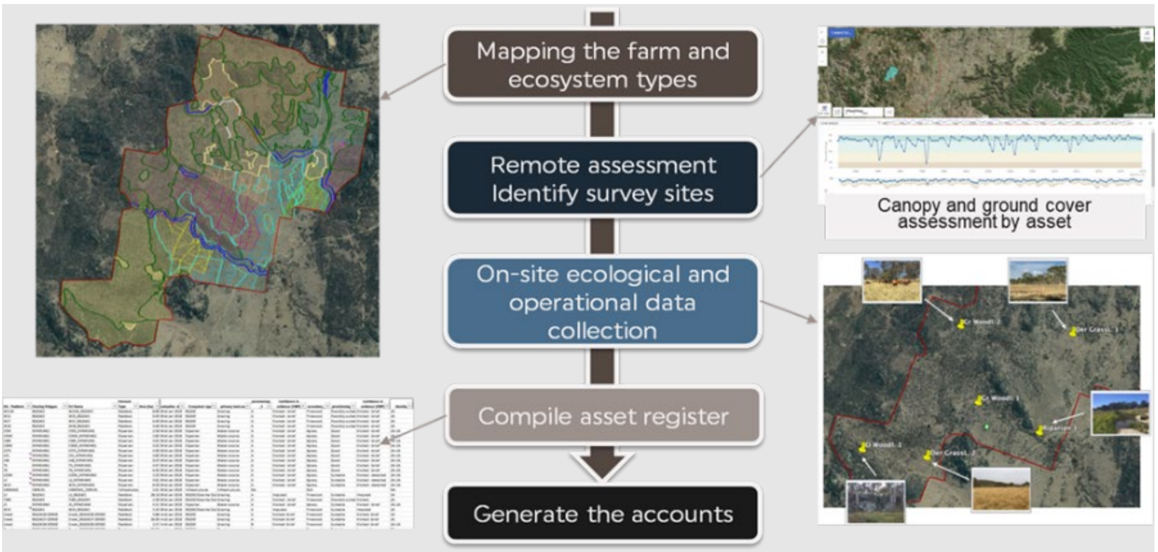
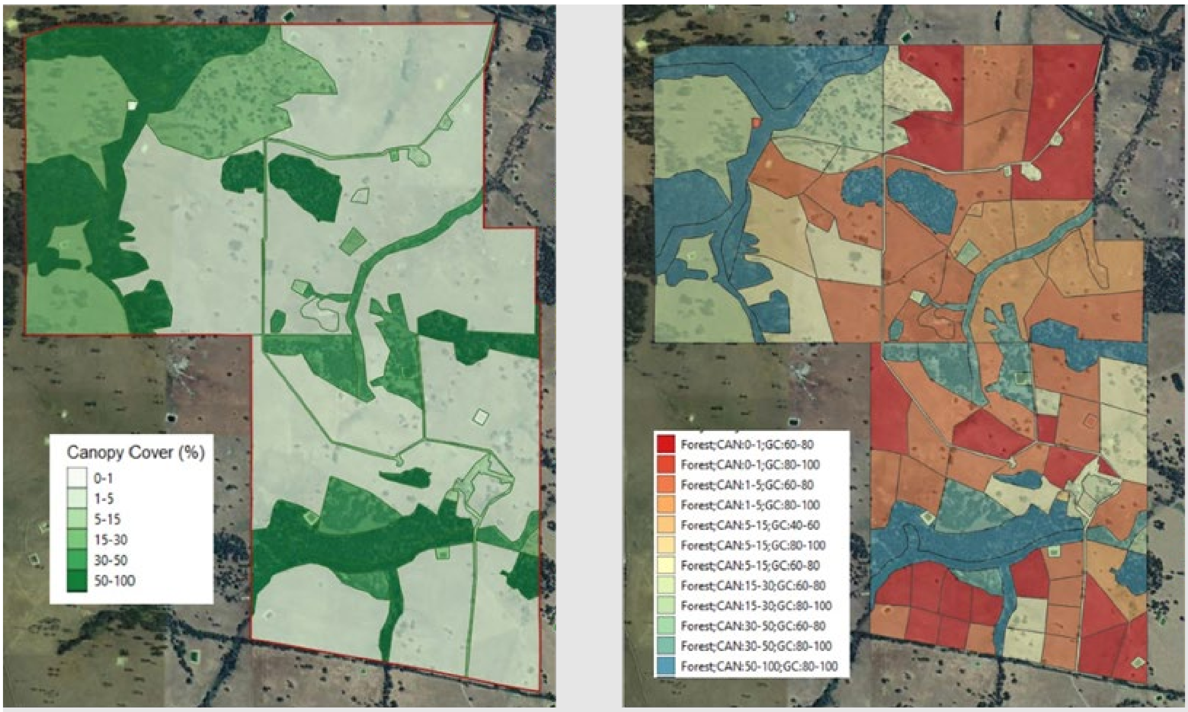


Figure 12: Example of A) ecological overlay with canopy classification and B) combined classification of ecosystem units for a farm.

A B



3.2.3 Generating natural capital indices

To enable the analysis of relationships between farm natural capital and farm business performance, *Farming for the Future* has developed indices of on-farm natural capital. These indices represent the capacity of on-farm natural capital to generate ecosystem services that are inputs to agricultural production.

Six principles guide the definition of these indices:

P1: Natural capital indices should be based on scientifically justified principles that relate measured indicators to a stock of natural capital.

P2: Natural capital indices should not report on social, economic, or farm management actions in order to avoid circularity in measurement. Natural capital indices should represent biophysical properties, not whether a management practice has been applied (or not applied, or poorly applied).

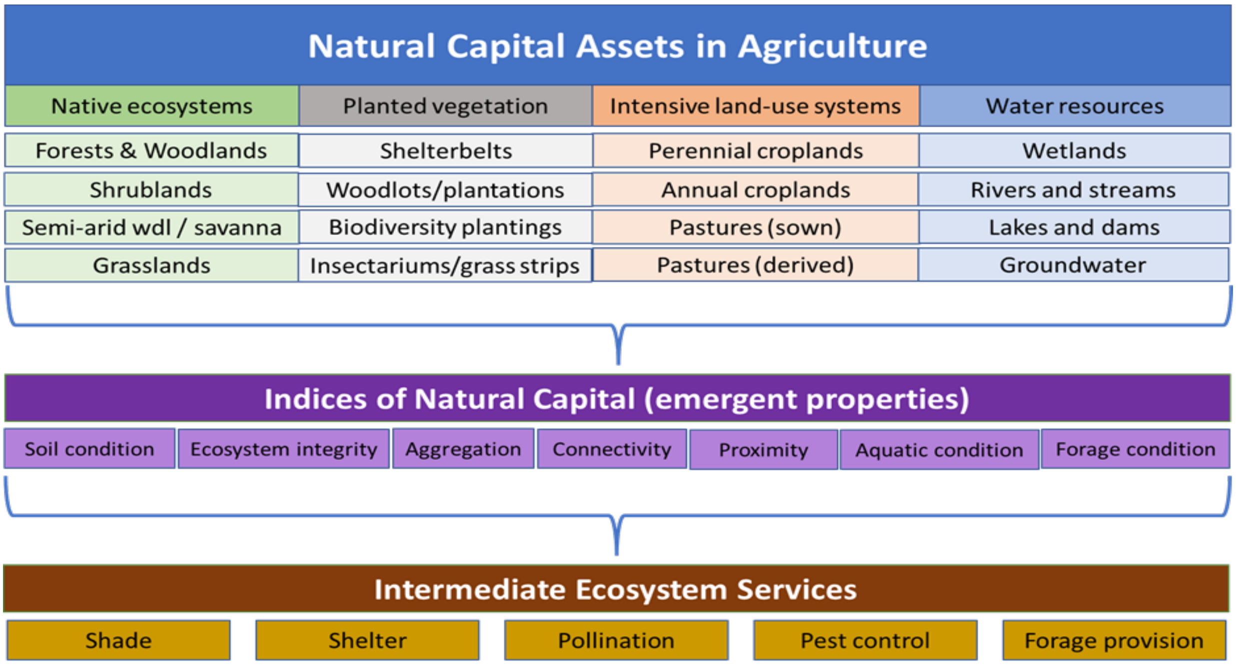
P3: Natural capital indices should represent the capacity of ecosystem assets (individually or collectively) to provide ecosystem services or intermediate ecosystem services.

P4: Natural capital indices should be independent from the performance measures (output metrics)that are plotted on the y-axis of graphs showing natural capital – farm performance relationships.

P5: Natural capital indices should measure components of the environment that are relevant to management decisions (i.e., they should be 'actionable' through management decisions).

P6: Natural capital indices should be generated from data drawn from natural capital accounts of a farm combined with remote sensing data or other publicly available derived datasets.

Figure 13: Relationship between natural capital assets on a farm, the indices of natural capital that represent emergent properties (purple shading) and the intermediate ecosystem services generated by natural capital (brown shading).



We used a set of seven indices that were defined to capture the emergent properties (structure and function) of natural capital assets that represent a range of intermediate ecosystem services at the farm scale (Figure 13). Collectively, these indices describe the capacity of the farm's natural capital to provide inputs to production and benefits to society beyond the farm gate. The seven natural capital indices are described in Table 4.

Table 4: Seven indices used to rate different elements of on-farm natural capital.

Index	Description
NC1 Ecological Condition	An important aspect of natural capital is the degree of modification of a particular parcel of land from its 'natural' or 'reference' condition. For example, a grassy woodland that retains its tree canopy layer, shrub layer and a high proportion of native grasses and forbs in the ground layer has been modified substantially less (and therefore has higher ecological condition) than a grassy woodland that has had its tree canopy cleared, and the native ground layer replaced with introduced grasses. Ecological condition will influence the extent to which a parcel of land contributes to the flow of virtually all ecosystem services but is particularly relevant to Supporting and Cultural ecosystem services, such as habitat for species (biodiversity) and maintenance of genetic diversity.
NC2 Aggregation	Aggregation is the extent to which a particular land cover type is arranged into larger, contiguous patches or distributed across smaller, discrete patches. Here, we are interested in the aggregation of wooded vegetation (e.g., forest,

Index	Description
	woodland, shrubland) that may be native or exotic, planted or remnant vegetation. The aggregation of wooded vegetation across the farm will influence the capacity of that vegetation to provide a range of ecosystem services. From a biodiversity perspective, aggregation is probably the second most important aspect of landscape configuration (after extent/amount of different land cover types) (Fahrig 2013; Gustafson 2019). Farms with more aggregated wooded vegetation will likely provide more biodiversity services than farms with an equivalent amount of wooded vegetation that is less aggregated. More aggregated wooded vegetation may also be more efficient for provision of some regulating services, such as mitigation of extreme (climate) events.
NC3 Aquatic condition	Water quality (i.e., purity, amount) is difficult to measure directly from remote sources and may be disproportionately influenced by external (off-farm) inputs (e.g. sediment loads from upstream, runoff from neighbouring properties). While multiple factors contribute to water quality, such as ground cover (see NC6) and chemical inputs (e.g., fertilisers, pesticides), the extent to which natural and artificial water bodies are fringed by vegetation plays a critical role in water quality. Moreover, riparian (streamside) vegetation is disproportionately important in agricultural landscapes, providing refuge and habitat for species (Bennett et al. 2014), filtering surface flows for regulation of water flow and provision of freshwater (downstream), and capturing carbon for sequestration and storage (as riparian areas are in more productive areas, they capture and store more carbon than surrounding areas).
NC4 Connectivity	Landscape connectivity is the degree to which the landscape facilitates or impedes movement of organisms among resource patches (Taylor et al., 1993). Landscape connectivity can be decomposed into two elements: structural connectivity (the physical arrangement of land cover types in the landscape) and functional connectivity (how individual organisms interact with and are affected by landscape structure and composition to determine their ability to move through the landscape). Functional connectivity is organism-specific so the search for a generic metric of functional connectivity that adequately represent movement abilities across the full spectrum of life has proven both challenging and elusive. Our measure is a measure of Landscape connectivity.
NC5 Forage Condition	Provision of forage for livestock is a key input to production on grazing farms. Areas on a farm used for grazing often have different historical land-use, management inputs and contemporary livestock management, leading to variation in composition and cover of pasture species which in turn influences forage quality (i.e., nutritional benefit for livestock), quantity (i.e., biomass) and dependability.
NC6 Ground cover	The physical, chemical and biological properties of soil determine its capacity to store and supply soil-water, substrate and nutrients for multiple natural capital assets: native ecosystems, planted vegetation and particularly, intensive land-use

Index	Description
	systems, including crops and pastures. We use groundcover as a proxy for soil condition.
NC7 Proximity	Proximity captures the average distance of all production areas on the farm to wooded vegetation (native and exotic, planted and remnant). This metric will influence the likelihood and quality of some regulating ecosystem services received by production areas. For example, to receive micro-climate regulation benefits (e.g., shade, wind-reduction), the production land must be relatively close to wooded vegetation. Similarly, the extent of pollination and pest-suppression services delivered by beneficial invertebrates will be influenced the proximity of production areas to natural habitat (in combination with NC6: Ground cover).

Although we measured NC3 Aquatic condition, this was relevant to only a small subset of farms that had rivers or creeks within their farm boundary. Given the small sample size, this indicator was excluded from subsequent analyses.

Further details about the conceptual framing and generation of these indices are available in the Supplementary Document E: *Natural Capital Indices_V0.5*.

3.2.4 Livestock enterprise data

Farming for the Future partnered with producers and their advisors and accountants to collect financial, operational, production, and social and behavioural data for 130 farms included in our Livestock Pilot Program sample. Our farm financial surveys collected close to 800 raw business and production variables for each participating farm. Calculations, sums, weighted sums and other functions were applied to produce 70 aggregate variables ready for analysis. After cleaning and inspection, we found data relating to 113 farms to be complete and suitable for analysis.

We undertook consultation with farm advisors to explore the types of financial and production data they would find most useful, and most compatible with their farm accounting and advisory functions (Advisor co-design workshop #3 – see Section 3.2.5). As a result of this consultation process, our analyses focussed on the key business performance metrics presented in Table 5.

Table 5: Metrics used to assess and report on livestock enterprise performance.

METRIC	DEFINITION / RATIONALE	UNIT
Production efficiency	A comparative measure of how much output is produced from the inputs used; maximum score in the dataset = 1	Index (0 to 1)
Gross margin	A measure of variable profit (not including fixed costs) for a particular activity, enterprise, or business.	$/ha
EBIT	Livestock enterprise earnings (revenue minus variable costs) before interest and tax	$/ha
Resilience	Stability of earnings (EBIT) relative to climate or market shocks (rainfall, input prices, output prices or terms of trade).	Variance

Each of the indicators identified in Table 5 can be expressed in a variety of ways using different units as the basis of calculation and comparison (for example, they may be expressed per DSE, per ha, and/or per ha/100mm rainfall). Each of these different units is relevant in different contexts, and *Farming for the Future* will provide farm advisors with the flexibility to explore different indicators for different purposes. For the purposes of this report, however, we analyse and report all indicator in the units specified in Table 5. Underlying rainfall inputs are also accounted for in our efficiency calculations (see Section 3.3.2).

Our engagement with farm advisors identified a desire that reporting include detailed information about the types of on-farm natural capital management actions employed by the farms in our dataset, so that links between management actions, natural capital condition and farm business performance could be explored. We have identified and reported on 12 natural capital management activities, as presented in Table 6.

Table 6: Indicators of farm management

	Label	Indicator	Unit
1	LIVESTOCK AREA	Proportion of farm under livestock production	%
2	CANOPY	Proportion of farm area under canopy	%
3	CONSERVATION	Proportion of farm area where vegetation has been set aside explicitly for conservation purposes	%
4	SHELTERBELTS	Proportion of the farm area planted to shelterbelts	%
5	SOWN PERENNIALS	Proportion of pasture area with perennials (ecosystem state classified as DG5, DG5(i), MG5, MG5(i)) *	%
6	SOWN ANNUALS	Proportion of livestock area sown with annuals (ecosystem state classified as DG6, DG6(i), MG6, MG6(i)) *	%
7	NATURALISED PASTURE	Proportion of livestock area with native or naturalised pasture (ecosystem state other than those described for sown perennials and sown annuals above)	%
8	CHEMICAL INTENSITY	Aggregate quantity of chemicals used in the livestock enterprise over the calendar year, per ha. This is calculated across all chemical inputs based on a price-weighted quantity aggregate.	Tonnes/ha
9	STOCKING RATE	Cattle and sheep	DSE/ha
10	STOCKING VARIABILITY	Variance in mean annual stocking rate over the 5-year time series included in our analysis	%
11	LIVESTOCK FENCING	Length of fencing per ha of livestock production	m/ha
12	PADDOCK COUNT	Number of paddocks per DSE of stock	No/DSE

* full ecosystem state classification schema can be found here

3.2.5 Co-designing activities for relevance and adoption

Farming for the Future designed and delivered a series of targeted co-design workshops and activities with producers and other stakeholders (farm advisors, NRMs, policymakers) to determine how natural capital information should be presented in order for the benefits of natural capital to farm business performance to be clear and compelling.

Initial co-design sessions focused on testing the focus of the project on production, the concepts of natural capital used in the project and the definitions of data. Insights from the sessions were captured using Slido (www.slido.com).

The insights gained from these sessions were used to create a 'clickable prototype' to explore the required functionality of the proposed natural capital benchmarking module. The clickable prototype' is a device commonly used in product development as an action-learning approach to requirements definition. In *Farming for the Future*, the prototype was built using Figma (www.figma.com). Producers and advisors were given an opportunity to 'click around' to explore the proposed display of the research findings and encouraged to provide feedback about what was missing or not useful for them. Focus points and feedback was captured with Useberry (www.useberry.com), a no-code platform designed for user experience testing.

Timing, attendance, objectives and outcomes from sessions are outlined in Table 7 and Table 8 below.

Table 7: Farm Advisor and Accountant & NRM organisation co-design and consultation sessions

Dates	Attendance	Objective	Key messages	Take-away for co-design
21/11/2022	FftF research team and advisor data collection partners. Advisors unable to attend at the scheduled time were followed up independently.	To uncover issues or concerns about quantifying how natural capital contributes to farm business performance.	Sampling designed to include otherwise similar farms with differences in natural capital. Business data definitions designed to capture productivity and avoid price effects. Natural capital data definitions include all agricultural ecosystem types and field observations for accuracy and credibility.	Good levels of support for the design and data definitions. Recommendations to involve the producers in a similar workshop to gain their confidence and support their participation in the project.
28/04/2023	FftF research team and advisor data collection partners. Advisors unable to attend at the scheduled time were followed up separately.	To review the 'clickable prototype' of the natural capital benchmarking module.	It is important to understand preferences for using the findings and the information that is necessary to make the findings actionable.	The first draft 'clickable prototype' was fit for purpose and well-accepted by farm advisors. A second design was not required.

16/08/2023 17/08/2023	FftF research team and advisor data collection partners. Advisors attended one of two workshop options.	To review potential metrics for Y axis of natural capital curves and explore utility / desirability of each option	Different metrics are used for different purposes and will be important to different clients in different settings.	5 metrics retained for display with final curves.

Table 8: Producer participant / producer co-design and consultation sessions

Dates	Attendance	Objective	Key messages	Take-away for co-design
15/12/2022 07/02/2023 13/02/2023	FftF research team and landholders participating in the project. Estimated engagement of 40% of participating landholders.	To support landholder engagement in the project. To uncover issues or concerns about quantifying out natural capital contributes to farm business performance.	Natural Capital is a fancy term for the resources producers already manage to meet your business and personal goals. FftF is seeking to understand how natural capital supports producers to meet business and personal goals.	Good levels of support for project overall, its focus on farm business performance and on the design and definition of natural capital. Curiosity about how natural capital is measured and valued is high. Outputs should be designed to provide information about quantities that is intuitive.

In addition to direct engagement of farm participants and their advisory networks (farm advisors, accountants and NRM organisations), *Farming for the Future* engaged a Research Adoption and Advisory Committee (RAAC) composed of natural capital/ecological expertise (ANU, CSIRO), industry insights (MLA, AWI, NSW DPI), agricultural statistics (ABS), and a leading producer. Chaired by NFF, the RAAC provided important feedback and insights with regard to the design of the project and the use of the findings. Feedback from RAAC members about the project design and execution have been significantly positive and the insights that emerged from questions and suggestions arising from their experience in other projects was invaluable in guiding the approach to generating actionable insights for the industry.

3.3 Data analysis

Data Envelopment Analysis (DEA) was used to assess the relationship between natural capital and farm performance. A brief guide to benchmarking using DEA was provided in Section 3.1.4. Here we provide further,technical detail on how analysis is structured according to farm enterprise, and on the implementation of DEA methods.

3.3.1 Enterprise separation

A farm ‘enterprise’, in the context of farm management and optimisation, refers to a specific farming system within an overall farm business. For example, ‘broadacre cropping’ is one common farm enterprise, as is ‘livestock, sheep’ and ‘livestock, cattle’. Farming systems are typically separated for the purposes of analysis in order to ensure that farm performance assessment is based on the activities a farm undertakes, and to account for common management approaches wherein an enterprise can supply inputs to another farm enterprise or where farm enterprises share land area at different points in time.

Much of the extant research on the relationships between natural environmental assets/services and farm performance use whole-of-farm data. Yet farms, even those within the same agri-ecological zones, can choose drastically different farming systems. It is common, for example, for farms in the same region to vary in terms of the types of enterprises they incorporate, the relative importance of those enterprises, and overarching management choices like intensity of production. This means that there can be significant differences in farm management that are important to capture at the enterprise level. These may be missed if analysis only considers the whole-of-farm as a single management unit.

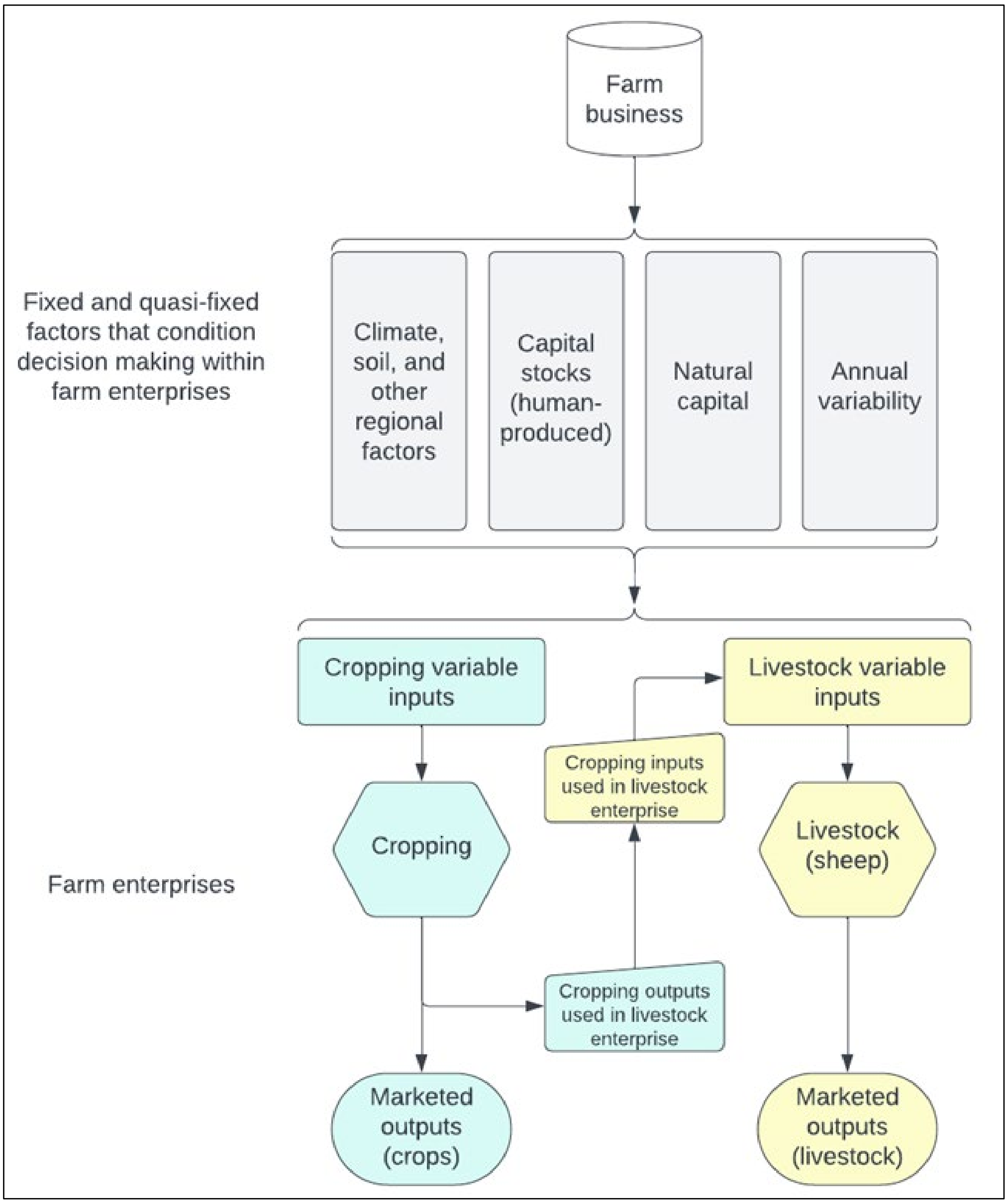
Farming for the Future data collation and analysis activities use an explicit enterprise-based separation framework. Given the focus on red meat production our initial analysis highlights livestock enterprise activities and performance.

We describe two constituent efficiencies and an overall efficiency score for each farm in our dataset. These are:

1. Within Efficiency: How efficient a farm is relative to others in a sub-group of similar farms. This is equal to 1 for the ‘frontier’, or best-performing, farms in the sub-group.
2. Between Efficiency: This is how efficient the ‘best’ farms in a sub-group are compared to the ‘best’ farms in the most efficient sub-group. This is equal to 1 for the group that is most efficient.
3. Overall Efficiency: This is how efficient a farm is overall. It is equal to the within-efficiency score multiplied by the between-efficiency score. This is equal to 1 for the ‘frontier’, or most efficient, farms in the whole *Farming for the Future* sample.

These are reported to producers (via farm advisors) in the individual farm benchmark reports produced by *Farming for the Future*. An example report is provided in Supplementary Document F: *Farm Benchmarking Report (html)*.

Figure 14: A hypothetical depiction of the enterprise-based approach to considering farm enterprise performance used in Farming for the Future.



3.3.2 Key assumptions chosen for DEA analysis used in *Farming for the Future*

Table 9 provides an overview of the core choices made in the application of DEA to farms included in the *Farming for the Future* program.

Table 9: Assumptions included in Farming for the Future DEA analyses.

Modelling choice	**Description**
Variable Returns to Scale (VRS)	Variable Returns to Scale (VRS) is one of the more flexible choices that can be made for a production model. VRS allows for efficiency to be based on different scales of production. It allows for a stronger 'benefit of the doubt' in calculated efficiency levels by allowing for farms to be compared to production possibilities that are close to their current scale of operation rather than to the most optimally scaled farm under the more restrictive (but also common) specification of Constant Returns to Scale (CRS).
Output oriented efficiency scores	An output orientation for efficiency scores rather than an input orientation or directional (analyst-selected) orientation. This choice is less important than for VRS but is strongly related to it. An output orientation was chosen for the pilot toolset to reflect a decision-making focus on production maximisation that was reported to us by producers over the course of our study and based on advice from statistical reviewers. In the future, models may be estimated under both orientations. Directional orientations are special cases that are used to answer specific research questions or organisational objectives. One use case commonly applied in the literature is the use of directional orientations to incorporate environmental pollutants into DEA. Another allows for the incorporation of non-market inputs into DEA alongside priced inputs when the analyst has information on the 'shadow' (unobserved) prices of the non-market input. All of these are potentially of interest from a research perspective for *Farming for the Future* but are not viable currently as mechanisms for explorations of farm performance by farm managers and farm advisors.
Fixed inputs included as fixed factors	Fixed factors of production are those that are chosen by the manager only in the long run (over many years in the case of farming systems). This means that they should be included in benchmarking performance analysis as *contextual* but not *management* factors (consistent with our use of annual observations of farm production). We include fixed factors of production as fixed inputs to ensure that the contextual environment of production is properly accounted for, ensuring that fixed factors are not treated as short-term management variables.
Uncontrollable inputs not treated as management inputs	A key focus of DEA benchmarking is to inform organisational management of performance improvement pathways. As a result, it is critical that both: 1. Contextual factors are incorporated so as not to present unattainable outcomes as being attainable 2. Contextual factors *that are not under the control of management* are not treated as if they are 'management variables'. To this end, we follow best practice in incorporating factors that are not under the control of management as fixed factors of production. This places them outside of the 'optimisation control function' of managers but retains those as contextual factors that constrain production possibilities. Examples include rainfall, temperature, number of days over 30 degrees, and region.

3.3.3 Model estimation

Table 10We used DEA to assess production efficiency across all of the 113 livestock enterprises for which appropriate data was available. Our use of DEA was jointly informed by objectives within the project to utilise well-known economic models of performance and through discussions with farm advisors to utilise performance outcomes that reflected notions of performance widely understood within the red meat industry. Accordingly, we parameterised our DEA as specified in Table 10.

Table 10: Models parameters used to estimate production efficiency.

Model element	Description of parameters
Outputs	Liveweight sold (for cattle and sheep: kg) Closing stock (liveweight for cattle and sheep: kg) Wool sold (kg)
Inputs	Liveweight purchased (for cattle and sheep: kg) Opening stock (liveweight for cattle and sheep: kg) Labour (weeks, FTE) Chemicals (tonnes) Health costs ($) Contractor costs ($) Energy ($) Fodder (tonnes) Irrigation water (ML) Livestock area (ha)
Uncontrolled factors	Average annual rainfall (mm) Monthly rainfall variability (relative variance) Days 5 – 30 degrees (number per year) Days >30 degrees (number per year) Mean elevation (m)

3.3.4 Natural capital and farm performance

The key output of DEA benchmarking analyses are efficiency scores. These indicate the extent to which an enterprise (or organisation) has achieved the greatest potential efficiency of production based on its current production technology and other, uncontrollable, factors it faces. Efficiency scores were used as the basis for considering the relationship between natural capital and farm performance because:

- Compared to normal KPI measures (e.g. EBIT/DSE/mm) efficiency measures are *comprehensive* in that they already account for inputs used by the enterprise and contextual factors the enterprise is facing.
- Efficiency measures have a clear interpretation as 'more is better' where KPIs depend on contextual information to indicate negative, neutral and positive outcomes.
- Efficiency measures are univariate and so can be easily represented on a graph against a natural capital indicator whilst still conveying a comprehensive performance outcome.

Natural capital – livestock enterprise performance relationships were explored individually for each of our natural capital indices, although we note that these are often interdependent in the landscape and so are likely to be correlated. More complex composite indices that take in a broader range of natural capital measures will be developed in future phases of the program (see Section 6.1).

The relationship between natural capital and farm performance was considered using:

1. Cluster analysis based on the farm management variables identified in Table 6, which enabled us to simplify and account for the large amount of variability within the Australian broadacre farming sector. Cluster analysis increases our confidence in any links between natural capital and farm business performance identified because it ensures that we are comparing outcomes from farms that have different natural capital levels, but which are similar in all other aspects. By analysing trends in business performance associated with increasing levels of natural capital within each cluster, we have sought to understand whether and how different farms might benefit from improved natural capital, irrespective of their current production mode or starting point. Additional industry-level insights may be gained by comparing performance across clusters, but this is a much larger question with important implications for production trade-offs (for example between farm size, stocking rates and production efficiency) at the industry-scale. We would require larger sample sizes than are currently available to robustly address these important issues.

2. Testing for statistical significance of relationships between natural capital indices and financial performance metrics using Generalised Additive Modelling (GAM) using the Mgcv package in r. This approach allows simultaneous testing of the statistical significance of regression relationships and the extent to which they are linear versus non-linear in nature. It also allowed us to account for other key factors that might influence natural capital – livestock enterprise performance relationships (rainfall, number of days over 30 degrees, farm size and sampling region – similar to the uncontrolled factors included in the DEA analysis).

   The GAM technique is susceptible to the influence of outliers. Given that our primary objective in this current study is to understand the shape of the relationships between natural capital and farm business performance, we have removed outliers (any point more than 2 standard deviations from the mean). This has some implications for the interpretation of our analysis:

   - It increases confidence in the shape of the observed relationships between natural capital and farm business performance as we can be certain these are not driven by outliers.
   - It narrows the range of natural capital scores and efficiencies assessed. Because efficiency scores have a maximum of 1, and most farms are close to the frontier (a feature of DEAs in the agriculture sector), this means that lower efficiency outliers have been removed, leaving the most efficient farms in our set. This has some advantages in that it ensures we are comparing outcomes from the most capable (efficient) producers in our sample, so observed outcomes are less likely to be influenced by differences in producer education or experience levels. But it also means that the size of any observed difference in farm business outcomes for high versus low natural capital farms is likely to minimised (as it is measured across a smaller range).

Our analytical approach has been peer reviewed by respected agricultural economists. Details of these reviews. Additional details on GAM modelling are provided in Appendix 1. A high-level summary of peer-review feedback is presented in Appendix 2.

3.4 Modelling landholder adoption

3.4.1 Understanding landholder motivations

Landholders may invest in natural capital for many different reasons, including personal environmental values, aesthetic values, a desire to participate in markets or ESG supply chains, or an ambition to build farm profitability and resilience.

Recent policy to encourage investment in on-farm natural capital in Australia has either sought to leverage landholders' own environmental values, or to encourage participation in formal market schemes. Both approaches have significant limitations. In the case of policies that rely on producers' existing environmental values, investment does little to achieve *additional* natural capital improvement beyond what the producer would have been likely to implement in the absence of a policy or incentive ('limited additionality'). In the case of market-based incentive schemes that are administered by government, participation rates remain low despite a long (and expensive) history of implementation and engagement activity ('limited uptake').

Motivating and accelerating behaviour change *at scale* requires good alignment between producers' motivations and the support / information / interventions that governments, NGOs, industry bodies and others provide. Given the dynamic nature of emerging opportunities in on-farm natural capital (which include credit markets, price premiums, ESG supply chains etc.) we felt it prudent to evaluate this suite of potential drivers of behaviour change to compare the degree to which they can motivate producers to improve natural capital management.

We conducted a survey of 60 producers during online landholder workshops, asking them to rank a list of potential motivators in terms of how compelling they found each on for investing in their on-farm natural capital. Results were used to inform program design, as well as estimates of landholder adoption, as described in the following section.

3.4.1 Background to the ADOPT model

The ADOPT model is a CSIRO model that collates the best available Australian and international evidence and is supported by extensive academic research. Access to the ADOPT model is at Home – CSIRO ADOPT.

The ADOPT tool incorporates a very broad range of factors known to affect landholder uptake of new natural resource management initiatives, including factors relating to the landholder population (e.g. demographics, profit versus environmental orientation, connectedness to industry and community, financial constraints, capacity) as well as the initiative to be implemented (e.g. cost, nature of costs, visibility of impacts, potential for large scale demonstration and many others). High levels of uptake are projected to occur when a specific policy or innovation is well-matched with the preferences of the target landholder group.

Ground-truthing of the ADOPT model shows excellent model performance across a number of natural resource management initiatives that have been introduced to the Australian agricultural sector, including no-till cropping systems in the south Australian wheatbelt and use of salt bush as a forage shrub on low rain fall stock farms.

3.4.2 Application of the ADOPT model to *Farming for the Future*

We have used the ADOPT model to forecast the impact of *Farming for the Future* on the adoption of on-farm natural capital management and investment innovations.

We acknowledge that there is increasing interest in natural capital amongst producers, industry bodies and governments around Australia, and that some baseline level of adoption of natural capital management and investment innovations would occur even without *Farming for the Future*. We model our baseline – i.e. likely future investment in on-farm natural capital in the absence of *Farming for the Future* – based on current regulatory settings and funded government policies that are scheduled to be implemented over the coming 5-7 years to match the time horizon used in this analysis.

We modelled the impact of *Farming for the Future* based on the program's ability to deliver adoption of on-farm natural capital management beyond the baseline level. Increased adoption comes from five aspects of *Farming for the Future*:

- Exposition of the financial benefits associated with improved on farm natural capital, which expands the program's reach beyond producers who wish to improve natural capital for personal or environmental reasons, to also include producers who are interested in investment for the purposes of improved financial performance.
- Administering *Farming for the Future* through farm advisors provides increased ease and convenience and reduces innovation complexity for producers wishing to invest in their natural capital.
- Providing a benchmarking tool to enhance peer-to-peer learning improves the 'trialability' and 'observability' of the outcomes of natural capital management and investment.
- Producers retain autonomy over decision-making. They are not required to lock in any contract or set aside land in perpetuity to participate in *Farming for the Future* and gain access to the associated benefits. The natural capital investment decisions they make are reversible.
- Upfront costs and associated risk to the producer are reduced through *Farming for the Future* funding of farm surveys and preparation of natural capital accounts.

Input parameters used to model baseline and program outcomes are provided in Table 11. Estimates of uptake have been made separately for 4 different types of landholders based on a landholder typology developed for NSW landholders from ABS and primary research data (Kirby 2020). These have been collated based on the relative distribution of these 4 landholder types within the farming population.

Table 11: Scoring used for ADOPT parameters in baseline and program impact modelling. Parameters that vary for baseline vs. FFTF are highlighted in red. For a description of score definitions, visit Home – CSIRO ADOPT

Program attribute	Baseline	FFTF	Comment
Relative upfront cost of project	4	3	Lower score = lower upfront cost
Reversibility of the innovation	3	4	Higher score = more reversible
Profit benefit in years used	2	2	
Future profit benefit	4	4	
Time to future profit realised	4	4	
Environmental costs & benefits	4	4	
Time to environmental benefit	4	4	
Risk exposure	2	1	Higher score = higher risk
Ease and convenience	3	4	Higher score = greater ease / convenience
Trialability	4	5	Higher score = increased trialability
Innovation complexity	3	2	Higher score = higher complexity
Observability	3	5	Higher score = higher observability

4. Results

4.1 Producer motivations to invest in natural capital

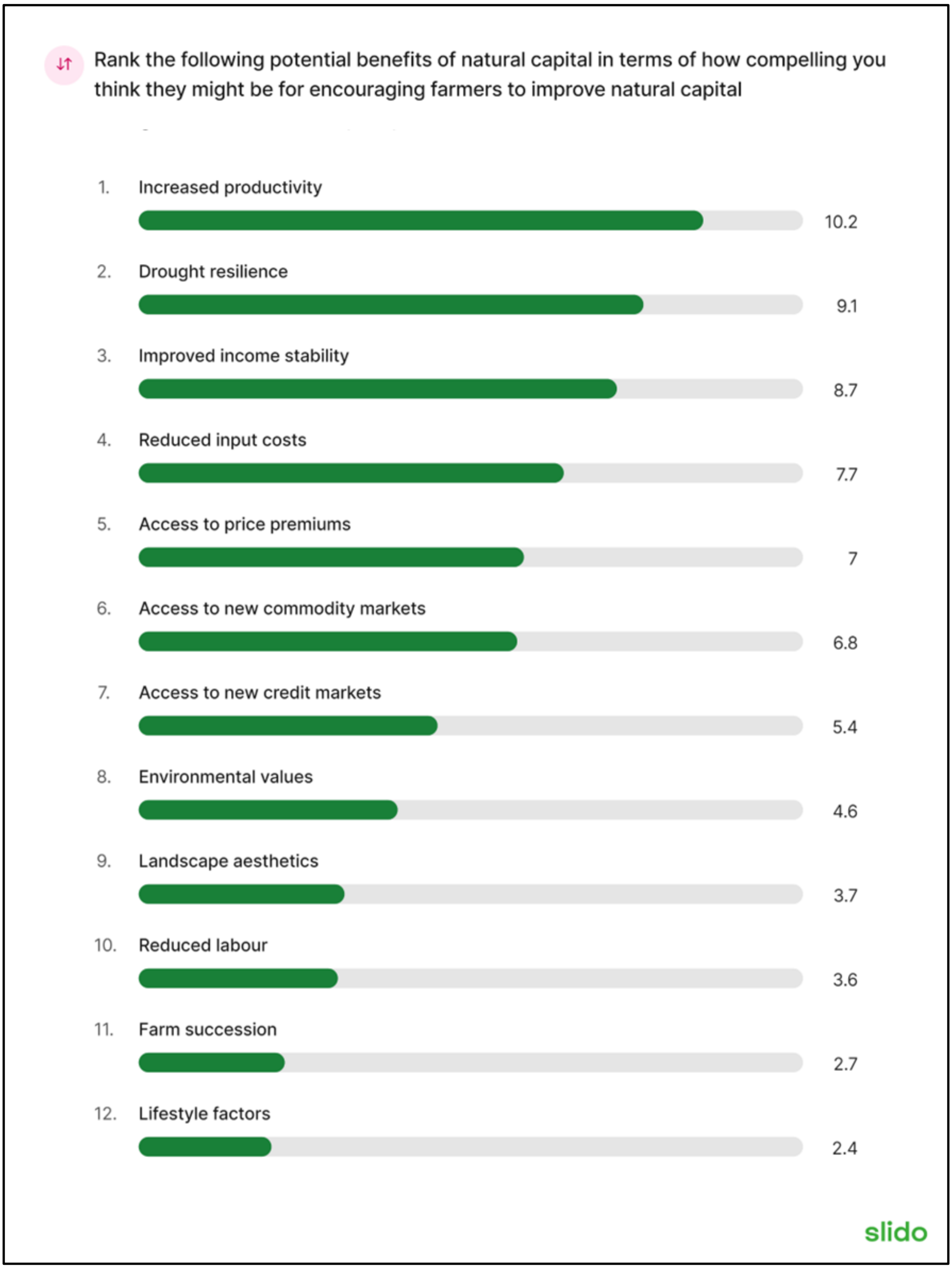
Natural capital can offer a range of services and benefits to producers. The extent to which different interventions or policies can be effective in achieving broad-scale practice change in the agricultural sector will depend on their ability to influence producer behaviour.

Our producer survey results found that private production benefits are the most compelling reason for encouraging improved management of on-farm natural capital (Figure 16). Producers were also compelled by the potential for natural capital to help improve resilience during times of drought. This is consistent with observations in the literature that economic returns and weather-related risks are key factors in producers' decisions to adopt new management practices (He et al. 2022 citing Li et al., 2017; Meier et al., 2020a; Meier et al., 2017; Nash et al., 2013, Lam et al., 2013).

Our results indicated that many of the market mechanisms most often championed for agricultural management change are a poor match with landholder preferences. This includes ecosystem service credit markets. Although these are currently the focus of government investment and policy development, they ranked 7th out of 12 potential motivators. This raises opportunities for more efficient public investment to accelerate producer uptake of improved on-farm natural capital management and help move Australian agriculture towards a climate resilient future.

Figure 15: Producer responses relating to the types of benefits and services that on-farm natural capital provides (unprompted open response using Slido.com).

Figure 16: Results of landholder survey regarding motivations to invest in on-farm natural capital (n=60).



4.2 Natural capital – livestock enterprise performance relationships

4.2.1 Revealing the curve: natural capital and livestock enterprise efficiency

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'. The marginal effect[1] of natural capital on livestock enterprise efficiency is presented in Figure 17 and discussed further below.

We used Generalised Additive Modelling (GAM) to assess the relationship between natural capital and livestock enterprise efficiency. GAM is a non-linear modelling technique that enabled us to test whether the observed natural capital - production efficiency relationships were linear (straighter trendline) or curvilinear (curved trendline that indicate threshold or other non-linear relationships) (Table 12). It also allowed us to test for the statistical significance of the observed natural capital – production efficiency relationships.

GAM identified statistically significant relationships between production efficiency and three of our natural capital indices: Ecological condition, Proximity and Ground cover (Table 12). Proximity and Ground cover showed a positive relationship with natural capital across the full range of natural capital scores recorded within our farm set, demonstrating linear (straight line) correlations with production efficiency (edf[2]=1, Table 12). This suggests that farms with higher ground cover achieved higher levels of productivity over our study period. It also suggests that ecosystem services provided by on-farm vegetation may be greater when vegetation is near enough to production areas to influence the production process.

Ecological condition had a significant curvilinear trend line; and Aggregation had a non significant curvilinear trend (edf ~2, Table 12). We would describe the relationships observed for Ecological condition and Aggregation as 'trade-off thresholds', whereby the relationship between natural capital and production efficiency is positive at low natural capital scores, but negative at higher natural capital scores beyond a specific threshold (Ecological condition scores >0.4 and Aggregation scores>0.15).

For the remaining two natural capital indicators (Connectivity and Forage condition) no statistically significant effect was observed. This is likely to relate to the sample size used in this pilot stage of our program (see Section 4.2.6).

Our comparison of input costs (Figure 18) suggests that farms with higher production efficiencies have lower input costs across certain of the cost types examined (contractors, energy, fodder, and, to a lesser extent, labour). We suggest that natural capital may support production efficiency by replacing / substituting for some of these inputs. This is consistent with treatment of natural capital as a 'factor of production'. It is also likely to have a positive secondary effect on farm profitability and resilience, as 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. The impacts of natural capital on livestock enterprise profitability and resilience are explored further in Section 4.2.4 and Section 4.2.5 respectively. Our comparison of farm characteristics (Figure 19)

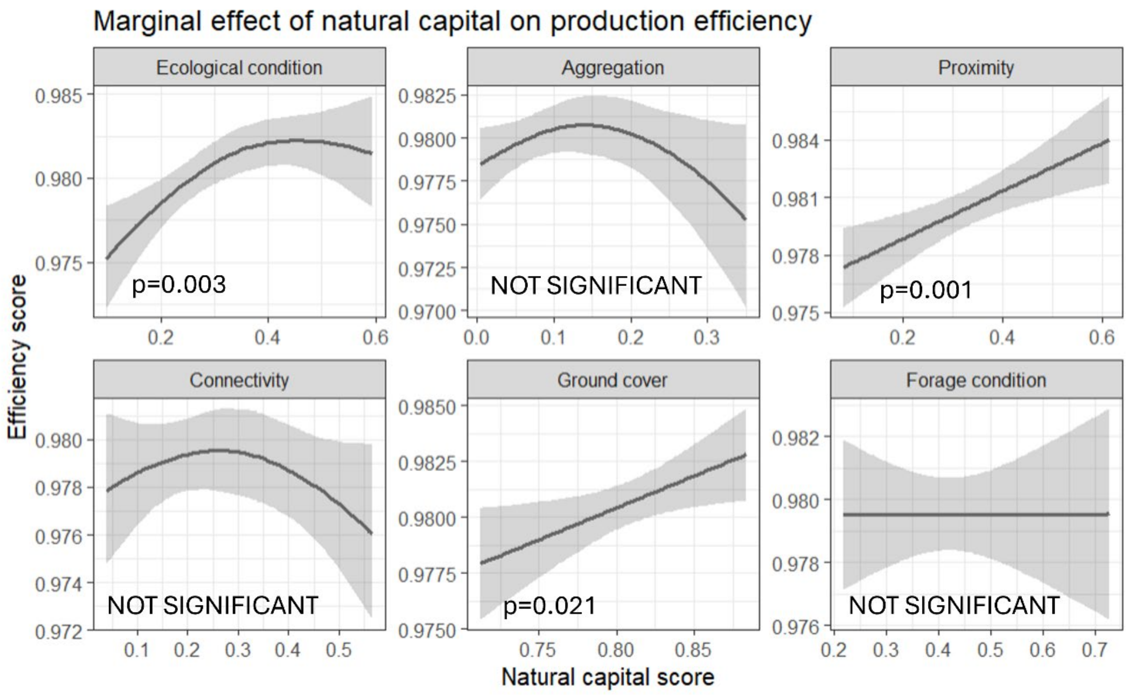
[1] 'Marginal effect' refers to the impact of natural capital once other influencing factors like rainfall, farm region and differences in managed input have been taken into account. This is discussed further in Appendix 1.
[2] 'edf' = estimated degrees of freedom. a summary statistic that reflects how curvilinear the relationship between predictors and the response variable is within a GAM. An edf = 1 corresponds to a linear relationship; an edf between 1 and 2 indicates a weakly non-linear relationship; an edf greater than 2 suggests a highly non-linear relationship likely to exhibit likely to exhibit inflection points and threshold responses.

shows that high and low efficiency farms are similar in terms of their underlying characteristics (farm size, stocking rates), and that efficiency can be achieved across a broad range of farm sizes and stocking rates.

The effect size of increasing natural capital on production efficiency presented in Figure 17 is in the order of 0.5 – 1%, which appears on first assessment to be relatively small. But we suggest that this effect is non-trivial for a number of reasons:

- Based on figures reported by ABARES[3], there has been slow (or even negative) productivity growth in the Australian livestock sector over the past 20 years, so even small percentage increases in efficiency may be important for industry growth
- Because we have removed outliers (see Section 3.3.4) the reported effect sizes arise from analysis of a relatively narrow band of natural capital states and production outcomes. Trends in the broader data suggest productivity effect sizes of 5% or more, but these would need to be verified with a larger sample size.
- Region- and cluster-specific analyses suggest larger effects size, with productivity gains of up to 3% reported for specific regions (Figure 20) and specific clusters (Figure 23).
- Small percentage gains in productivity can drive much larger percentage gains in profitability as discussed in Section 4.2.4.

Figure 17: Revealing the curve: Natural capital – livestock production efficiency relationships for 113 farms. Grey shading shows 95% confidence interval.



[3] Australian Agricultural Productivity - Broadacre and Dairy Estimates - DAFF (agriculture.gov.au)

Table 12: Statistical analysis of the role of natural capital in supporting livestock enterprise production efficiency. We use the 'edf' value to determine the shape of the natural capital - efficiency relationship[4] and the p-value (p<0.05) to indicate statistical significance.

Natural capital indicator	edf	Ref.df	F	p-value
Ecological Condition	1.81	1.96	7.17	0.003 **
Aggregation	1.83	1.97	2.40	0.093
Proximity	1.00	1.00	11.2	0.001 **
Connectivity	1.20	1.36	0.09	0.78
Ground cover	1.00	1.00	5.40	0.021 *
Forage condition	1.00	1.00	0.12	0.73

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

[4] An edf = 1 corresponds to a linear relationship; an edf between 1 and 2 indicates a weakly non-linear relationship; an edf greater than 2 suggests a highly non-linear relationship likely to exhibit likely to exhibit inflection points and threshold responses. GAMs included a fixed terms relating to FftF sample regions to account for underlying spatial differences. Additional details are provided in Appendix 1.

Figure 18: Mean inputs (per DSE) for least efficient (bottom 25%) and most efficient (top 25%) of livestock enterprises in our sample. Units for each input are as presented in Table 10.

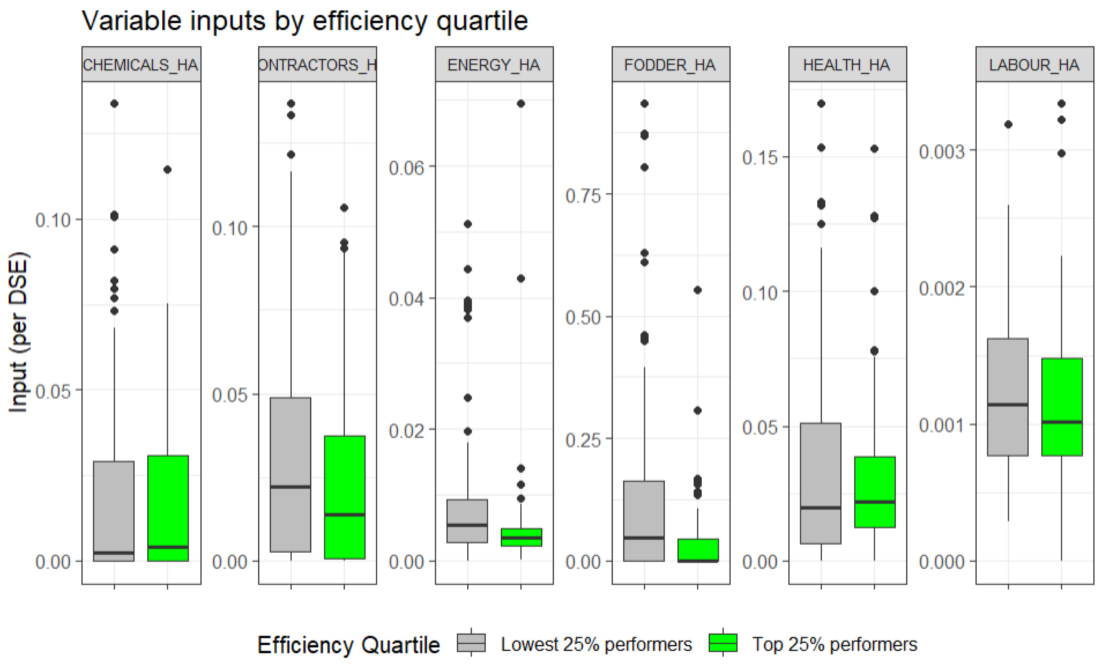
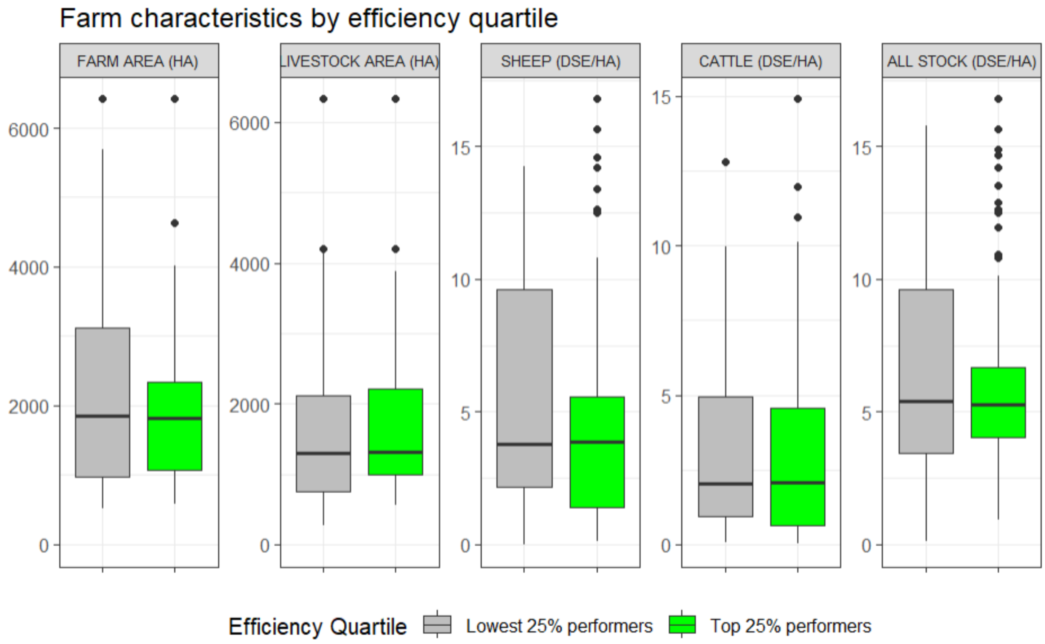


Figure 19: Characteristics of least efficient (bottom 25%) and most efficient (top 25%) of livestock enterprises in our sample.



4.2.2 Natural capital – production efficiency relationship by region

We repeated the GAM analysis described above to investigate relationships between natural capital and livestock production efficiency within individual study regions.

Regional trends in the Central and Tablelands and South-east regions followed patterns observed in the overall data: with evidence of a trade-off threshold relationship with Ecological Condition (in the Central and Tablelands region) and Aggregation (in the South-east region) (Figure 20). Regional trends also showed evidence of a possible trade-off zone between natural capital and livestock production efficiency for Forage condition and Connectivity, particularly in the Central and Tablelands region).

Few of the trends relating to individual regions metrics were statistically significant, particularly for the Western region. This is likely to be related to the smaller sample size involved with splitting our sample to region-specific subsets, and the associated loss of statistical power. These issues are explored further in Section 4.2.6.

Figure 20a: Natural capital – livestock production efficiency relationships in the Central and Tablelands study region. Grey shading shows 95% confidence interval.

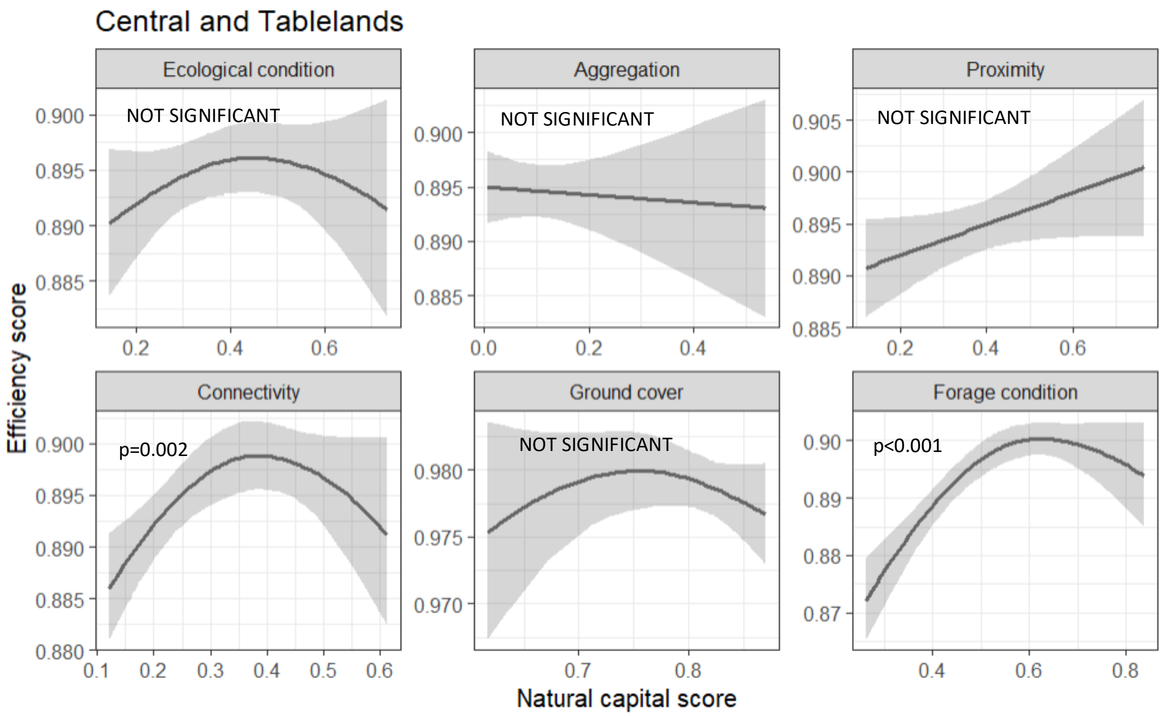


Figure 20b: Natural capital – livestock production efficiency relationships in the South-east study region. Grey shading shows 95% confidence interval.

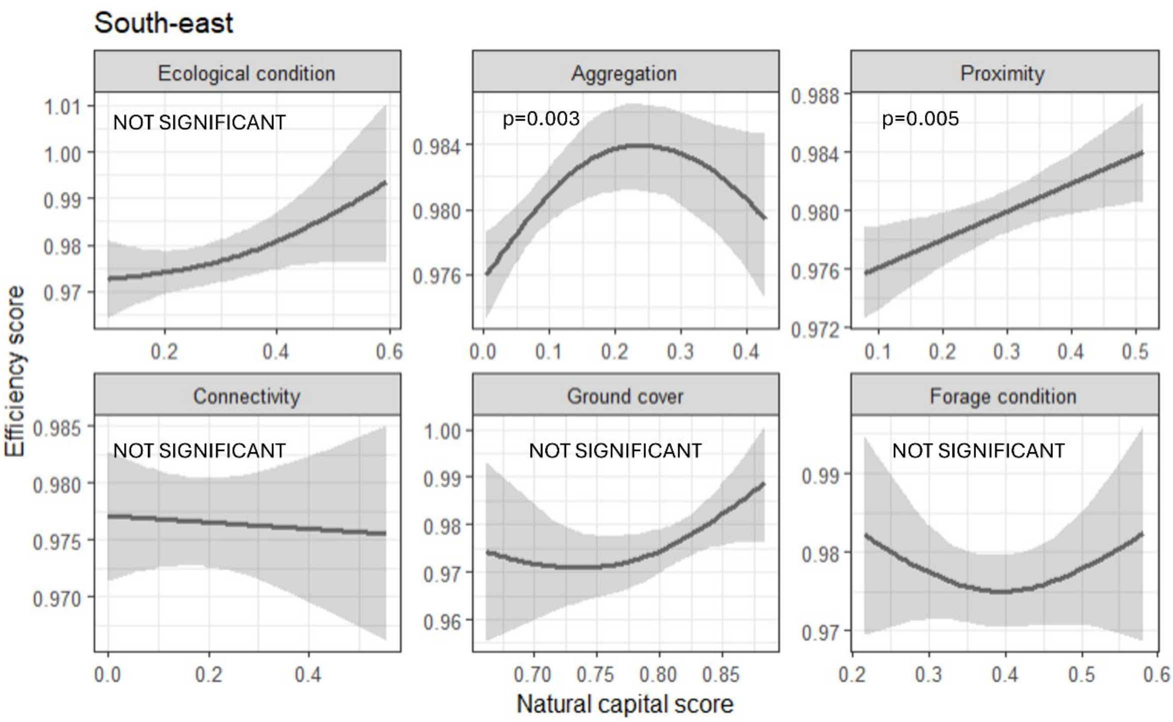


Figure20c: Natural capital – livestock production efficiency relationships in the Western study region. Grey shading shows 95% confidence interval.

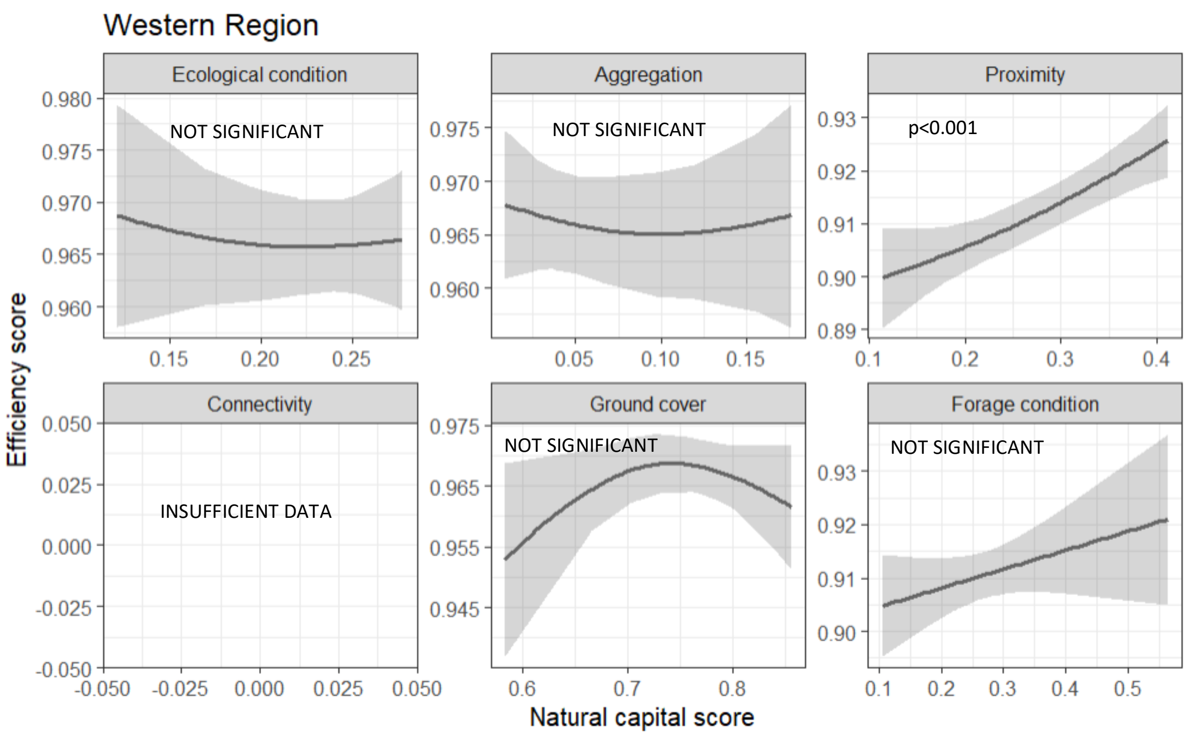


Table 13: Farming for the Future natural capital indices and significance of relationship with livestock production efficiency, assessed by region. The nature of each natural capital-livestock production efficiency relationship (positive, negative or mixed) is shown in Figure 20.

Label	Description	Central / Tab p value	South-east p value	Western p value
NC1 Ecological condition	The degree to which a farm has been modified from the original biome (pre-development condition).	0.36	0.11	0.82
NC2 Aggregation	The extent to which wooded vegetation is arranged into contiguous patches.	0.76	**0.003**	0.83
NC3 Proximity	The distance between production areas and wooded vegetation.	0.06	**0.005**	**<0.001**
NC4 Connectivity	The degree to which wooded vegetation forms corridors or 'stepping-stones'.	**0.002**	0.81	-
NC7 Ground cover	Living vegetation and/or litter/stubble; used as a proxy for soil condition.	0.38	0.10	0.14
NC5 Forage condition	Pasture condition based on categories of palatability, productivity and perenniality.	**<0.0001**	0.47	0.18

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

4.2.3 Exploring natural capital - farm management relationships

In response to feedback from farm advisors, we have explored the relationship between specific natural capital management actions and farm financial performance. We provide a comparison of management actions employed by the top 25% versus the bottom 25% of farms (as measured on the basis of livestock production efficiency) in Figure 21.

We have not undertaken formal statistical testing of the relationship between production efficiency and each of the management variables in Figure 21. This is because of the large number of management variables tested, and the high degree of correlation amongst them – both factors that undermine robustness of statistical testing and associated p-values. Moreover, there are no clear trends in any of the individual management indicators that separate top versus bottom performers. This is likely to relate to interdependencies amongst management actions: it is only through the simultaneous implementation of a suite of management actions that a desired outcome is likely to be achieved. Accordingly, we have investigated interactions between management interventions, natural capital and livestock enterprise performance using a multivariate cluster approach.

Our cluster analysis identified three 'farm type' clusters, which were used as a proxy for different farm management modes. We labelled these Type 1, Type 2 and Type 3 farms. Key characteristics and summary statistics for each farm type are provided in Figure 22 and Table 14. These farm types were used to account for variability in farming modes in our subsequent analyses of natural capital management effects on production efficiency, profitability and resilience. Farms from Western Australia were observed to be different from farms in the other sample regions included in our study, so these were considered to be their own 'cluster' or 'farm type'. Information about these farms is provided in the regional analysis in Section 4.2.2. A full cluster diagram is provided in Appendix 1.

We observed that different elements of natural capital are more- or less- important for different farm modes. For example, production efficiency in Type 1 farms was associated with high Aggregation and Ground cover scores; production efficiency in Type 2 farms was associated with high Ecological Condition and Aggregation scores (although a threshold trade-off was seen at higher

Aggregation levels); production efficiency in Type 3 farms was associated with higher Forage condition (Figure 23).

We also identified different types of relationships between natural capital and livestock production efficiency. Most of the cluster-specific relationships observed throughout this study were positive and linear (Figure 20, Table 15), providing strong evidence for the presence of a 'double dividend zone', as described in Section 3.1.2. However, only one of the efficiency-natural capital relationships reported for individual farm types demonstrated a significant threshold trade-off effect (Aggregation in Cluster 2) consistent with the 'trade-off zone' described in Section 3.1.2. A number of non-significant natural capital – business performance relationships had edf>1.5 (Table 15), which suggests that threshold effects may be more common (but not detected as significant due to our sample size), and that some increases in natural capital may come at the expense of agricultural production.

We did not observe any negative relationships between livestock production efficiency and natural capital. Even where there was not an adequate sample size to detect statistically significant relationships, we note that most associations between natural capital and production efficiency have a positive trend. Based on this observation we expect that further research with larger sample sizes will yield additional insights into the types of natural capital, and the associated management actions, that can benefit agricultural production.

Given the complexity of the relationships observed in this analysis, it is anticipated that the potential for natural capital management interventions to improve business performance for a specific farm enterprise in a specific region would be explored on a case-by-case basis by farm advisors, combining information from our benchmarking dataset with their own expertise and local knowledge. Regional scale analyses of natural capital management actions and their relationship to farm business performance relationships are presented in Appendix 3.

As discussed in Section 3.3.4, we have analysed trends in business performance associated with increasing levels of natural capital within each cluster in order to understand whether and how different farms might benefit from improved natural capital, irrespective of their current production mode or starting point. Additional industry-level insights may be gained by comparing performance across clusters, but this is a much larger question with important implications for production trade-offs (for example between farm size, stocking rates and production efficiency) at the industry-scale. Future analyses based on larger sample sizes will aim to address these important issues.

Figure 21: A comparison of management interventions by livestock enterprises with high versus low production efficiency (measured as top 25% versus bottom 25% of performers). Results are shown for all sample regions combined; results for individual regions are presented in Appendix 3. Note that these graphs do not account for background factors (other than coarse spatial region) so they do not represent the marginal impact of individual management actions. This would require more complex modelling and a larger dataset (see Section 4.2.6).

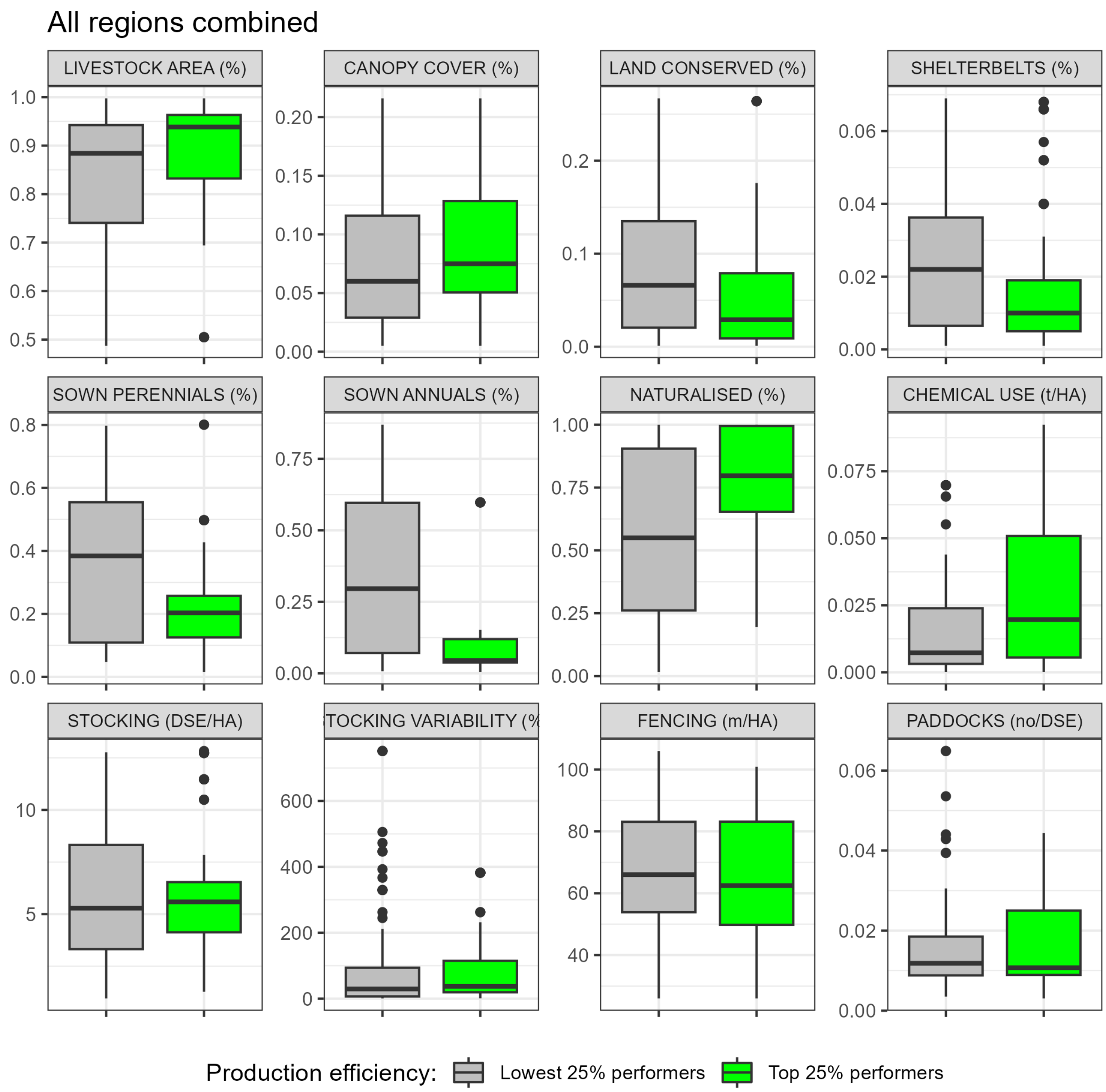
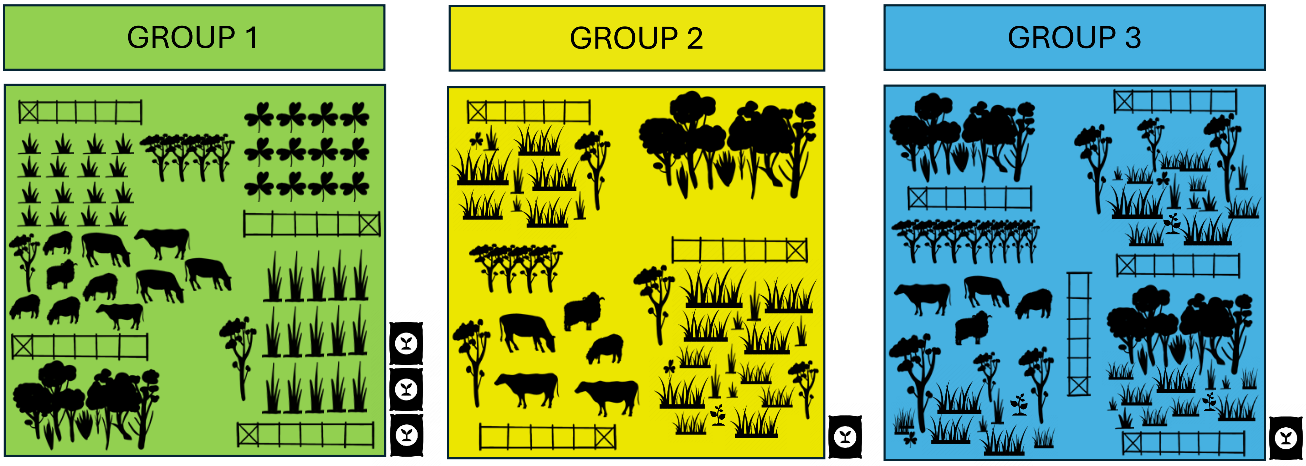


Figure 22: Farm types identified via cluster analysis of farm management activities (as in Table 14).



Group 1

- High chemical use
- High % sown exotic pastures
- High stocking intensity
- Low stocking variability
- Low canopy cover
- Trees as set-aside
- Few shelterbelts
- Low no. paddocks per DSE

Group 2

- Low chemical use
- High % naturalised pasture
- Moderate stocking intensity
- Low stocking variability
- Moderate canopy cover
- Trees integrated
- Few shelterbelts
- Low no. paddocks per DSE

Group 3

- Low chemical use
- High % naturalised pasture
- Low stocking intensity
- High stocking variability
- High canopy cover
- Trees integrated + set-aside
- More shelterbelts
- High no. paddocks per DSE

Table 14: Descriptive statistics of our farm sample, by farm type.

		Type 1			Type 2			Type 3		
Variable	**Units**	**mean**	**median**	**sd.**	**mean**	**median**	**sd.**	**mean**	**median**	**sd.**
Farm area	Ha	1660	1660	841	2410	2150	1280	1910	1740	1270
Livestock area	Ha	1190	1190	523	2210	2110	1190	1720	1520	1120
Cropping area	Ha	521	378	599	334	239	399	92	92	273
Av. annual rainfall	mm	602	570	86	676	679	164	711	733	121
Days 5 – 30 degrees	no	315	313	29	310	306	32	318	324	27
days >30 degrees	no	49	49	30	53	59	34	42	30	30
Average min. temp	deg C	5.1	5.1	1.5	5.4	5.2	1.7	4.9	4.7	1.5
Average max. temp	deg C	24.3	24.3	2.4	24.7	25.2	2.7	23.8	23.1	2.5
Stock	DSE	10500	11100	5220	9970	8190	6380	6030	4230	5600
Stocking rate	DSE/ha	9.22	9.47	3.67	4.88	5.20	2.14	3.59	3.36	1.92
Sheep stock	DSE	8300	6320	5030	7190	4850	5120	2750	2610	2200
Sheep stocking rate	DSE/ha	7.61	7.12	4.02	3.31	3.30	1.72	2.09	1.80	1.75
Cattle stock	DSE	4240	1950	5020	4830	3520	4710	4430	3230	5490
Cattle stocking rate	DSE/ha	3.34	1.21	3.69	2.54	1.96	2.11	2.24	1.77	1.80
Canopy cover	%	0.04	0.03	0.04	0.07	0.06	0.07	0.14	0.13	0.09
Shelterbelts	%	0.03	0.03	0.02	0.01	0.01	0.01	0.04	0.02	0.05
Area conserved	%	0.07	0.06	0.10	0.02	0.01	0.03	0.10	0.07	0.12
Sown perennials	%	0.53	0.50	0.20	0.19	0.15	0.13	0.14	0.10	0.12
Sown annuals	%	0.15	0.12	0.14	0.08	0.07	0.04	0.05	0.04	0.03
Naturalised pasture	%	0.37	0.41	0.20	0.88	0.92	0.14	0.85	0.89	0.15
Chemical use	t/ha	0.04	0.02	0.04	0.01	0.01	0.02	0.01	0.00	0.01
Fencing intensity	m/ha	78.30	77.60	19.5	53.90	52.90	13.50	75.60	74.50	23.70

Figure 23: Natural capital - production efficiency relationships, by farm type. We present all farm types together on a single graph to allow visual comparison amongst farm types. Coloured bands show 95% confidence interval. Results of statistical testing, including p values, are provided in Table 16.

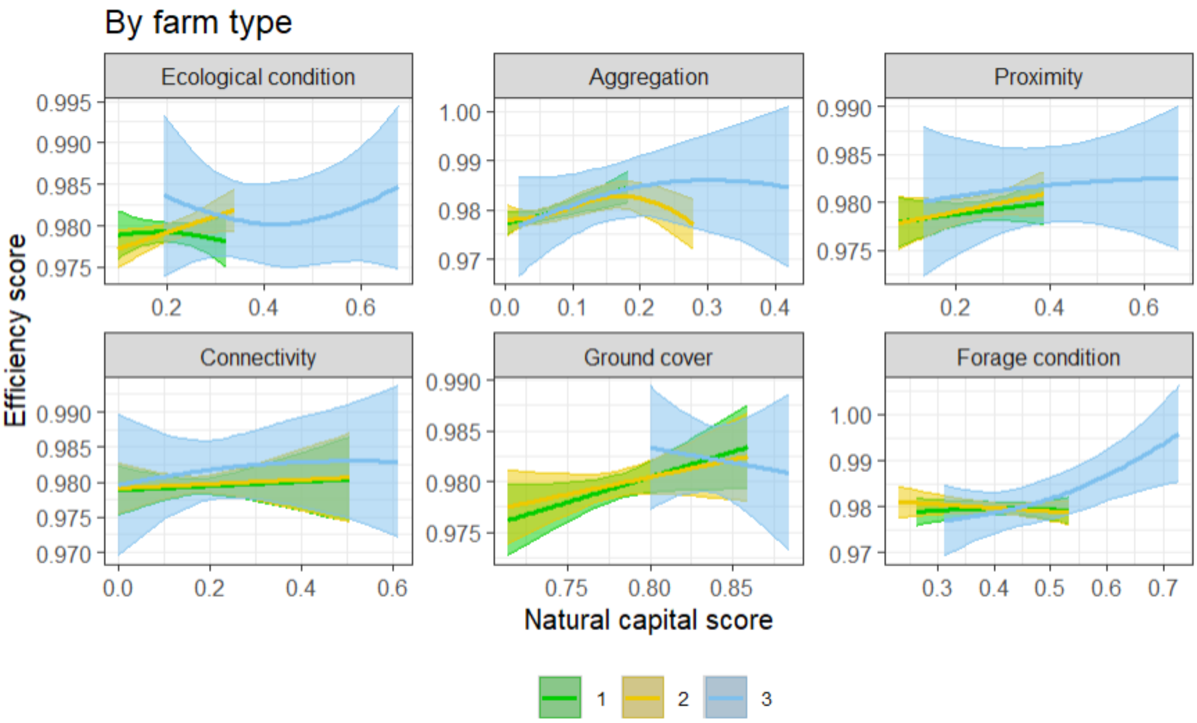


Table 15: Relationship between natural capital indices and livestock production efficiency, by farm type. Results of the statistical testing used to estimate relationships are provided in Table 16. Blank squares indicate cases where statistical testing identified no significant relationship.

	Type 1	Type 2	Type 3
Ecological condition		Positive	
Aggregation	Positive	Threshold trade-off	
Proximity			
Connectivity			
Ground cover	Positive		
Forage condition			Positive

KEY:

Positive: significant linear (or approximately linear) positive association.
Negative: significant linear (or approximately linear) negative association.
Threshold trade-off: curvilinear (second order polynomial) relationship that is positive at lower natural capital scores, but plateaus and becomes negative at higher natural capital scores.

Table 16: Nature and significance of natural capital – livestock production efficiency relationships, by farm type. We use the 'edf' value to determine the shape of the natural capital - efficiency relationship[5] and the p-value (p<0.05) to indicate statistical significance.

Cluster	Natural capital indicator	edf	Ref.df	F	p-value
Type 1	Ecological Condition	1.335	1.557	0.143	0.764
	Aggregation	1.325	1.544	4.902	0.009 **
	Proximity	1	1	0.838	0.362
	Connectivity	1	1	0.113	0.738
	Ground cover	1	1	3.949	0.05 *
	Forage condition	1.267	1.463	0.107	0.852
Type 2	Ecological Condition	1	1	4.763	0.031 *
	Aggregation	2.991	3.695	2.644	0.04 *
	Proximity	1	1	1.712	0.193
	Connectivity	1	1	0.103	0.749
	Ground cover	1	1	1.698	0.195
	Forage condition	1	1	0.712	0.4
Type 3	Ecological Condition	1.469	1.719	0.38	0.655
	Aggregation	1.609	1.965	0.873	0.38
	Proximity	1.084	1.162	0.088	0.798
	Connectivity	1.134	1.25	0.184	0.823
	Ground cover	1	1	0.162	0.689
	Forage condition	1.535	1.783	4.706	0.025 *

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

[5] Edf close to 1 indicates a linear relationship, edf close to 2 indicates a 2nd order polynomial relationship. GAMs included a fixed terms relating to FftF sample regions to account for underlying spatial differences. Additional details are provided in Appendix 1.

4.2.4 Natural capital impacts on livestock enterprise profitability

The results presented in Section 4.2.1 – 4.2.3 show the relationship between natural capital and livestock production efficiency. Reporting on farm efficiency provides valuable insights, but efficiency measures are reported as a 0-1 variable. This can make it difficult for producers to identify their own financial performance and compare it to other farms. It also makes it difficult to estimate the dollar value of natural capital improvements that producers might be considering for implementation.

We have sought to address this communication gap by expressing the impact of improved natural capital on livestock enterprise performance dollar terms. We have used GAMs (as previously described for productivity analyses) to estimate the relationship between natural capital and farm profitability. We focus two financial indicators: gross margin and EBIT. Figure 24 shows that relationships between natural capital and farm financial efficiency are typically positive, but with a threshold trade-off point suggesting that continued natural capital improvement beyond this point may come as a trade-off with farm profit (see Section 3.1.2). This was the case for the relationship between gross margin and Forage Condition, and between EBIT and Connectivity, Ground Cover and Forage Condition. The natural capital indices that displayed a significant association with profitability (Ground Cover, Forage Condition) are different to those that are associated with productivity (Ecological Condition, Aggregation, Proximity; see Section 4.2.1). This suggests that there may be different costs associated with maintaining or improving different types of natural capital. These are internalised in our analysis to some degree by our use of net financial performance metrics over a 5-year time series, but more detailed analyses of implementation costs may also assist when producers are considering options for natural capital investment.

We have estimated the difference in financial performance between low natural capital and high natural capital farms by estimating the change in gross margin and EBIT that each farm in our sample would be expected to experience if it had optimised Connectivity and Ground Cover scores (considered to be 0.3 and 0.8 respectively). These figures were taken from Figure 23 although we note that most natural capital indicators are correlated to some degree, and they are therefore likely to co-vary with changing management regimes.

We found that for all of the farm types investigated, optimised natural capital index scores were associated with better financial outcomes. Optimised natural capital levels delivered higher EBIT, with median \$75 - \$175 /ha/yr higher in the Central and Tablelands region[6], \$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.

The results of the analyses described in this section suggest that livestock enterprises across the full range of natural capital values measured in our sample could increase at least one element (and usually multiple elements) of their on-farm natural capital whilst maintaining or improving their production efficiency. Because our farms are representative of the broader population of farms within our focus study regions (see Supplementary Document C: *FftF sample balance M1 report 04072023-final*) we conclude that most livestock operations within regions we have investigated to date could increase their on-farm natural capital whilst maintaining or improving their efficiency (although we note that larger sample sizes and additional analyses are necessary to establish causal relationships)

[6] Simulated gains were smaller for Type 3 farms in the Central and Tablelands region (average -\$9 and median +\$31 in gross margin per year) because many of these farms already have natural capital levels close to the optimised value.

Figure 24: Natural capital - financial efficiency relationships. Coloured bands show 95% confidence interval. Results of statistical testing, including p values, are provided in Table 17.

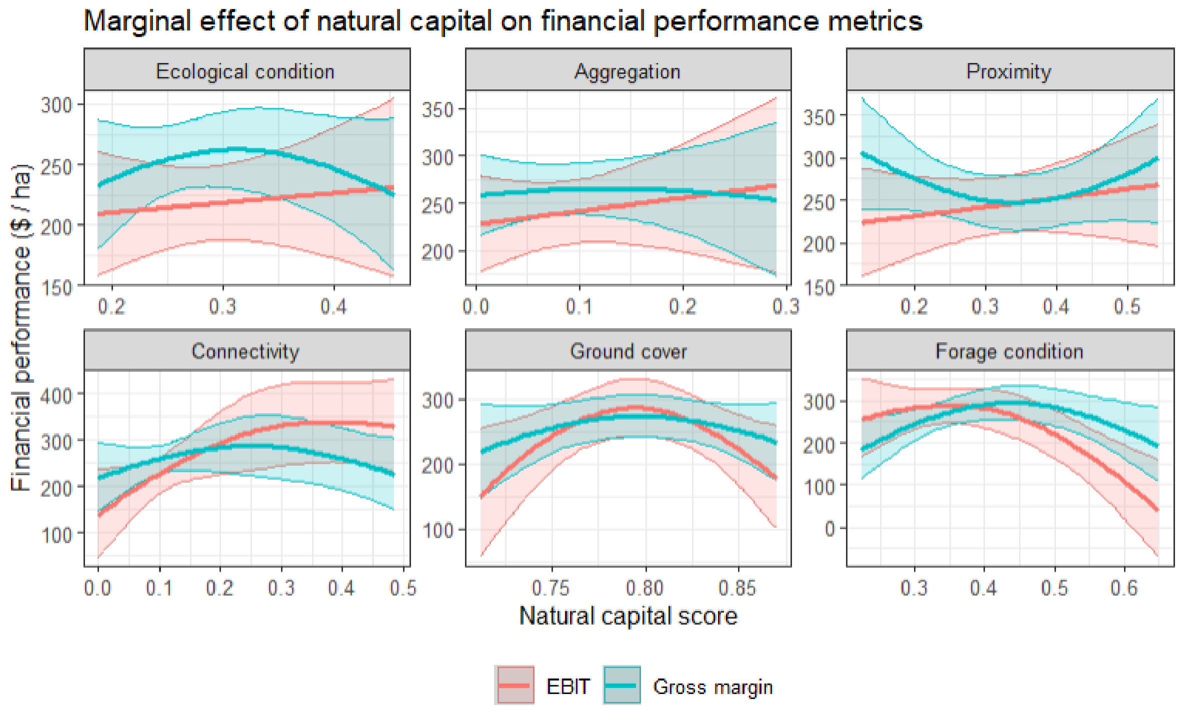


Table 17: Nature and significance of natural capital – livestock financial efficiency relationships. We use the 'edf' value to determine the shape of the natural capital - efficiency relationship[7] and the p-value (p<0.05) to indicate statistical significance.

Metric	Natural capital indicator	edf	Ref.df	F	p-value	
Gross margin	Ecological Condition	1.644	1.873	0.885	0.397	
	Aggregation	1.197	1.356	0.083	0.914	
	Proximity	1.728	1.926	1.405	0.268	
	Connectivity	1.684	1.9	1.451	0.304	
	Ground cover	1.706	1.914	1.11	0.314	
	Forage condition	1.887	1.987	3.866	0.021	*
EBIT	Ecological Condition	1	1	0.153	0.696	
	Aggregation	1	1	0.407	0.524	
	Proximity	1	1	0.55	0.459	
	Connectivity	1.659	1.884	2.575	0.061	
	Ground cover	1.882	1.986	3.654	0.026	*
	Forage condition	1.849	1.977	7.494	0.002	**

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

Table 18: Financial outcomes associated with on-farm natural capital improvement (measured as mean or median change in financial performance from increased natural capital condition and associated production efficiency improvements)[8].

		Gross Margin ($/ha)			EBIT ($/ha)		
Region	**Farm type**	**Mean**	**Median**	**sd.**	**Mean**	**Median**	**sd.**
Central and Tablelands	1	97	61	73	20	84	100
	2	78	111	25	114	177	37
	3	-9	31	33	-30	74	41
South East region	1	115	54	59	68	86	68
	2	45	138	49	-106	22	68
	3	188	230	22	253	137	124
Western region	-	225	256	20	93	71	34

[7] Edf close to 1 indicates a linear relationship, edf close to 2 indicates a 2nd order polynomial relationship. GAMs included a fixed terms relating to FftF sample regions to account for underlying spatial differences. Additional details are provided in Appendix 1.

[8] Simulated gains were smaller for Type 3 farms in the Central and Tablelands region (average -$9 and median +$31 in gross margin per year) because many of these farms already have natural capital levels close to the optimised value.

4.2.5 Natural capital impacts on farm resilience

The results of our producer engagement presented in Section 4.1 underscore the importance of resilience when producers are deciding about whether or not they should invest in improving on-farm natural capital. Our study collected financial data relating to livestock enterprises over a period of five years between 2017 and 2022. This period included a number of difficult years, with all study regions experiencing some level of drought declaration in the early part of our time series, and many experiencing additional difficulties associated with wide spread flooding in 2021. Our time-series also encompassed the COVID-19 period, which brought supply chain and other market interruptions. This has provided us with the opportunity to explore links between natural capital and resilience.

We identify four different types of shocks:

1. Rainfall – using annual average rainfall as a shock index
2. Input prices – using ABARES data '*Agricultural prices paid*' (all categories) as a shock index[9]
3. Output prices – using ABARES '*Prices received for livestock products*' as a shock index[10]
4. Terms of trade – using ABARES '*Farmers' Terms of Trade*' as a shock index[11].

We investigate the role that natural capital might play in conferring resilience to each of these types of shock by preparing a resilience index using the formula:

Resilience = -1 x (variance in EBIT) / (variance in shock index)

This measure was scaled between -1 and 1 with greater resilience being indicated by a score closer to 1. We used GAM modelling to estimate the relationship between natural capital and the resultant resilience measures. We use Ecological Condition as our measure of natural capital for this analysis.

Results of our modelling show that natural capital (Ecological Condition) was significantly correlated with resilience against all four types of shocks investigated (Table 19). This was true for all data combined, and when we explored resilience by farm type (Table 19; Figure 25).

We note from Figure 25 that the impact of natural capital on livestock enterprise resilience appeared to be a plateauing effect, whereby increasing levels of natural capital had a very strong positive effect on resilience at the lower end of the natural capital range, especially up at a natural capital score of approximately 0.3 – 0.4, with resilience increasing much more slowly after that point. This result suggests that some minimum level of natural capital is required to confer livestock enterprises with financial resilience to climate and market shocks.

The type of resilience that high levels of natural capital conferred varied by farm type. For example, Type 1 farms experienced higher resilience to market shocks in association with natural capital but remained vulnerable to rainfall shocks irrespective of natural capital levels (Table 19). Type 2 farms were relatively resilient to all types of shock across the range of natural capital values measured, and Type 3 farms showed improved resilience to both climate and market shocks at higher natural capital levels (> Ecological Condition score of 0.4; Table 19). This suggests that the role of natural capital in supporting farm resilience is context specific, and that investing in improved resilience for the Australian agriculture sector will require a nuanced understanding of the link between natural capital and resilience across a variety of farm types.

[9] Agricultural Commodity Statistics 2022, Identifier MA2945
[10] Agricultural Commodity Statistics 2022, Identifier MA2974
[11] Agricultural Commodity Statistics 2022, Identifier MA2943

Figure 25: Ecological condition – resilience relationships for full farm sample, and by farm type.

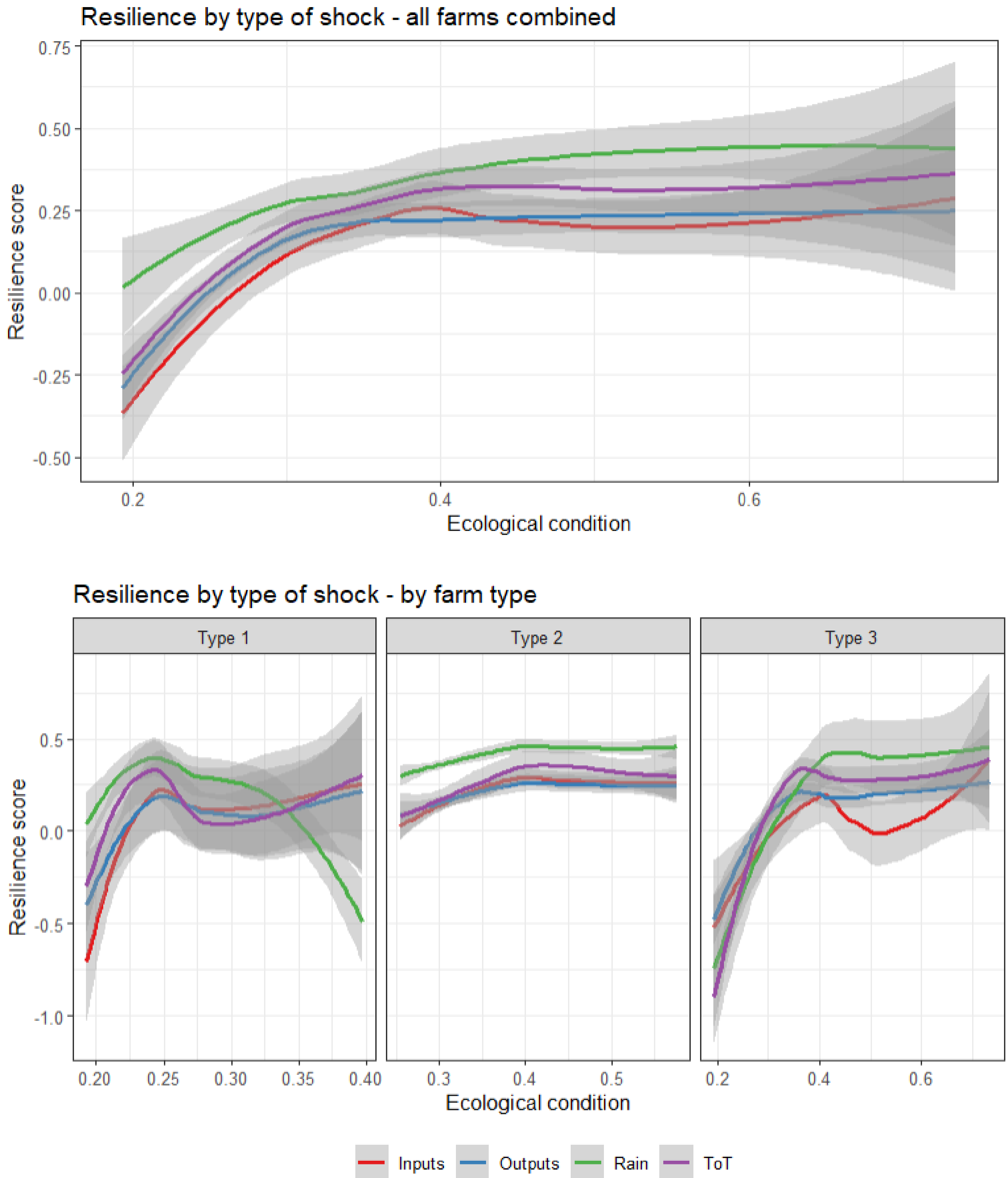


Table 19: Statistical significance of Ecological condition – resilience relationships

	Rainfall	Input prices	Output prices	Terms of Trade
All farm types	<0.0001 ***	0.11	0.007**	<0.0001 ***
Cluster 1	<0.0001 ***	0.0006 ***	0.0005 ***	0.0004***
Cluster 2	0.002 **	0.002 **	0.001 **	0.001 **
Cluster 3	0.0002***	0.031*	0.002**	0.002**

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

4.2.6 Issues of scale and statistical power

The variability in Australian farming landscapes, and Australian farming businesses, means that natural capital inputs and associated benefit pathways are also likely to be highly variable. This represents a challenge for sampling and data analysis: how can we design a program that adequately controls for local contextual factors, whilst also delivering insights that can be generalised to the broader farming population?

We have used the results of this *Farming for the Future* Livestock Pilot Program to undertake a power analysis to explore the farm sample that would be required to identify natural capital – livestock enterprise performance relationships with 95% confidence. 'Power analysis' refers to statistical tests that are used to determine what sample size is required for statistical confidence (detecting a trend with p value of 0.05 or lower if it is present within the system being observed).

Results of our power analysis suggest that a sample of approximately 300 farms would be necessary to bring this level of confidence to the analyses undertaken in our current sample regions (Table 20). The results of this power analysis were used to inform planning for future phases of *Farming for the Future* (Section 6.1).

Table 20: Building the evidence base: results of the power analysis to determine how many samples are required to identify natural capital – livestock enterprise production efficiency[12] relationships with 95% confidence in our current regions. Statistic, p value and effect size were calculated from chi-squared comparison of quintile groups.

Measure	Statistic	p value	Effect size	Sample req
PRODUCTIVITY	13.15	0.61	0.20	**312**
GROSS MARGIN	19.45	0.25	0.24	**211**
EBIT	13.87	0.63	0.20	**296**
RESILIENCE	14.13	0.61	0.20	**290**

[12] Ecological condition was used as the basis of statistical testing for this power analysis. Because each natural capital indicator will display a unique pattern of variability, the results presented are indicative only.

4.2.7 Other limitations

We note a number of limitations associated with the study below:

- This study provides evidence for correlations between natural capital and livestock enterprise performance. These represent a first step towards understanding causal relationships, but they should not be interpreted as causal relationships at this time. Building evidence for causal relationships will require greater sample sizes (as discussed in Section 4.25) and causal analysis approaches.
- Related to the above, we note that there is an important role for ensuring that interpretation is guided by the deep knowledge and experience held by producers and farm advisors. We propose that the dataset could be used to test hypotheses that are generated from the ground-up through consultation with these important stakeholders. We note that this hypothesis testing approach, and the associated insights into process- or causal- connections between natural capital and livestock enterprise performance are largely lacking from the current analysis. This will be an important element of future phases of *Farming for the Future*.
- This project makes a significant contribution to the development of natural capital indices that are both SEEA compliant and actionable at the farm scale. But further improvements could be made. We note particular difficulty in accounting for temporal variability in some of our natural capital indicators. For example, pastures and grasslands can respond very rapidly to seasonal and recent weather conditions and so they vary dramatically according to the conditions at- and leading up to- the time of survey. Consequently, the data that feeds into the forage condition score is unavoidably influenced by those recent and current conditions. This aspect can be remedied both through extending the time period of data capture (i.e. through the continuation of programs such as FFTF) and/or through the generation of high-validity measurement approaches that are also cost-effective and able to be applied at scale.
- The benchmarking outputs produced in this project have been designed to be consistent with behaviour change theory, as discussed in Section 3.1.5. But changing behaviour and attitude takes time. Although it was our intention to measure changing knowledge, attitudes and behaviours of the producers participating in our study as part of this current project, dependencies in the project timeline, whereby the benchmarking and other communication outputs could only be produced at the end of the study once all statistical analyses had been completed, mean that there has not been the opportunity to do this. We have undertaken baseline knowledge, attitude and behaviour data as part of the current study, and this will allow us to track change over time through future survey work.
- Our analysis looks at natural capital – farm business performance trends within the different farm types identified. Our clustering approach also lends itself to industry-scale analyses whereby industry-level insights about the optimal mix of farm types and/or production modes could be gained by comparing performance across clusters. We highlight that this is a much larger question, with important implications for production trade-offs (for example between farm size, stocking rates and production efficiency) at the industry-scale. Future analyses based on larger sample sizes will aim to address these important issues.

4.3. Project impact

4.3.1 Supporting farm advisors

4.3.1.1 Natural capital benchmarking module

Farming for the Future has developed a natural capital benchmarking module to assist producers and farm advisors to determine whether and how they might achieve higher levels of farm performance by increasing the level of natural capital on their farms.

Core objectives of the natural capital benchmarking module are to:

1. Identify performance and natural capital achievements/shortfalls with respect to relevant ‘peer’ farms.
2. Motivate potential changes to the use of, or investment in, natural capital on participating farms where these are appropriate.
3. Identify farms that demonstrate higher performance levels and extract relevant insights about the use of natural capital as a factor of production.
4. Make across-time comparisons to understand the extent to which natural capital may confer an advantage in specific climate or market conditions.
5. Present benchmarking data in a way that improves producers’ understanding of the contribution of natural capital to farm performance, and that can motivate investment in improved on-farm natural capital outcomes.

Representatives from collaborating organisations were invited to help co-design the benchmarking module to increase its value to the sector and accelerate its further development and adoption. Interim benchmark prototypes and associated feedback from co-design workshops is presented in Appendix 4.

Co-design identified the specifications listed in Table 21 as being important for uptake of the proposed natural capital benchmarking module into farm advisory services. Where relevant to the current *Farming for the Future* scope, these have been integrated into a clickable prototype of the proposed benchmarking module as presented in Figure 26 - Figure 29. The full clickable prototype is available in Supplementary Document F: *Farm Benchmarking Report (html)*.

Table 21: Co-design specifications for the natural capital benchmarking module (clickable prototype). Specifications not currently addressed have been captured for future phases that are currently unfunded, including building an operational benchmarking module.

Co-design specification	Addressed in Livestock Pilot deliverables?
The ability to drill down into the natural capital of the farm to view all natural capital metrics and identify practical actions they could take to move their natural capital indices in the desired direction	**Yes** – Seven different farm scale Natural Capital Indicators are included in the current benchmarking prototype (see Figure 29). Advisors are expected to play a key role in providing farm specific advice about management actions and this advice is provided to them in aggregate format. Providing management advice directly to producers is considered out of scope for *Farming for the Future*.
Alignment with key financial metrics, including Gross Margin, EBIT and ROAM	**Yes** – Six common financial metrics are included in the benchmarking prototype (see Figure 26 Figure 28)
Ability to integrate the module into existing tools and workflows	**No (future phase)** – interoperability is a key design feature captured for a future operational benchmarking tool.
Good context and definitions to enable full understanding of natural capital and associated metrics	**Yes** – Context and definitions are included in the current benchmarking prototype (e.g., see Figure 27). Noting that more testing of this prototype is required.
Access to historical data to view change over time	**No (future phase)** – *Farming the Future* is not currently committed to repeat measurements of producer natural capital over time. Most[13] of the Natural Capital Indicators are currently measured at a point in time rather than over time. Methods developed allow for future repeat measurements and comparative data has been captured as a key design feature for a future operational benchmarking tool.
Aggregate peer comparisons to maintain privacy whilst still identifying relative farm performance in terms of performance bands, deciles or similar.	**Yes** – de-identified peer comparisons are included in the current benchmarking prototype. (e.g., see Figure 27 - Figure 29)
Program outputs for producers and advisors are presented in plain English, allowing for easy interpretation	**Yes** – The current benchmarking prototype has been developed to be plain English. Noting that more testing of this is required.

[13] The exception is Soil Condition which is based on 5 years worth of remote sense ground cover data.

Figure 26: Farming for the Future benchmarking module: screenshot of context page.

About

Summary

Definitions

Benchmarking: Livestock enterprise

Benchmarking: Farming systems

Natural Capital

Natural Capital outcomes

Natural capital and farm performance

In this short report you will be provided with a range of insights into your farm performance outcomes. The analysis is based on up to the last five years of your business operations.

Data used

Your business was analysed in the years 2020, 2021, 2022 based on data made available by you and/or your advisor.

report focus

The focus enterprise of this report is your LIVESTOCK enterprise. We have not analysed any other enterprises (e.g. cropping) separately. However, a range of farm business-level models provide some insight into how well your overall farm business (inclusive of all enterprises/systems) has performed.

Overall efficiency results

Your farm report shows that you have Moderate efficiency, on average, across the range of models estimated and across the years that your business is included in this analysis. Confidence in this performance estimate is Low.

Overall natural capital rank

Your natural capital rank for your region is 1 out of 5 in your region. Across all farms in the Farming for the Future database your natural capital index rank is 12 out of 86. Overall, your natural capital level is Low indicating you natural capital increases are likely to be able to be achieved alongside business performance improvements.

Figure 27: Farming for the Future benchmarking module: screenshot of efficiency reporting.

About

Summary

Definitions

Benchmarking: Livestock enterprise

Benchmarking: Farming systems

Natural Capital

Natural Capital outcomes

Natural capital and farm performance

Three main models were estimated for your LIVESTOCK enterprise. These are:

1. A **PRODUCTIVITY** model that considers how well you use your farm inputs to produce livestock outputs. This model allows for variation in input choices and multiple livestock outputs, summarised as sheep and cattle outputs.
2. A **GROSS MARGIN** model that considers your livestock enterprise gross margin efficiency. This is similar to the Productivity model but uses your gross margin (instead of output) as the single target performance variable.
3. A **EBIT** model that considers your livestock enterprise profit efficiency with Livestock Earnings Before Interest and Tax (EBIT) as the single target performance variable.

These three models are summarised in the gauges plot to the right.

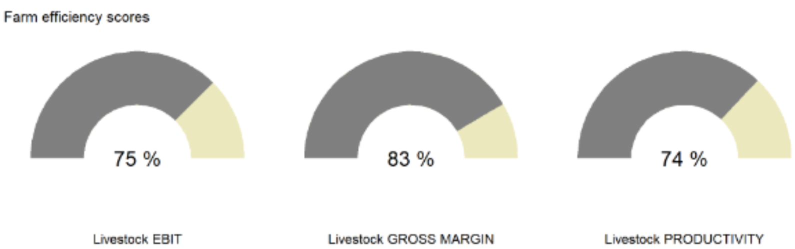


Figure 28: Farming for the Future benchmarking module: screenshot showing performance of an individual farm (black dot) in relation to peers. Grey band show 95% confidence interval.

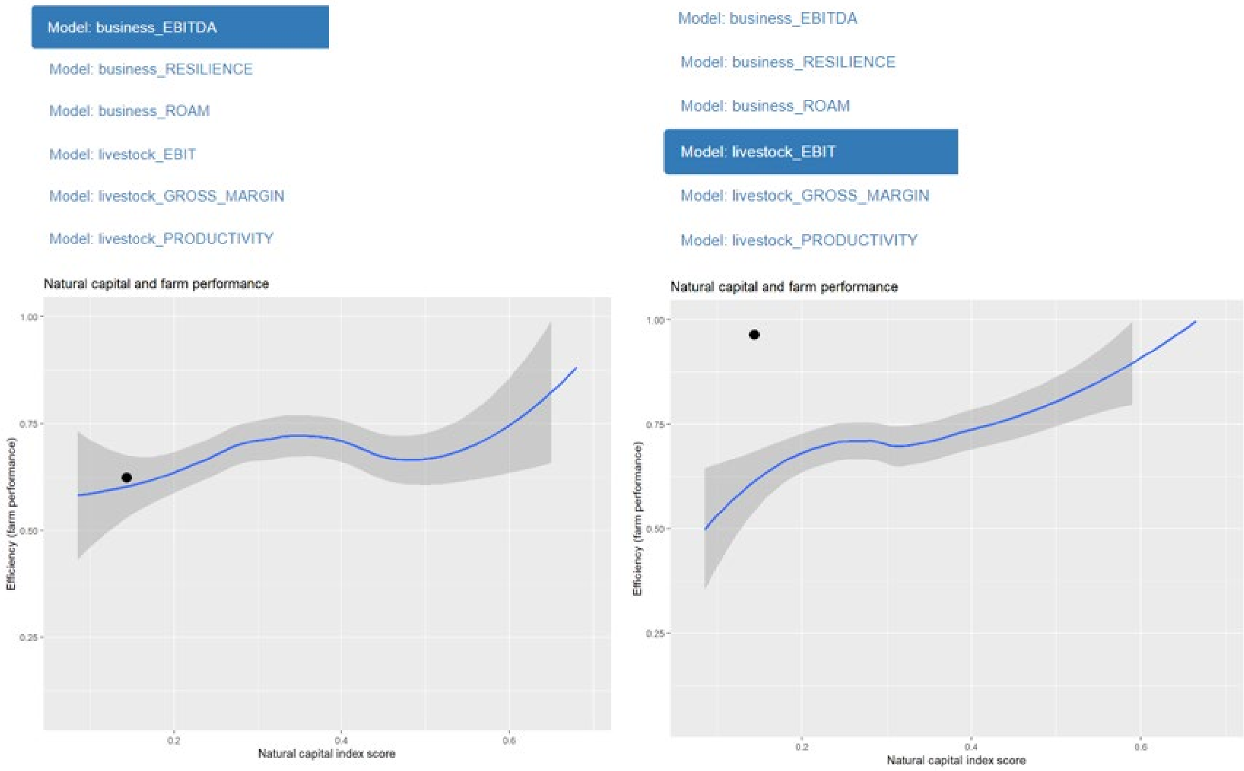
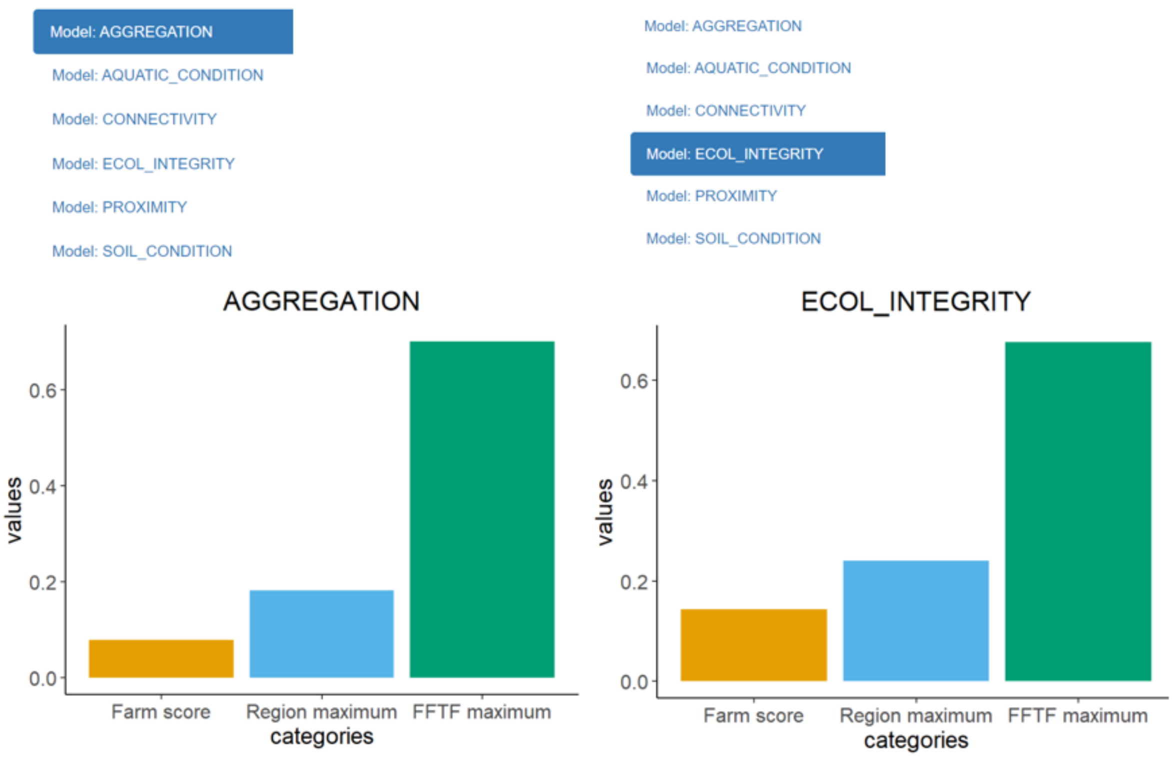


Figure 29: Farming for the Future benchmarking module: screenshot of natural capital performance comparisons.



4.3.1.2 Advisor use case and feedback

The natural capital benchmarking module presented in Section 4.3.1.1 was presented to farm advisors at a co-design workshop in July 2023. Feedback was overwhelmingly positive, with advisors indicating that the insights would be useful to them for a range of business purposes. Recommendations for improvements and further development, and *Farming for the Future*'s responses to them, are provided in Table 21.

The use-case for *Farming for the Future*'s natural capital benchmarking module is presented, in participating farm advisors' own words, below. Additional feedback from the co-design workshop is provided in Figure 30.

How would you use the information presented today to support your clients?

Useful products and deliverables

- The farm efficiency versus NC condition curve.
- Reports.
- Getting higher level reports for individual reports.
- Getting the full suite of metrics in an individual farm report and then group report.

Identifying and evaluating opportunities

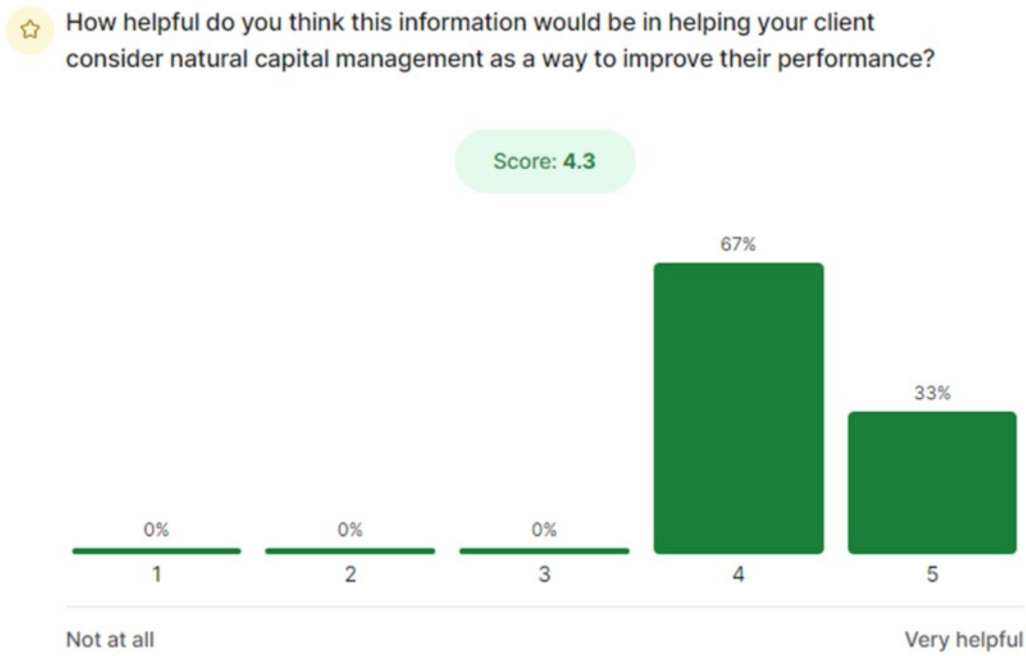
- Identifying independent comparison of farm businesses to identify opportunities and possibilities (areas for improvement) consistent with clients' goals.
- Identify actions to improve or maintain natural capital or performance.
- Identify where they are currently placed and areas to improve. Tracking it over time.
- Understand where they are at the moment, identify the options moving forward and select the one/s most relevant to them.
- Compelling reasons to change practices.
- Identify management practices that have enhanced natural capital and its long-term benefits to natural capital. Understand any potential trade off in terms of profitability.

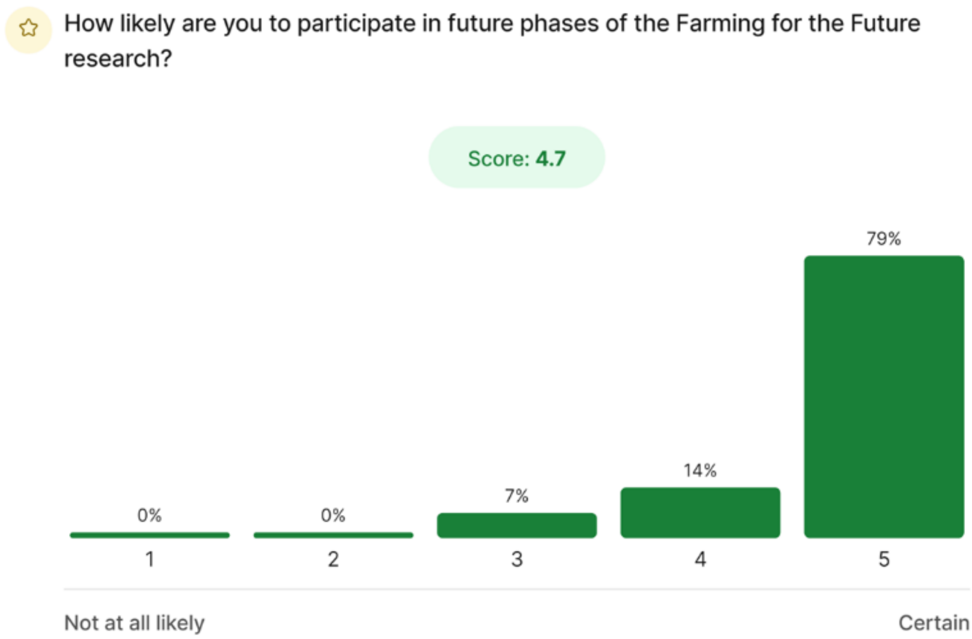
Long-term strategic planning

- Fits into a long-term plan for sustainable business growth.
- Increasing productivity.

As further evidence of advisor interest and user needs, *Farming for the Future* has developed an example case study with farm advisor Mark Gardner (Vanguard Business Services). This is available in Supplementary Document G: *Farming for the Future* Case Studies.

Figure 30: Feedback from Faming for the Future co-design workshop, July 2023





4.3.2 Supporting producers

4.3.2.1 Natural capital reports

To provide participating producers with actionable insights into how they might alter the natural capital of the farm to improve their business performance, producers are provided with detailed natural capital reports. These reports serve as a record of the data collected for their farm. They also provide the producer with a baseline of the farm's natural capital and the environmental performance of the farm business. This report is separate and additional to the benchmarking module described in Section 4.3.1.

Natural Capital Reports are prepared to be coherent with the United Nations System of Environmental Economic Accounting (UN SEEA). They describe the type and extent of the different ecosystem assets of the property. While these are only prepared at a point in time for the *Farming for the Future* project, they can be updated in future to show change over time. Natural Capital reports include high quality digitised farm maps plus maps and tables quantifying and illustrating the natural capital of the farm. Seven indices of natural capital are estimated for farms and depicted in images to reveal the indices in the context of the farm map. Additional detail is provided for the condition of ecosystems with respect to capacity for livestock grazing (Forage Condition –Figure 31) and for biodiversity (Ecological Condition – quality for habitat for native species – Figure 32).

Figure 31: Map of Forage generating assets of the farm in different categories of quality for livestock grazing. A is best condition for grazing, D is in poor condition for grazing.

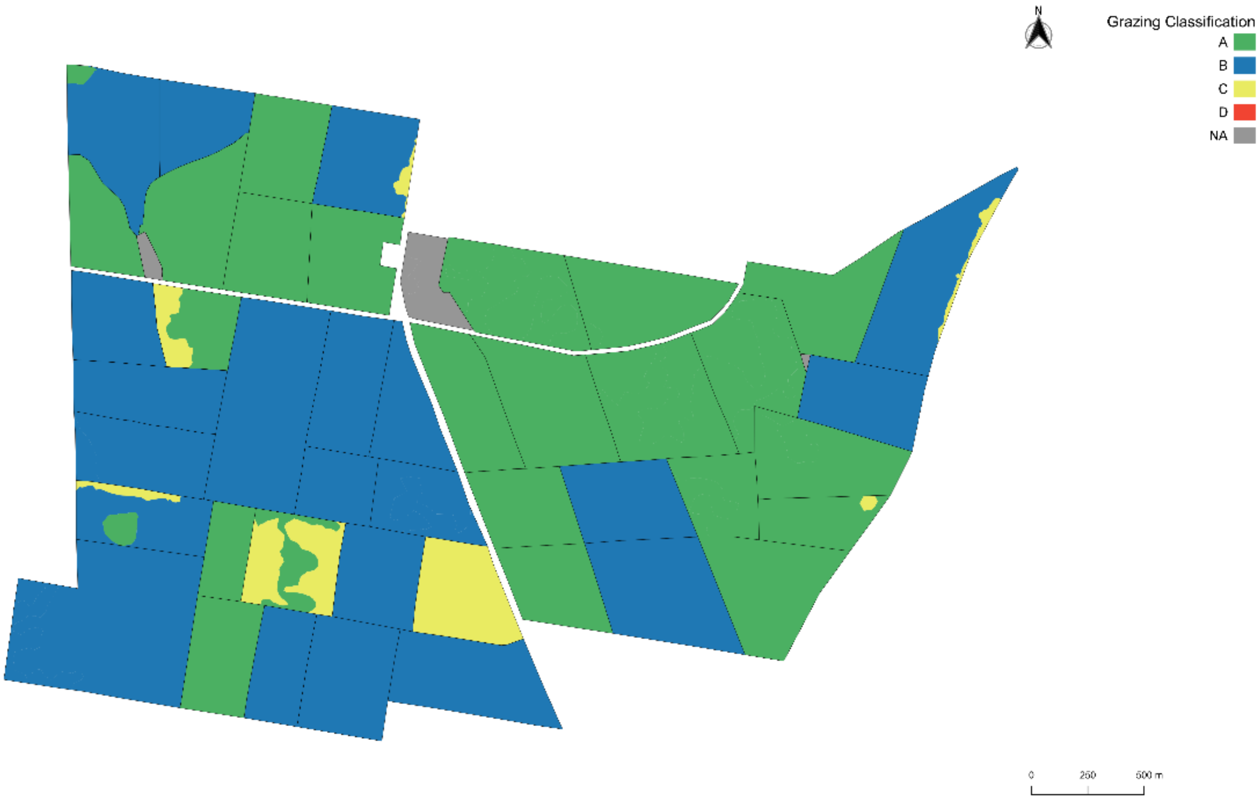
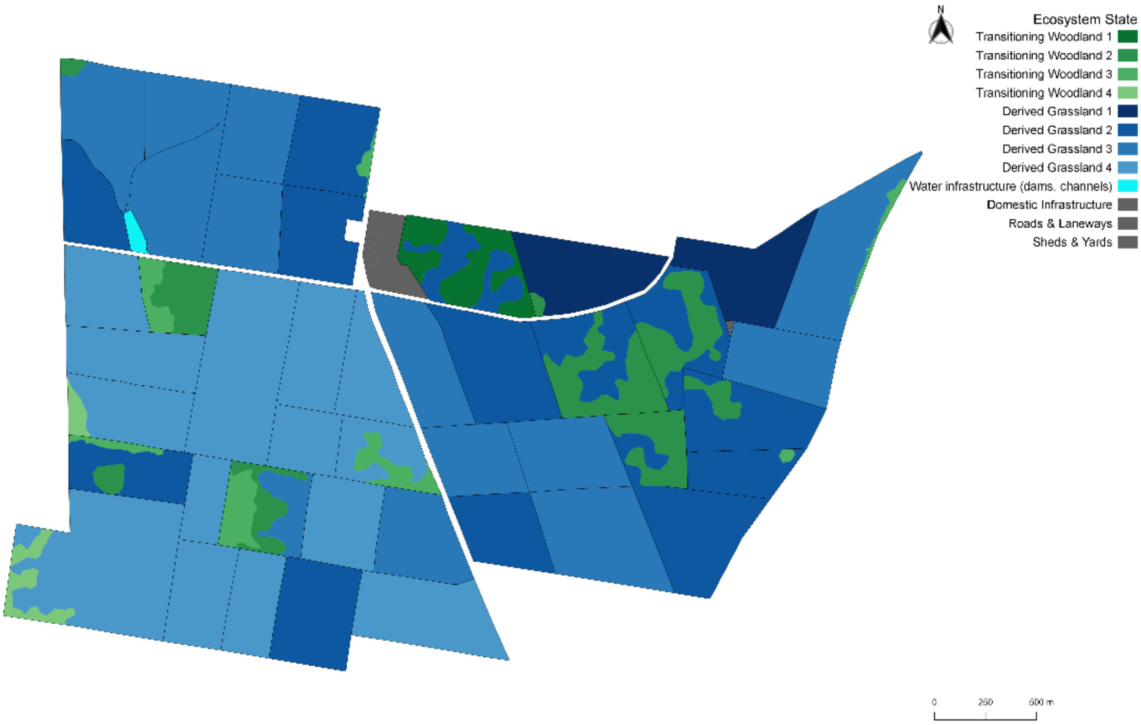


Figure 32: Map of Ecological Condition of a participating farm. Areas of the farm in different condition states of the S&T model are shown.



Estimates of carbon storage and sequestration (woody vegetation only) are included in farm reports to provide producers with information about their net carbon position. This information is also valuable for analysis of the public good generated by participating farms.

Environmental Performance information is compiled from production and other records to provide insight into the impact of the farm operations on the environment. Reports include estimates of the major environmental performance indicators for the major products of the farm (e.g., wool, livestock, crops) including estimates of:

- Greenhouse gas emissions (Scope 1, 2, and select[14] Scope 3)
- Air and Water Pollution
- Waste generated
- Water use
- Rainfall use efficiency,
- Normalised stress-weighted water consumption (including evaporation)
- Nitrogen use efficiency,
- Lime use efficiency,
- Phosphorus use efficiency,
- Finite resource use.

[14] Only the following livestock enterprise purchases are included in Scope 3 emissions; live sheep and cattle, synthetic fertiliser, superphosphate, urea, feed (grain, hay/silage, lucerne). This is expected to cover the vast majority of Scope 3 emissions overall by covering the vast majority of the following GHG Protocol Scope 3 Standard categories; Category 1 (Purchased goods & services) and respective Category 4 (Upstream transport). Category 3 (Upstream fuel and energy) is also included.

Farming for the Future Natural Capital Reports prepared for producers do not include financial or production performance analysis. This makes the report less sensitive and easier for producers to share with external parties such as supply chains.

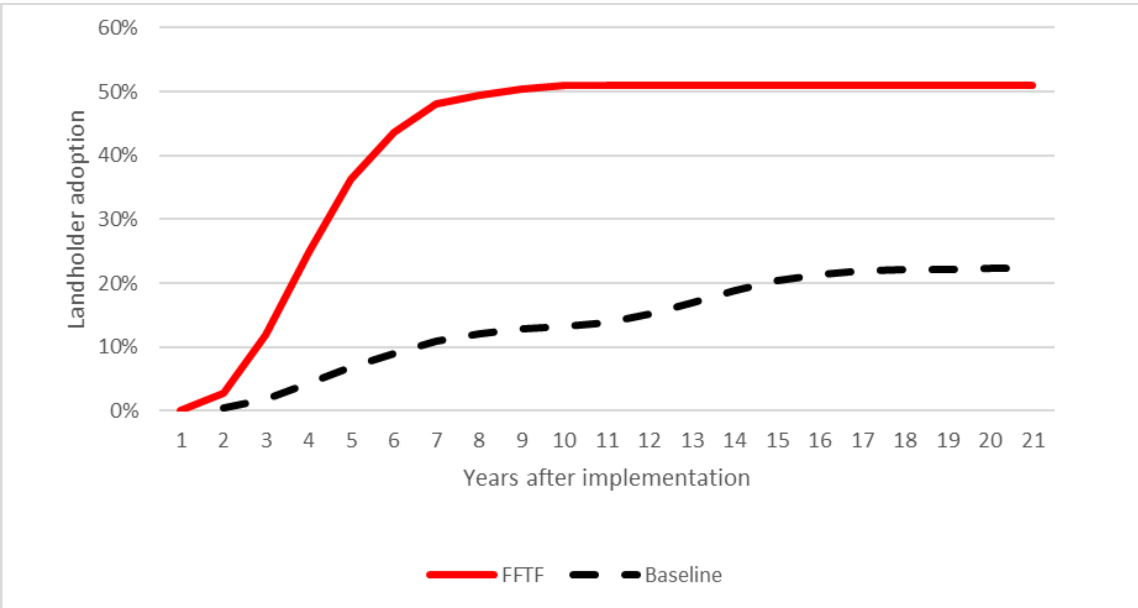
A sample of a full farm report is provided in Supplementary Document G: *Farm Report Template (Natural Capital – Development Mock-up)*. An example case study with producer participants Angus & Lucy Maruice (Pastured egg, grain, oilseed, lamb, wool and beef producers, Spicer's Creek NSW) is also available in Supplementary Document H: *Farming for the Future* Case Studies.

4.3.2.2 Landholder adoption

The positive financial impact of on farm natural capital demonstrated in Section 4.2. leads to a step change in the adoption improved on-farm natural capital management. Most programs or policies aimed at improving on-farm natural capital rely on the environmental values and preferences held by producers. Recent analysis suggests that this is sufficient motivation for approximately 15% of producers. But it is inadequate to engage the remaining 85% of producers and achieve broad-scale change across the Australian agricultural landscape[15]. *Farming for the Future*'s research and engagement with producers shows that private production benefits, including increased productivity, increased profit and improved income stability are much more compelling reasons for producers to invest in natural capital improvements (Section 4.1).

ADOPT modelling estimates the uptake rate of our benchmarking module at ~50% of relevant producers, with peak adoption within 6 to 7 years. This represents increased or marginal adoption by 38% of landholders compared to baseline adoption over a 7-year assessment period, and a marginal increase of 30% over a longer (20-year) planning horizon. It also means peak industry adoption is brought forward by 8-10 years. Comparative adoption rates with and without *Farming for the Future* are shown in Figure 33.

Figure 33: Estimates of landholder adoption under base case and Farming for the Future program assumptions.



[15] Pers comm based on research undertaken in collaboration with Southern Cross University; publication forthcoming

4.3.3 Supporting system activation

4.3.3.1 Industry scale impact

Farming for the Future implements its natural capital and farm financial performance data collection activities, and delivers the insights arising from them, through a network of participating farm advisors. This allows the program to reach a larger number of farms and to streamline and accelerate the uptake of its research findings.

Farming for the Future's current network of farm advisors have access to more than 10,000 farm clients. Of these, an estimated 60% are livestock producers operating in the wheat-sheep belt in the southern states (southern herd). This means the results from *Farming for the Future* can be immediately and effectively rolled out to approximately 6,000 producers.

As presented in Section 4.3.2.2, modelling using the CSIRO 'ADOPT' model indicates that *Farming for the Future* could achieve natural capital improvement on +38% of farms relative to the baseline (without *Farming for the Future*) scenario. This means that our current findings are likely to initiate natural capital improvements on 2,280 livestock farms over a 7-year time frame.

These above estimate of the industry-scale outcome from *Farming for the Future* is considered to be a minimum bound estimate. With additional engagement activities and the continuation of *Farming for the Future'*s research activities to bring a larger number of farms that are representative of a broader range of farming operations into its benchmarking dataset, *Farming for the Future* has the capacity to achieve broad-scale adoption of natural capital management and associated financial benefits for a much larger number of Australian producers.

The observed link between natural capital and income stability means that accelerated producer uptake of natural capital investments delivered by *Farming for the Future* will minimise the negative financial and well-being impacts of drought on producers and farming communities over the next 5-10 years and beyond. It will also minimise the associated requirement for government drought subsidies.

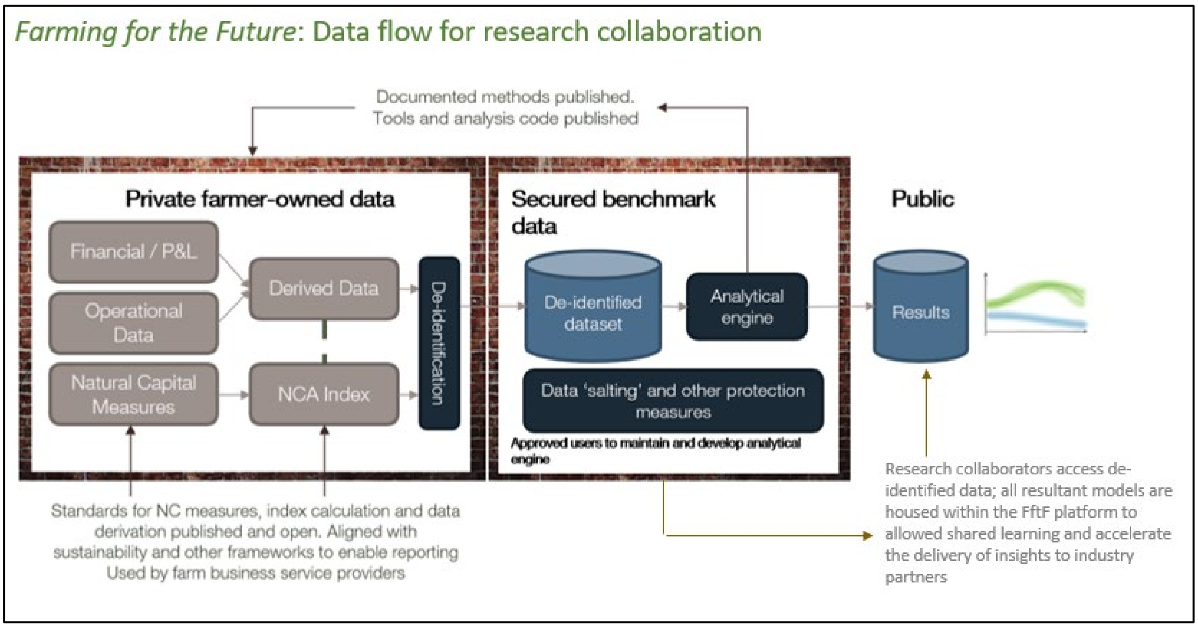
An example case study with Dr Alison Southwell (Executive Officer, Holbrook Landcare Network) is also available in Supplementary Document H: *Farming for the Future* Case Studies.

4.3.3.2 Natural capital benchmarking model – access for impact

In this Livestock Pilot Program, *Farming for the Future* has sought to build an enduring toolset for use in benchmarking farming enterprises. Accordingly, our prototype benchmarking module has been designed to allow for ongoing updates derived from research partners who can contribute new insights into natural capital – farm performance relationship and integrate them back into the *Farming for the Future* module.

Part of *Farming for the Future's* envisaged architecture for the benchmarking module is the enablement of the capacity for natural capital measures, natural capital indices and farm business derived data (light brown/grey shapes in) to be generated by service providers chosen by the producer. This will require development and publication of broadly agreed, widely adopted measures and data definitions. *Farming for the Future* envisages that work on an 'open standard' for these data definitions would accelerate and amplify the positive impact of farm business performance of having better information and significant robust evidence on which to base farm business decisions.

Figure 34: Design of the Farming for the Future benchmarking toolset and process for research collaboration.



Farming for the Future will provide its benchmarking module as a pre-competition, pre-commercial research output. Commercialisation will occur through third party beneficiaries, like farm advisors, natural capital accountants, banks and ESG supply chains. These beneficiaries will be invited to integrate *Farming for the Future* research outputs into their product and service offerings. *Farming for the Future* will support this process through capability building, co-design and other support activities (for example see Section 4.3.3.4).

Commercialisation of *Farming for the Future* data, analyses and insights will be via further development of a the natural capital benchmarking module – to become a centrally held database that provides insights into how differences in natural capital of Australian farms are associated with differences in productivity, resilience, and other economic outcomes. The module will have the capability to generate robust estimates of the productivity and resilience of farm businesses with different natural capital portfolios.

4.3.3.3 Connecting key players

Farming for the Future has engaged with leading organisations in agricultural industries and in emerging natural capital areas to build connection, relevance and impact. These include, but are not limited to:

- National Farmers Federation (NFF)
- Task Force for Nature-Related Financial Disclosures (TNFD)
- The Nature Conservancy
- CSIRO (especially the Perennial Prosperity Project)
- La Trobe University (especially the Farm-scale Natural Capital Accounting Project)
- Accounting for Nature (through the scientific advisory committee)
- ClimateWorks Centre (especially the Natural Capital Measurement Catalogue)
- NSW DPI (the Rangelands Living Skin project)

These partnerships allow *Farming for the Future* to leverage interest in the program, ensure program design elements remained relevant to producers, farm advisors and other key stakeholders, and developed effective adoption pathways to assist with the uptake of *Farming for the Futures*' research outputs and its associated industry impact.

4.3.3.4 Collaborating with the financial sector

To understand the degree of support from the financial services sector for development of a natural capital benchmarking module, *Farming for the Future* Program Director, Sue Ogilvy, and Taxonomy Lead of the Australian Sustainable Finance Institute (ASFI), Nicole Yazbek-Martin, conducted a series of semi-structured interviews with individuals considered to be leaders in natural capital thinking within the major banks and selected investment corporations. The interviews were conducted online during December 2022 and ran for approximately one hour. Insights were recorded in meetings notes and discussed in post-meeting debriefs. Integrating natural capital information into finance is considered critical for supporting systems activation of this *Farming for the Future* information.

The interview process revealed strong support for the design of *Farming for the Future* as a research and change program. They also revealed acknowledgement that individual banks did not have the capability to accomplish this in-house. The banks perceived significant value of the potential national coverage of the benchmarking module in enabling them to incorporate natural capital into lending risk and to compare the risk profile of their lending book with a broader sample. The consultation with the financial services sector resulted in the establishment of the partnership between *Farming for the Future* and ASFI 'Valuing Natural Capital' (www.asfi.org.au/valuing-natural-capital).

The *Farming for the Future* – ASFI partnership will seek to equip the financial services sector with tools to incorporate natural capital into financial decision-making as a way to drive increased flows of private capital to nature-positive outcomes on productive landscapes:

- Explore the key natural capital indicators established by *Farming for the Future* to determine their linkages with increased agricultural productivity and profitability, climate adaptation and resilience, nature risk dependencies and carbon mitigation and carbon sequestration benefits.
- Identify and link natural capital indicators to key financial indicators utilising *Farming for the Future* research project outputs to enable financial institutions and agricultural businesses to better understand risk and productivity.

- Identify and validate key natural capital indicators to underpin agricultural land valuations based on the productive capacity of the landscape.
- Establish and work with a Natural Capital Advisory Group (NCAG) to test and support the outcomes of the partnership. The NCAG will review case studies and undertake piloting of integrated climate and nature risk assessment and disclosure reporting.

The ASFI partnership 'Valuing Natural Capital' will enable banks to prepare a common foundation for the inclusion of natural capital indicators in differentiated debt and equity products that value and reward the management and protection of natural capital, and the development of sophisticated and cost-effective natural capital data collection protocols and methods to inform the aggregation of natural capital financial indicators that can be readily aggregated across portfolios and loan books.

In addition to participating in the work of 'Valuing Natural Capital', a number of banks have elected to sponsor some of their agricultural lending customers to participate in the *Farming for Future* research program.

4.3.3.5 Impact summit

Farming for the Future project held a 'Natural Capital Summit' in partnership with the NFF on 13 September 2023. This event was designed to provide project findings and insights to a general audience. Audience members include some participating producers, farm advisors and accountants, and NRM partners who have worked within the project, industry (NFF, producer membership organisations, MLA, AWI, GRDC), government (Commonwealth and State), and Private Sector (banks and supply chain members). Attendance was by invitation.

The format of the summit included presentations and panel sessions over lunch with a networking event in the early evening designed to allow informal discussion about the research. The agenda was designed to:

- Reveal the preliminary findings of our research into relationships between natural capital and farm business performance in the context of our hypothesis that better farm business performance is associated with better levels of natural capital.
- Demonstrate the potential for empowering producers with evidence, acknowledging that producers make evidence-based decisions.
- Demonstrate the readiness and capability of producers and farm advisors to inform the development of sustainable practices and shape the future of environmental performance.
- Demonstrate that the project is multidisciplinary, including working in partnership with producers and their trusted advisors.
- Provide key insights into policy and program design to accelerate producer investment in natural capital for a dividend to the producer as well as a dividend to society.

5. Conclusions/recommendations

5.1 Significance

Farming for the Future represents one of the most significant global data collection efforts for detailed farm natural capital, business data, and production data. The dataset compiled by *Farming for the Future* in its Livestock Pilot Program is the largest of its kind in the world. It has enabled:

- The development and calibration of natural capital data collection protocols
- Identification of significant positive relationships between natural capital and farm business performance
- The identification of different natural capital benefit pathways that arise from interactions between natural capital and the local farming context
- The development of a natural capital benchmarking module (clickable proof of concept) to guide producers, and their advisors, in decision-making about natural capital investment
- Testing of the statistical power and associated sample sizes required to quantify natural capital – farm performance relationships with 95% confidence.

Beyond the collection and analysis of data, *Farming for the Future* has helped to accelerate and streamline industry adoption of natural capital management and associated opportunities by building capacity and collaboration across diverse networks that include producers, farm advisors, government, philanthropy, industry, the banking and investment sector and others.

5.2 Key findings

The *Farming for the Future* Livestock Pilot Program has provided the first large scale evidence of a positive relationship between natural capital and farm performance. Key findings are summarised below:

- 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.

- We analysed natural capital – livestock enterprise relationships separately for three different ‘types’ of farms that were evident in our dataset, rather than making comparisons between modes (i.e. where conventional farms are compared to ‘regenerative practice’). Each individual farm type showed a positive association with natural capital across some or all of the range of natural capital scores measured. Given that our farm sample was representative of farms present in the broader study area, this suggests that that most farms could improve one (or usually more) elements of natural capital to improve livestock production efficiency (although we note that larger sample sizes and additional analyses are necessary to establish causal relationships).
- We also saw evidence of a ‘trade-off zone’ for some elements of natural capital in some farm types (Ecological Condition and Vegetation Aggregation for productivity benefits; Ground Cover and Connectivity for profitability benefits), suggesting a role for natural capital markets or incentives in a limited set of circumstances.
- We provide a range of deliverables (farm-scale natural capital and benchmarking reports) so that the potential for natural capital management interventions to improve business performance can be explored on a case-by-case basis by farm advisors with their clients, combining information from our benchmarking dataset with their own expertise and local knowledge.
- Delivering insights into natural capital-farm business relationships across a broader range of focus regions and enterprise types would help to drive large-scale industry adoption of improved natural capital management (+38% of farms beyond forecast baseline levels).

5.3 Benefits to industry

Natural capital is now firmly on the global agenda as a priority for governments and supply chains as they interact with the agricultural sector. Global initiatives like the Taskforce for Nature-related Financial Disclosure (TNFD) and Australian initiatives like Australian Agricultural Sustainability Framework (AASF) point to a future where agriculture industry reporting will move beyond emissions to include comprehensive information about biodiversity impacts and interactions.

Farming for the Future is providing measurement protocols, evidence base, tools, and resources for producers to manage their natural capital in a way that builds more profitable and climate-resilient farm businesses. These outputs also provide producers with the capacity to report natural capital baselines, and associated improvements through time, to supply chains, industry bodies and other relevant parties and associated market opportunities. This information can be accessed on the *Farming for the Future* website at Natural Capital Methods Paper – Farming for the Future.

Farming for the Future provides national and public benefits that include:

- Delivery of evidence-based decision-making to achieve growth in agriculture that incorporates consideration of financial, social and environmental sustainability.
- Building producers’ and farm advisors’ capacity and participation in ecological literacy (including detailed natural capital reports) for their own informed decision-making.

- Accelerating the emergence of high fidelity, low cost and harmonised methods of measuring producers' delivery of nature-positive solutions (and supporting Australia's COP-15 commitments, especially around Targets 1 and 10).
- Business engagement across the agricultural supply chain and financial services and supporting enhanced trade opportunities for climate aware Australian farm produce.

Our findings suggest that producers who are seeking to improve their farm business performance can simultaneously provide significant public good increases in the form of carbon and biodiversity (both are conceptually and physically related to the Ecological Condition index used in this study). But we note that *Farming for the Future* is not implying that producers should necessarily transition back to native reference state / condition. Instead, it is used as a key test to the research question by understanding how closely natural capital is related to farm business performance, including if and where a trade-off zone exists. Industry and governments may choose to incentivise producers to move beyond the 'double dividend zone' and into the 'trade-off zone' (natural capital that benefits the public at the cost of current farm business performance; see Section 3.1.2).

Farming for the Future engages the farm advisory/accounting industry as the key pathway to sharing information and insights and collaborates with a diverse network of industry partners. By building capacity across all relevant stakeholders, *Farming for the Future* is catalysing large scale adoption of beneficial land management practices, and helping to build a more financially prosperous, climate-resilient, and environmentally positive agriculture sector for Australia.

6. Future research and recommendations

6.1 Expanding the dataset

To date the, *Farming for the Future* project has undertaken sampling on 130 farms in selected agri-climatic zones in NSW, Victoria, Tasmania and the south of WA. Power analysis[16] undertaken based on data collected to date indicates that approximately 300 farms should be sampled across these regions in order to deliver insights into natural capital farm business performance relationships with the desired degree of statistical confidence (95%). Accordingly, our next research phase will include sampling an additional 170 farms in our existing focus regions.

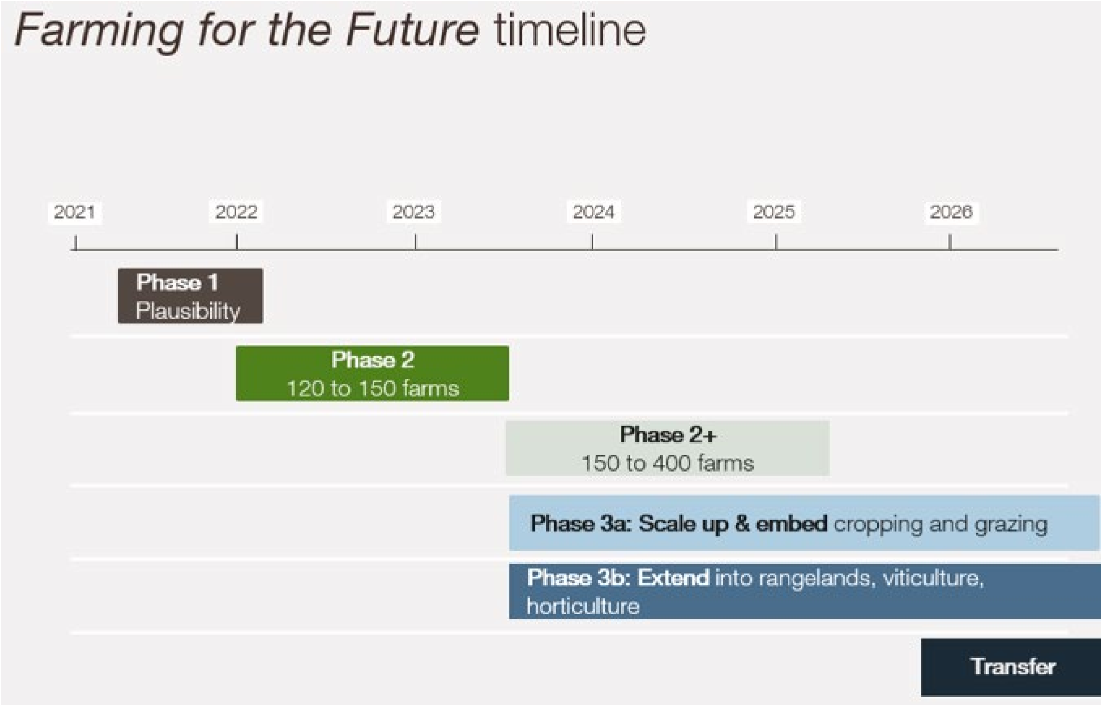
In its next research phase (2024-2026), *Farming for the Future* also plans to expand its reach to include approximately 50 new farms in two new focus regions (one in Queensland and one yet to be determined). As part of this proposed expansion, we will aim to include new agricultural enterprises, like cropping and horticulture operations, in order to provide increase our relevance to the agricultural sector, and to allow for a better understanding of potential for land-use or other natural capital trade-offs relevant to whole-of business performance in mixed livestock-cropping systems.

Over the next 5 years, *Farming for the Future* will continue to expand our research activities to include 1,500 livestock, cropping and mixed cropping-grazing farm enterprises across all Australian states and territories. This will enable us to create a dataset that is representative of the breadth of operation types and farm types, sizes, and locations across the Australian agricultural sector. In doing so it will help build a financially prosperous, climate-resilient and decarbonising agriculture sector for Australia.

Data analysis for this Livestock Pilot has focussed on trends in business performance associated with increasing levels of natural capital <u>within</u> different farm types. This has allowed us to investigate whether and how producers might benefit from improved natural capital, irrespective of their current production mode or starting point. Additional industry-level insights may be gained by comparing performance <u>across</u> different farm types, but this is a much larger question with important implications for production trade-offs (for example between farm size, stocking rates and production efficiency) at the industry-scale. Future analyses based on larger sample sizes will aim to address these important issues.

[16] Power analysis' refers to statistical tests to determine what sample size is required for 95% statistical confidence. See Section 4.2.5 for more.

Figure 35: Farming for the Future: Timeline for expansion.



6.2 Improving data processes across the natural capital sector

6.2.1 Streamlining business data collection

Farming for the Future's Livestock Pilot Program collected very detailed farm business and natural capital information, which included field observations. The data collection involved a significant proportion of manual manipulation, making it relatively expensive to collect and requiring quality assurance procedures.

We note that the data required for the benchmarking of farm productivity and efficiency is largely the same dataset required to estimate GHG emissions on a per kilo of product basis. Feedback from producers about the increasing need to be able to estimate and manage GHG emissions indicates that this is a suitable motivation to improve the quality of record-keeping. We acknowledge the current investments by MLA and others to improve the quality and ease of use of carbon calculators.

We would suggest future research be designed to deliver a significant breakthrough in improving the cost of achieving these estimates by enabling the ag-management packages to incorporate these calculations in their systems so that emissions estimates can be made 'at the push of a button' rather than a separate data entry exercise. The same/similar data can by also used for productivity/efficiency analysis and benchmarking with little/no extra effort. We believe that this might present an opportunity to improve producer business management capability and reduce the burden of reporting.

6.2.2 Streamlining natural capital data collection

Our analysis prior to initiating *Farming for the Future*'s Livestock Pilot Program indicated that publicly available remotely-sensed datasets for natural capital, ecosystems and land types, while fit for their regional and sub-national scale purposes, are not capable of generating credible descriptions of the natural capital of farms. These views were confirmed with feedback from producers who had been early adopters of some of the leading remote-sensing information providers.

Farming for the Future has successfully pilot tested the use of field observations to improve the capacity of remote sensing to accurately identify different types and condition states of farm natural capital. This presents a key pathway to unlocking the emergence of good quality, cost-effective natural capital data services for producers.

To accelerate update, adoption and innovation in technology and service delivery in natural capital measurement, provide producers with choice and switching capability, *Farming for the Future* advocates for methods of natural capital measurement to be openly accessible. We recommend future research be configured to enable the developers of remote-sensed natural capital measures to access field observations by *Farming for the Future* (and others) to improve the quality of the solutions they are developing for Australian producers.

6.3 Putting natural capital on the farm balance sheet

As part of the consultation *Farming for the Future* has conducted during the project we were asked, and agreed, to provide feedback to a number of emerging natural capital measurement and reporting frameworks.

In providing this feedback, we noted the difficulty that these organisations are having in defining measures and metrics that are practical, inexpensive and useful. In conducting our co-design sessions with our data collection partners (Farm Advisors and Accountants and local NRM organisations), we observed a strong level of knowledge and competence with respect to these criteria.

We recommend that future research be designed to enable the involvement of Australian producers, Farm Advisors and Accountants and local NRM organisations in the development of ways to satisfy the information required for environmental performance reporting that is:

- Useful to producers in making decisions about their land use and natural capital.
- Practical and fair – especially with consideration to the possibility of mistakenly blaming a producer for natural capital degradation that is due to factors beyond the producer's control.
- Tested against independent high-quality measures of natural capital such as those used in *Farming for the Future*.
- Enables the development of producer capacity to provide environmental information as a paid service to supply chain companies and financial services organisations to use in reporting their ESG performance and adhere to the IFRS S2 and TNFD requirements.

6.4 Building research capacity and collaboration

The *Farming for the Future* toolset has been built to facilitate the creation of Research Partnerships Program (RPP) that can engage Australian-based research organisations and allow for research partnerships that build a stronger knowledge base on the relationship between natural capital and farm performance. We envisage that this will be established as an initial program in the first half of 2024 subject to funding.

Farming for the Future's proposed RPP seeks to build a coalition between *Farming for the Future* and registered public, non-profit, research institutions. The RPP is targeted at leveraging the capability of researchers combined with the detailed insights provided by the *Farming for the Future* benchmarking toolset data and processes to:

1. Develop a globally significant evidence base around the role of natural capital as a factor of production in farming systems.
2. To leverage research capacity to develop unique and targeted insights that provide for improved understanding of how to invest in natural capital to generate farm benefits.
3. To provide for ongoing improvements in the *Farming for the Future* program that can benefit agricultural industries whilst also increasing environmental sustainability.

Farming for the Future will continue to strengthen its network of contributors, collaborators and delivery partners across all future stages of our program.

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Appendices

Appendix 1: Statistical considerations

Alternative approaches

The analysis presented in this report represents just one of several ways that the *Farming for the Future* dataset could be analysed. We are aware that other analysis approaches are possible, and we welcome the opportunity to apply them to address new questions and provide new insights as our dataset grows.

The presence of analysis alternatives gives rise to the question of how we have selected the specific method we have used in this report. This is particularly of interest given recent attention regarding cherry-picking of results (sometimes called ‘p-hacking’) in the scientific literature.

Farming for the Future is committed to providing information on natural capital -farm performance relationships whether they be positive, negative or neutral. Each possible relationship represents a different opportunity for producers and reveals the nature of the most appropriate intervention (for example investment in core production versus the need for markets or incentives). Understanding the true relationship between natural capital and farm performance will enable more effective intervention and hence a more efficient pathway to a prosperous future for the Australian agricultural sector.

Our reasons for choosing the main techniques used in this study are outlined in the following pages. We have sought to present the associated results as transparently as possible. For each of our analyses we present relationships between farm performance and natural capital for all six of our natural capital indicators. Each natural capital indicator reflects a different stock of natural capital with the capacity to provide a unique set of ecosystem services to supports production of crops and livestock. We see this as akin to agricultural studies that test and compare a suite of possible management interventions in order to identify those that might maximise returns for producers. We hope that this approach will enable producers to identify the types of natural capital that are most important in their own farming system.

We reiterate that the results of our Livestock Pilot Program are preliminary in nature. This report clearly recognises the need for larger sample sizes to provide definitive insights about natural capital – farm performance relationships across larger portion of the Australian agriculture sector. We invite ongoing collaboration with both academic and industry research organisations to achieve this objective.

Our own future research activities will, in the short term, will be focussed on gathering additional insights and collating information about the relationships identified in this report. We will achieve this via ongoing industry collaboration (e.g. by comparison with observations and experiences of producers who have invested in natural capital), and via meta-analysis of the scientific and industry literature. We note, however, that in some cases, supporting information may be difficult to come by; this project was conceived, and has been funded by MLA, Macdoch Foundation and others, because it fills an important gap in current knowledge. It follows that testing and verification of some of the insights we report may only be possible once a larger farm sample size has been achieved.

Data Envelopment Analysis (DEA)

We elected to use DEA for this pilot phase analysis because it is a robust and well-accepted econometric approach that has been used to analyse agricultural productivity for decades. This means it is a technique that allows for collaboration across research teams, encourages cross-referencing of ideas with academics and practitioners, and facilitates communication of findings with key stakeholder in the agricultural industry.

DEA is also an approach that makes best use of our data:

- Our extensive data collection process relating to the quantity of inputs and outputs used by individual producers means that the DEA analyses we have implemented are unlikely to suffer from omitted variable bias (which can otherwise be a limitation of this technique).
- Our data collection process relating to farm management practices, and the associated clustering of our sample into three 'farm types' also facilitates consideration of meta-frontiers (an extension of DEA analysis). We have used insights from a meta-frontiers approach in the design of our farm benchmarking reports that are deliver to producers (via farm advisors) as an outcome of this project. While we have not implemented this approach for research and reporting purposes to date, we will do so in the future.

We have sought to ensure that DEA has been robustly and optimally applied by:

- Ensuring full specification of the production function to avoid omitted variable bias. This was made possible by our collection of very detailed production and financial data from each of our participating farms.
- The inclusion of relevant environmental variables and use of bootstrapping for robust estimation of efficiency scores.
- Inspection of the distribution of efficiency scores. These had a large proportion of the sample close to the production frontier, as is expected for studies of agricultural production.

Future extensions of DEA modelling planned for future phases of the program include:

- Exploration of technical versus allocative efficiency
- DEAs that include natural capital as an input to production, rather than as a second stage analysis. For the purposes of this analysis, we have explored natural capital -efficiency relationships as a second stage analysis using GAMs (see below). We used this approach so that we could draw out and display the marginal effect of natural capital across the full range of values measured without confounding impacts from correlated input variables. Including natural capital as an input in a single stage DEA would require dimension reduction to overcome these challenges, but it would also allow additional insights, including:
    - Estimation of the relative contribution to production made by different elements of natural capital based on marginal rates of substitution identified through DEA benchmarking.
    - Estimation of dollar value shadow prices for individual natural capital elements.

Generalised Additive Modelling

We have used Generalised Additive Modelling (GAMs) as the basis of our second stage analysis comparing natural capital and production efficiency. We selected this technique primarily because it is non-linear in nature. Non-linear modelling enables the identification of curvilinear relationships (like thresholds, convex or concave relationships) so it has allowed us to explore the hypothesis that there may be both a 'double dividend' and a 'trade-off zone' in association with on-farm natural capital (see Section 3.1.2).

One of the key limitations of GAMs is that they do not deal well with correlated input variables. To overcome this issue, we have undertaking testing of natural capital – farm performance relationships on a one-at-a-time basis. This approach was considered preferable to the alternatives of a) exploring outcomes from only a subset of the natural capital indicators measured (a process open to 'cherry-picking') or b) implementing dimension reduction like Principal Component Analysis that diminishes the ability for interpretation and communication of results, but it means that the results relating to the impacts of different natural capital elements should not be treated as additive. Inter-dependencies between natural capital elements will be explored further using multivariate approaches in future research phases.

As noted in Section 3.3.4, the GAM technique is also susceptible to the influence of outliers. Given that our primary objective in this current study is to understand the shape of the relationship(s) between natural capital and farm business performance, we have removed outliers (any point more than 2 standard deviations from the mean). Some of the associated implications for the interpretation of our analysis (increasing confidence in the shape of reported relationships, minimising observed effect sizes) are discussed in Section 3.3.4. Although we have omitted them from parts of this current analysis, we believe that some of our outlying points will be extremely valuable in understanding whether and how the highest levels of natural capital, and associated natural capital management innovations, might benefit farm businesses, and to learn from these cases. Future research activities and approaches will be designed to harness these insights.

Interpreting farm comparisons

Our analysis has used multivariate statistics to identify different 'farm types'. Our subsequent analyses focus on ***within-type*** comparisons. This approach ensures that farms that are compared to one another are a good match in terms of their underlying characteristics (like size, stocking rates and management styles), and means that any differences in performance we observe can be more robustly attributed to difference in underlying natural capital stocks. A full cluster diagram is provided in Figure SA1.

Our clustering approach would make it possible to make *between-type* comparisons – for example, exploring difference in farm performance between intensively stocked versus lower stocking farms. But we highlight that we have not undertaken this type of analysis in the current report. We anticipate that with larger sample sizes this may be a fruitful area of future investigation.

Additional tables and Figures:

Figure SA1: Cluster diagram showing producer scores along two discriminating axes.

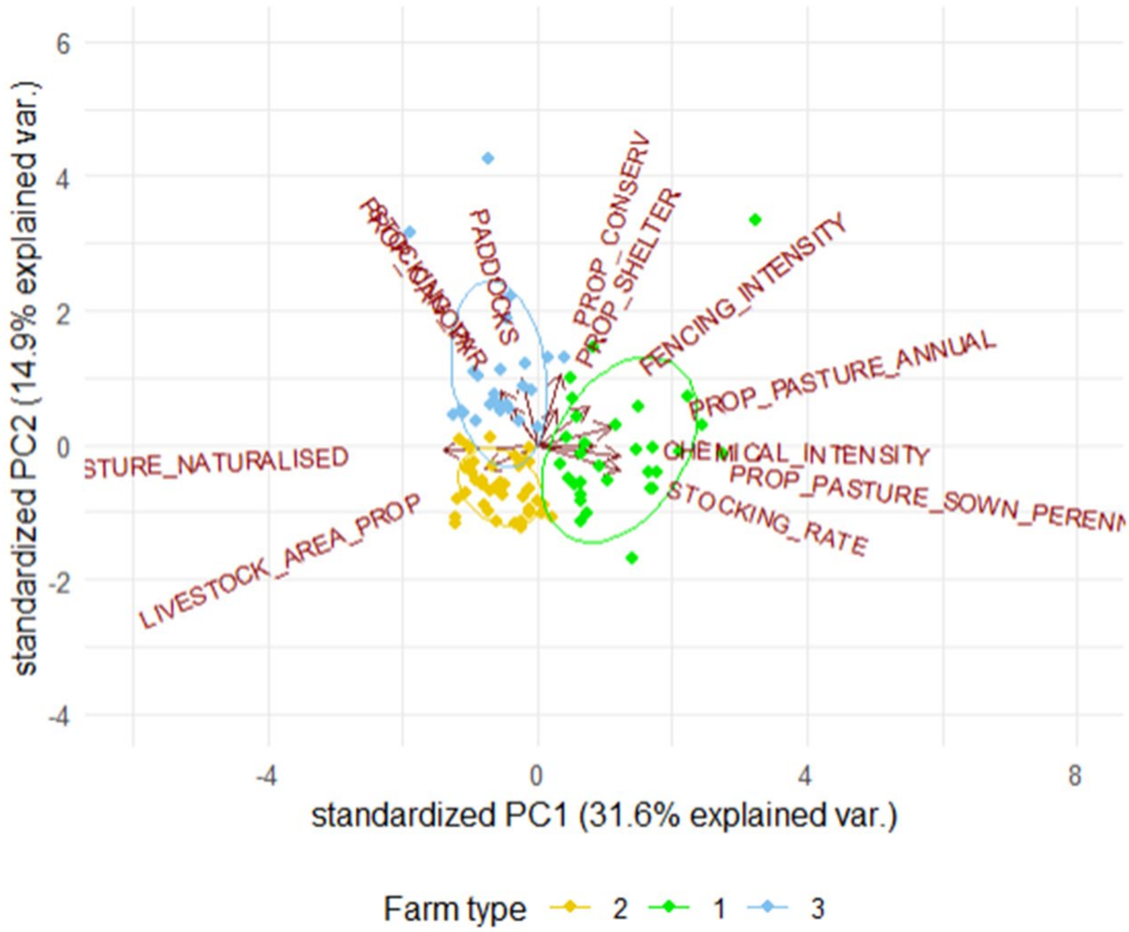


Table SA1: Farming for the Future natural capital indices and significance of relationship with livestock production efficiency, assessed by region. We use the 'edf' value to determine the shape of the natural capital - efficiency relationship[17] and the p-value (p<0.05) to indicate statistical significance. The nature of each natural capital-livestock production efficiency relationship (positive, negative or mixed) is shown in Figure 20.

Region	Natural capital indicator	edf	Ref.df	F	p-value
Central and Tablelands	Ecological Condition	1.00	1.00	5.07	0.03 *
	Aggregation	1.85	1.98	10.01	0.00 ***
	Proximity	1.00	1.00	4.09	0.04 *
	Connectivity	1.74	1.93	1.56	0.20
	Ground cover	1.00	1.00	0.91	0.34
	Forage condition	1.00	1.00	0.49	0.48
South-east	Ecological Condition	1.55	1.79	0.81	0.53
	Aggregation	1.00	1.00	1.22	0.27
	Proximity	1.44	1.69	1.21	0.42
	Connectivity	1.00	1.00	0.24	0.63
	Ground cover	1.00	1.00	0.05	0.83
	Forage condition	1.00	1.00	0.02	0.88
Western	Ecological Condition	1.32	1.54	0.25	0.81
	Aggregation	1.00	1.00	0.01	0.94
	Proximity	1.00	1.00	1.26	0.27
	Connectivity	1.74	1.93	1.56	0.20
	Ground cover	1.82	1.97	4.20	0.01 **
	Forage condition	1.63	1.86	0.75	0.42
	Proximity	1.00	1.00	5.07	0.03

Statistical significance: * = p<0.05, ** = p<0.01, *** = p<0.001

[17] Edf close to 1 indicates a linear relationship, edf close to 2 indicates a 2nd order polynomial relationship. GAMs included a fixed terms relating to FftF sample regions to account for underlying spatial differences. Additional details are provided in Appendix 1.

Appendix 2: Peer review of analytical methods

Research review and research partnerships were identified early-on as key factors that would enable *Farming for the Future* to act as both an impact and a research/knowledge program. Two key pathways were identified:

1. The use of formal 'peer' review mechanisms using researchers acknowledged as being leaders in the field of agricultural and environmental economics in Australia.
2. Building of the toolset in such a way as to enable the creation of research partnerships that could contribute to ongoing improvements and make the *Farming for the Future* toolset a world-leading example of research for impact in agricultural and environmental issues.

Farming for the Future has sought to integrate leading researchers to ensure that the conceptual foundations, methods, and results are regarded as robust and as valuable in terms of adding to the stock of knowledge on the relationship between natural capital and farm performance.

Five formal review sessions were undertaken, one at the beginning of the project (late 2021), two when data definitions and management protocols were being developed (May 2022) and the fourth toward the end of the project (June 2023) and the fifth being a supplementary session specific on forage condition information. Objectives, attendees and high-level outcomes are summarised in Table 22. Full details of the review comments and review responses are available on request.

In addition to formal reviews, when developing the forage condition classifications and scoring mechanism, the project team requested expert input from producers and a grassland ecologist.

Table 22: Peer review and expert consultation workshops – objectives, reviewers and high-level outcomes

	Objectives	Academic reviewers	High-level feedback
1	Testing objectives and basic methods in terms of validity and perceived impact	• Professor Sarah Wheeler (Professor, University of Adelaide, School of Economics) • Professor Tiho Ancev (Professor, University of Sydney, School of Economics) • Professor Chris O'Donnell (Professor, University of Queensland, School of Economics)	The reviewers indicated that the FftF project had a strong rationale, sound conceptual framework, and was seeking to use appropriate data and methods.
2	Testing the proposed methods of measurement of farm natural capital	• Dr Sue McIntyre (ANU, CSIRO) • Dr Anna Richards (CSIRO) • Dr Jacqui Stol (CSIRO) • Dr Suzanne Prober (CSIRO) • Dr Renee Young (WABSI) • Dr Libby Rumpff (Uni Melb) • Dr Peter Wilson (CSIRO) • Mick Taylor (FMG)	The reviewers indicated support for the project design and the use of the State & Transition (S&T) models to improve usefulness. Suggestions were made to improve stratification and consistency of data collection. These were

	Objectives	Academic reviewers	High-level feedback
		• Dr Gerard Grealish (CSIRO) • Dr Tony O'Grady (CSIRO)	incorporated into the methods. Reviewers acknowledged the elusiveness of methods for incorporation of soil health.
3	Testing the proposed methods for collection, security and management of farm business data	• David Lemon (CSIRO) • Dale Ashton (ABARES) • Rob Walter (ABS) • Olga Lysenko (DAWE) • Anwen Lovett (NFF) • Rick Knight (DPIRD) • Warwick Ragg (NFF) • Tiho Ancev (USyd)	The reviewers indicated that they supported the design of the project and the proposed methods for data collection, security and ownership and welcomed the effort being taken to reduce producer burden.
4	Showcasing early results; update on methods and data used/obtained; Introduce proposed Research Partnerships Program and data sharing processes	• Professor Chris O'Donnell (University of Queensland, School of Economics) • Professor David Pannell (University of Western Australia, School of Agriculture and Environment) • Professor Tiho Ancev (University of Sydney, School of Economics) • Professor Oscar Cacho (University of New England, School of Economics)	There was general satisfaction with the direction of the project. The concept of the Research Partnerships Program was noted as a key information pathway to yield greater impact and worthy of expansion.
5	Expert consultation regarding the forage condition classifications and scoring mechanism.	• Professor Wal Whalley (University of New England) • David Marsh – Producer. Landcarer of the Year 2018/19 • Tim Wright – Producer • Gordon Westlake – Producer • Graeme Hand – Farm Consultant	There was general agreement with the approach to the forage condition classification and the resulting classes and scoring mechanisms. Further developments should incorporate landscape function and proportion of summer and winter-growing plants.

Appendix 3: Natural capital management actions by region

Natural capital management interventions associated with high versus low financial performance (measured as top 25% versus bottom 25% of average Production efficiency). Results are shown by sample region. Results for the Western region are excluded due to low (insufficient) sample sizes. Note that these graphs do not account for background factors (other than coarse spatial region) so they do not represent the marginal impact of individual management actions. This would require more complex modelling and a larger dataset (see Section 4.2.6).

Figure 36: Natural capital management interventions and association with high versus low efficiency in the South-east survey region

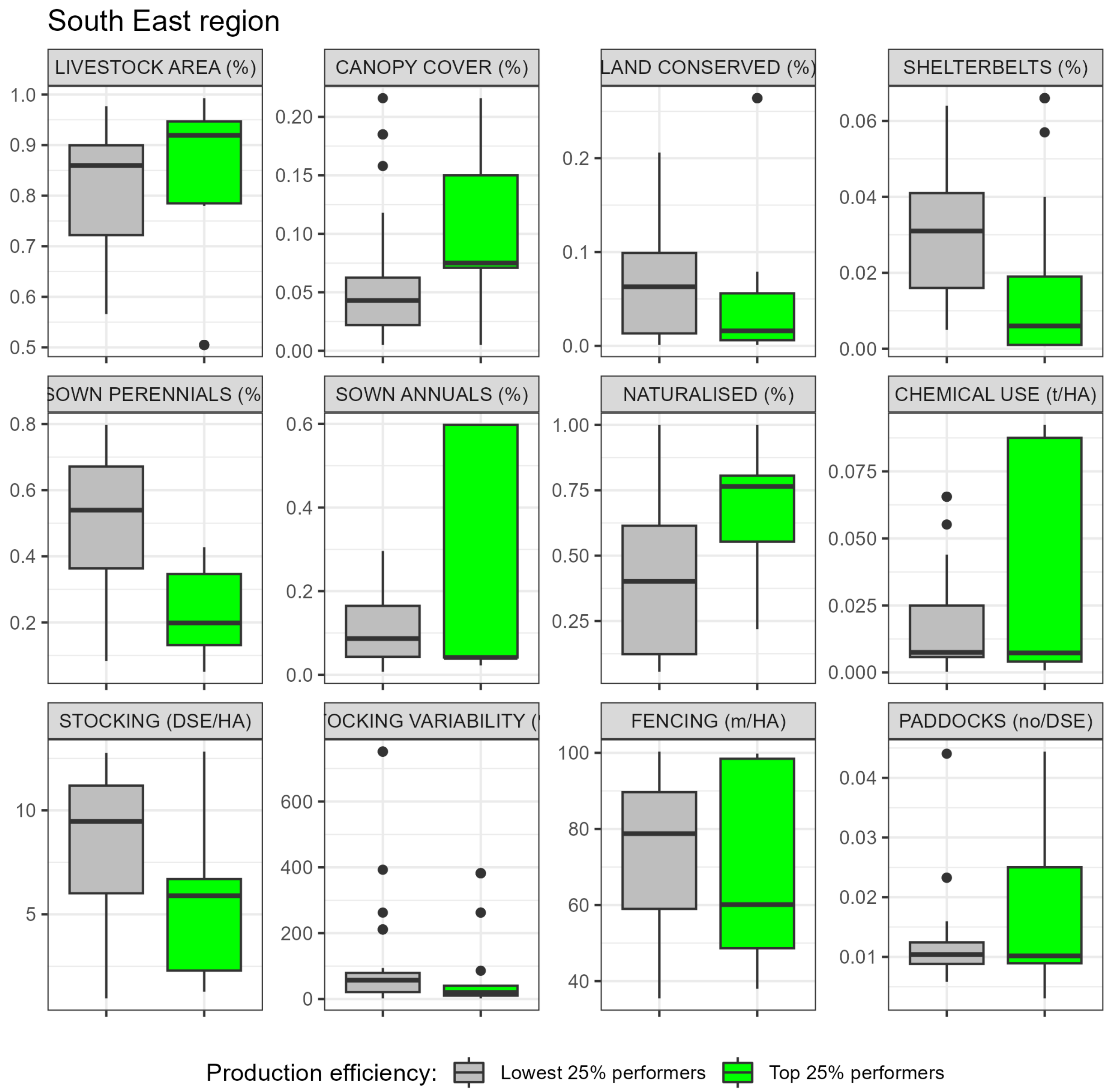
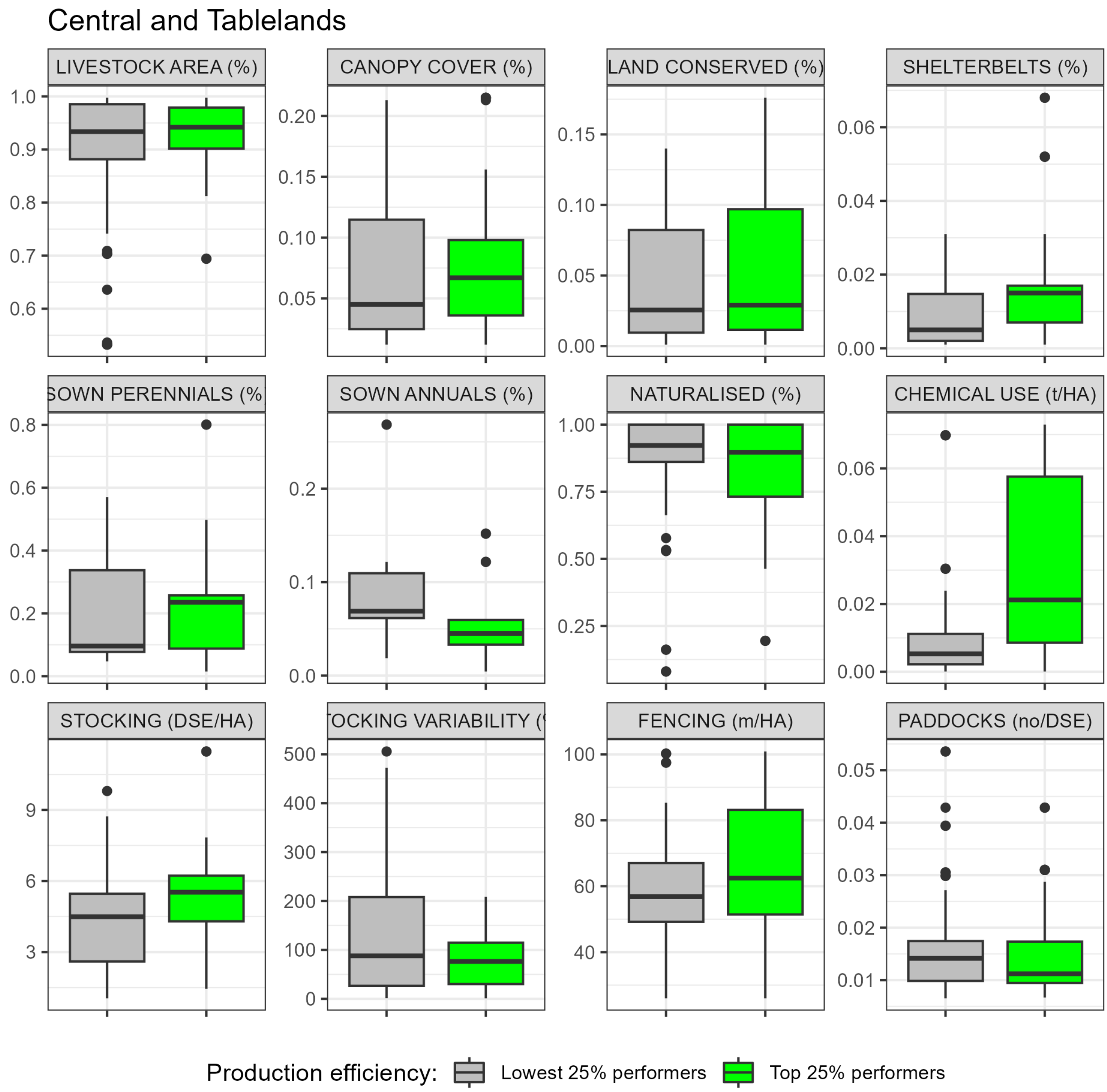


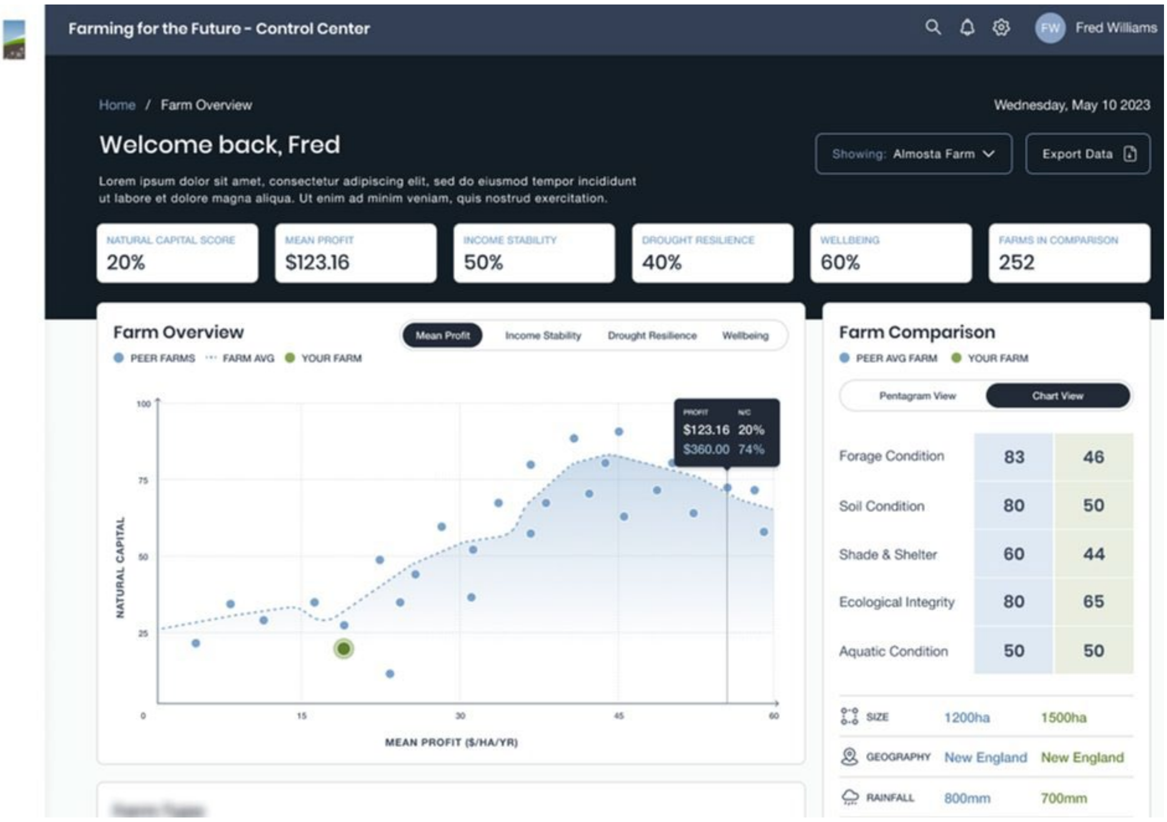
Figure 37: Natural capital management interventions and association with high versus low efficiency in the Central and Tablelands survey region



Appendix 4: Codesign process for Farming for the Future's natural capital benchmarking module

In April 2023, *Farming for the Future* held two co-design workshops for farm advisors, facilitated by To Zero Ventures (www.tozeroventures.com). The aim of these workshops was to explore a 'clickable prototype' of the program's proposed natural capital benchmarking module and to garner feedback about elements of data presentation and prototype design. The clickable prototype used for these workshops is presented in Figure 38.

Figure 38: Clickable prototype, as presented during Farming for the Future's farm advisor workshop

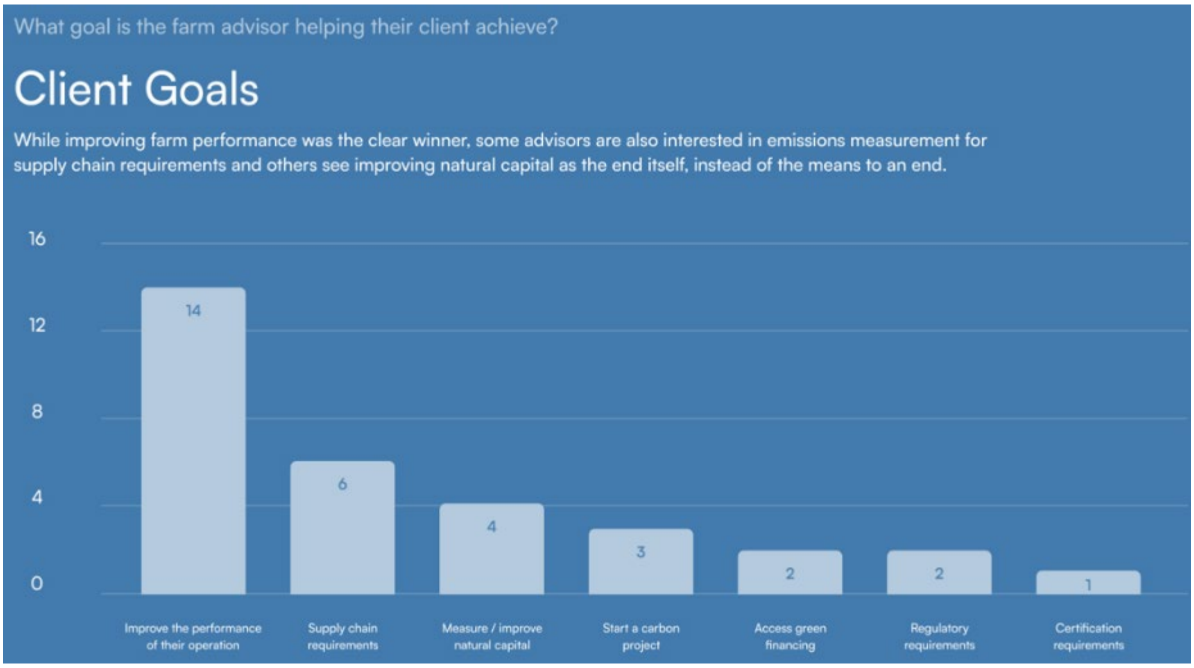


The landholder workshop identified the following key insights:

- Performance improvement is the primary motivation: *Farming for the Future*'s approach of showing natural capital investment as a driver of farm performance resonated with advisers. Carbon emissions tracking was surfaced as another potential value creator.
- Additional information and support is necessary to help producers and advisers bridge the gap between reading the research results and implementing change.
- There is a need to "double click" into indices and performance metrics. Farm advisors understood the link between natural capital and farm business performance based on the information presented but wanted to see the exact definitions and drivers of the performance metrics and natural capital indicators in order to share them with clients.

Additional feedback from the farm advisor workshop is presented in Figure 39.

Figure 39: Advisor feedback from farm advisor workshop exploring a 'clickable prototype' of a natural capital benchmarking module.



Appendix 5: Table of supplementary documents

Reference	Title
A	*Needs analysis_September 2021*
B	*DRAFT FftF_Nat-Cap-Productivity_Working-Paper_Aug2023*
C	*FftF sample balance_M1 report 04072023-final*
D	*Natural Capital Data Collection Methods Master DRAFT v0.2*
E	*Natural Capital Indices_V0.6*
F	*Farm Benchmarking Report (html)*
G	*28.7 Farm Report Template (Natural Capital - Development Mock-up)*
H	*Farming for the Future Case Studies* • *(Producer) Angus and Lucy Maurice. A Balancing Act* • *(Advisor) Mark Gardner: An Advisers View* • *(Landcare Network) Alison Southwell: Return on Investment*
I	*KASA Working Paper – January 2024*

Appendix 6: Monitoring & Evaluation Report (MER) update

This appendix reconciles progress against the broader MER Plan. The first two columns of each table below are copied from the MER Metrics document and the final column represents the *Farming for the Future* status as at date of this final report.

Process and evidence objective (PEO) activity and achievement metrics

PEO1: Measurement processes

Objective: Test and validate methods to estimate the relationship between natural capital and farm performance as a farm benchmarking mechanism
Target audience / recipients: Experts in natural capital, data governance, economic analysis (environment and agriculture) and social studies/psychology.

Pathway	Achievement metric	FftF status
PEO1.1 Development of methods documents for measurement of the natural capital/farm performance relationship **Outputs:** **Methods report PEO1.1[natural capital]** **Methods report PEO1.1[data governance]** **Methods report PEO1.1[economics]** **Methods report PEO1.1[impact evaluation]**	Provision of a **PEO1.1[natural capital]** methods document	Complete: See supplementary document C in Appendix 5
	Provision of a **PEO1.1[data governance]** methods document (research program focus)	Complete: Various data collection, security, and other data governance documents have been co-designed with producers, FAFA, and other experts. Co-design process and outcomes are documented in; • Section 3.2.5 co-design results • Appendix 2 for peer review results.
	Provision of a **PEO1.1[economics]** methods document	Complete: Included in Section 3 of this report.
	Provision of a **PEO1.1[impact evaluation]** methods document	Impact evaluation is an ongoing process. Current impact evaluation methods have been documented at: • Section 3.1.5 Creating systems change • Section 3.4 Modelling landholder adoption • Section 4.3 Project Impact.
PEO1.2 Selection of peer reviewers for research components.	A list of experts chosen by the project team as representing core expertise in the areas of research undertaken in the FftF(MLA) project.	Complete: see Appendix 2
PEO1.3 Peer review by field experts (with indicative support) of methods documents **Outputs:** **review summary PEO1.3[natural capital]** **review summary PEO1.3[data governance]** **review summary PEO1.3[economics]** **review summary PEO1.3[impact evaluation]**	Acceptance of **PEO1.1[natural capital]** as acceptable for the FftF goals by a majority of the selected expert reviewers.	Complete: Methods have been supported by expert reviewers as documented in; • Section 3.2.5 co-design results with producers, advisors, accountants. This also details the Research Adoption and Advisory Committee (RAAC) as chaired by the NFF • Appendix 2 for peer review results • Section 4.3.3.5 documents the natural capital impact summit held
	Acceptance of **PEO1.1[data governance]** as acceptable for the FftFgoals by a majority of expert reviewers	
	Acceptance of **PEO1.1[economics]** as acceptable for the FftFgoals by a majority of expert reviewers	
	Presentation of **PEO1.1[impact evaluation]** to expert reviewers for discussion	

PEO2: Industry integration

Objective: Establish accepted processes that will support integration of benchmarking processes into typical farm analysis activities
Target audience / recipients: Farm advisors/ farm accountants (FAFA), producer participants.

Pathway	Achievement metric	FftF status
PEO2.1 Review, workshops and/or interviews/discussions with FAFA to determine data gaps and existing processes **Outputs:** **FAFA current state report PEO2.1[state report] (data gaps, review of existing processes that link to natural capital farm benchmarking)**	Workshop/interview (dates, summaries) with all FAFA data providers regarding data gaps and summary of existing processes PEO2.1(workshop)	Complete: • Three co-design workshops were held with a mix of FAFA participants. Another three were held with producers. Collectively these covered definitions, data governance, methods, results and required outputs. See section 3.2.5 and 4.3.1.
	Provision of **PEO2.1[state report]** FAFA current state report (natural capital benchmarking) [short report]	Complete: • Various workshop materials have been provided to FAFA participants as part of co-design of benchmarking methods and processes. Methods are detailed in Section 3 of this Final Report. • Also see Section 4.3.1.2 and Appendix 4 for the development of a natural capital benchmarking module (clickable prototype) co-designed with participants.
PEO2.2 Review and testing of processes to support FAFA-based data collection and integration with benchmarking processes with interviews/reviews to assess perspectives on these **Outputs:** **FAFA review report PEO2.2[review report] on approaches to efficient and effective data collection/collation for farm-based natural capital benchmarking.** **FAFA position statement PEO2.2[joint statement] (a joint statement on approaches/principles of farm-based natural capital data collection/collation by FAFA**	Provision of **PEO2.2[review report]**.	Complete: • As described in Section 3.2. Data collection and compilation processes were co-designed and implemented with producers and advisors. Additional data collection templates and guidance documents have been provided to FAFA. • Signed data governance agreements (consent forms) exist between *Farming for the Future* and farm participants that stipulates the role of Farm Advisors and NRM partners, and stipulates types of data to be collected and intended use (including restrictions of use and data privacy).

PEO3: Benchmarking governance

Objective: Describe and assess approaches to data collection, storage, and integration that can provide pathways to implement benchmarking processes.
Target audience / recipients: Farm data experts, FAFA, industry stakeholders, government stakeholders.

Pathway	Achievement metric	FftF status
PEO3.1 Review of approaches to data collection, parsing, and integration for a benchmarking 'platform' in the future Outputs: **Report PEO3.1[benchmarking platform processes]**	Provision of report **PEO3.1[benchmarking platform processes]**	Complete**:** See Section 4.3.3.2 for capabilities of a future benchmarking tool. Also see Section 4.3.1.2 and Appendix 4 for the development of a natural capital benchmarking module (clickable prototype) co-designed with participants. This will enable further co-design for future phases in development of a future operational tool.
PEO3.2 Review and workshops on PEO3.1 **Outputs:** **Workshops, review (and support) of the PEO3.1 review report.**	Records of workshops/interviews on **PEO3** and **PEO3.1** including participation summaries Provision of a review summary **(PEO3.2[review summary])** for **PEO3.1**	Complete: Data collection, storage, integration, and other data governance topics have been co-designed with producers, FAFA, and other stakeholders as documented in; • Section 3.2.5 co-design results • Appendix 2 for peer review results
PEO3.3 A business case analysis of the potential and pathways toward a benchmarking platform **Outputs:** **PEO3.3[business case] a business case review for the potential operation of a farm-based natural capital benchmarking platform**	Provision of the **PEO3.3[business case]** review report	Complete: As documented in various Sections of this report, particularly: • Section 3.4 Modelling landholder adoption • Section 4.1 Producer motivations to invest in natural capital • Section 4.3 Project impact (how to support advisors, producers, and systems activation) – including Section 4.3.3.2 for capabilities of a future benchmarking tool

PEO4 Data collection

Objectives: Collect data that supports the core objectives of the FftF project.
Target audience / recipients: Internal project team.

Pathway	Achievement metric	FftF status
PEO4.1 Collection of Natural capital field data **Outputs:** **A dataset of natural capital field data (not available for publication due to data governance requirements)**	At least 130 farms in NSW, VIC, TAS and Sth WA and with a majority livestock focus have had field (ecological) data collected and collated for natural capital measurement. These farms are the same as those for other components in **PEO4.**	Complete: Field ecological data has been collected and collated for 130 farms. Complete: Remote sensed ecological data has been collected and collated for 130 farms. Complete: Production / financial data has been collected for 130 farms. Complete: final analysis and integrating into benchmarking results for all 130 farms. Complete: Social/behavioural-change data has been collected • Management practice data for 130 farms – showcasing current natural capital related behaviours. • Personal well-being surveys for 90 farms. This will be integrated into future benchmarking results.
PEO4.2 Collection of Natural capital remote sensed data **Outputs:** **A dataset of natural capital remotely sensed data (not available for publication due to data governance requirements)**	At least 130 farms in NSW, VIC, TAS and Sth WA and with a majority livestock focus have had remotely sensed data collected and collated for natural capital measurement. These farms are the same as those for other components in **PEO4.**	
PEO4.3 Collection of Farm production/financial data **Outputs:** **A dataset of farm production/financial data (not available for publication due to data governance requirements)**	At least 130 farms in NSW, VIC, TAS and Sth WA and with a majority livestock focus have had production/financial data collected and collated for natural capital benchmarking/analysis processes outlined in **PEO1.1[economics].** These farms are the same as those for other components in **PEO4.**	
PEO4.4 Collection of Social/behavioural change data **Outputs:** **A data set of social/behavioural data (not available for publication due to data governance requirements)**	At least 130 farms across a range of regions and with a majority livestock focus have responded to a social/behavioural survey outlined in **PEO1.1[kasa].** These farms are the same as those for other components in **PEO4.** This data collected at least once (start of project) to act as a baseline. Preferred collection of data prior to end-point as well to assess KASA changes.	

PEO5 Analysis

Objectives: Undertake analysis of the FftF data to produce initial results allowing testing of benchmarking toolset processes.
Target audience and recipients: All stakeholders.

<table>
<tr><th>Pathway</th><th>Achievement metric</th><th>FftF status</th></tr>
<tr><td>PEO5.1
Statistical testing of measurement processes (power tests, establishment of potential required sample sizes for target parameters, and refinement of benchmarking processes)
Outputs:
PEO5.1[statistical review]</td><td>A ‘farm-based natural capital for farm performance statistical measurement’ review report (PEO5.1[statistical review]) including statistical power/sample size estimates for key descriptive parameters and impact evaluation measures.</td><td rowspan="2">Complete: Statistical benchmarking results are included in (Section 4) as in line with the expert / peer-reviewed methods detailed in PEO3.
• Impact evaluation: Section 4.2.5 analyses the number of samples required to achieve statistical confidence at regional level for different metrics (via power analysis).
• The benchmarking module (clickable prototype) has been developed and sample tested with advisors.
Pending: delivery to all farm participants and further feedback integration.
• Individual Farm Reports have been developed and undergone some sample testing with producers and advisors.
• Pending: delivery of Farm Reports to all relevant participants and further feedback integration.</td></tr>
<tr><td>PEO5.2
Estimation of benchmarking models and collation of results based on model results (a summary and evidence report) and for individual farm-based participants.
Outputs:
PEO5.2[summary report]
PEO5.2[farm reports]</td><td>Accepted models (reviewer and/or peer-review) estimated and reported on for benchmarking analysis (e.g. a working paper with review)
Provision of PEO5.2[summary report]
Records indicating sharing of individual farm reports (PEO5.2[farm reports]) with participating farms
Feedback on individual farm reports (short feedback survey – farm participants)
Feedback on benchmarking results (short feedback survey – FAFA participants)</td></tr>
<tr><td>PEO5.3
Establish linkages to researchers to build capacity centred on FftF objectives</td><td>Research partnerships (informal and formal) established supporting FftF project research objectives including the generation of peer-review papers, training of young researchers (e.g. post-graduate students, post-doctoral researchers, and Early Career Researchers), and presentation of research results at research-related forums.</td><td>Complete: This is complete for the Livestock Pilot Program, noting that engaging and activating the research community is an ongoing effort.
• Section 3.2.5 details the Research Adoption and Advisory Committee (RAAC) as chaired by the NFF
• Appendix 2 for peer review results
• Section 4.3.3.5 documents the natural capital impact summit held
• Section 6.4 describes building research capacity and collaboration</td></tr>
</table>

IMO (Institutional and Market Objectives) activity and achievement metrics

IMO1: Engagement

Objective: Engage FAFA to enable achievement of target sample size.
Target audience / recipients: FAFA.

Pathway	Achievement metric	FftF status
IMO1.1 Engage FAFA participants through workshops and interviews in order to establish interest and support for engagement with the *FftF* project.	Substantial interest, supporting target project farm participation numbers (at least 130 farms) from potential FAFA participants achieved through a variety of engagement methods.	Complete: • Three co-design workshops were held with a mix of FAFA participants. See section 3.2.5 and 4.3.1. • Substantial interest has been obtained from farm participants. FftF is currently oversubscribed at 238 farms (see Section 3.1.5)
IMO1.2 Develop a contract for the engagement of FAFA that enables achievement of the target farm participation goal (at least 130 farms). **Outputs:** **IMO1.2[contract]**	Contract developed that supports the engagement of FAFA participants on the basis of shared value and data governance provisions (**PEO4**)	Complete: • Signed data governance agreements exist between farm and farm advisor participants, stipulating types of data to be collected and intended use (including restrictions of use and data privacy). • Effectiveness of the FAFA participant support is evidenced by data collection and compilation progress detailed in PEO activities (particularly PEO4 and PEO5).
IMO1.3 Communicate with target FAFA participants in order to gain formal support (signing of IMO1.2[contract]) that supports target farm participation numbers.	Contracts signed with sufficient FAFA to achieve target farm participant goal	

IMO2: Design

Objective: Establish collaborative programs that provide for co-design of benchmarking toolset procedures and outputs.
Target audience / recipients: Farm advisors/ farm accountants (FAFA), producer participants, experts (data, natural capital, economics).

Pathway	Achievement metric	FftF status
IMO2.1 Use of workshops on benchmarking approaches and results with FAFA participants and experts, and responses to ideas and concerns indicated in those workshops, to promote 'ownership' and value for farm and FAFA participants.	At program end, more than 70% of participants indicate support for the approach used and findings of the *FftF* project by farm and FAFA participants	Complete: See • Section 4.3.1 supporting farm advisors (particularly Figure 30). This includes the benchmarking module (clickable prototype of a toolset). • Section 3.1.5 that shows FftF is currently oversubscribed by farm participants • Section 3.2.5 of results of co-design workshops with FAFA and farm participants
IMO2.2 Development of a 'farm-based natural capital benchmarking toolset' interpretation and 'narratives' information set for use by FAFA and farm participants to assist in understanding benchmarking toolset outputs. **Outputs:** **IMO2.2[interpretation document]**	There is a more than 70% of participants indicating high level of understanding of benchmarking toolset outputs including interpretation and use to support farm planning/analysis.	

IMO3: Acceptance

Objective: Achieve a broad level of acceptance of the FftF program amongst key producer, industry, market, research, supporting, and government stakeholders.
Target audience / recipients: All relevant stakeholders.

Pathway	Achievement metric	FftF status
IMO3.1 Execution of MLA/ Farming for the Future communications plan *Outputs:* ***Summary report IMO3.1[engagement] of communication efforts (target, type, brief summary)***	A large range of stakeholders have been engaged in communications efforts regarding *FftF*, its objectives, and potential participation/partnership in it.	Complete**:** The communications plan has been developed and has been executed. Communications activities are expected to be ongoing.
IMO3.2 Partnership/interest development to support system-wide engagement in the *FftF* program **Outputs:** **Summary report IMO3.2[partnerships] indicating formal and informal partnerships supporting FftF over the project period**	There is a high level of indicative and actual support for continuation of the *FftF* program amongst non-farming stakeholders.	Complete**:** Multiple partnerships have been signed during the Livestock Pilot Program and other systems activation pathways developed: • See Section 4.3.3 supporting system activation. • Attendance at the Summit was diverse and enthusiastic (see Section 4.3.3.5)
IMO3.3 General communications and marketing efforts to engage with a general population through widely-consumed media/marketing channels **Outputs:** **Summary report IMO3.3[general comms] indicating published media and other marketing articles targeted at the general population**	*FftF* has been successful in engaging the general media landscape in promoting the core messages of the program.	Complete**:** The communications plan has been developed and has been executed. This has included • Various written media channels • Attendance at various events • Hosting of the Summit (section 4.3.3.5) • Podcast development Communications activities are expected to be ongoing

IMO4: Engagement

Objective: Capture engagement data at a regional, agricultural system, stakeholder, and other relevant basis. **Target audience / recipients:** All relevant stakeholders.

Pathway	Achievement metric	FftF status
IM04.1 Data capture from 'Review, share and learn' workshops to describe participants, learnings, engagement, and perspectives outcomes from workshop participation. **Outputs:** **Workshops summary report IMO4.1[knowledge]**	Technical and engagement workshops focused on producers, FAFA and other extension or producer support groups provide for an increased understanding of the concept of 'natural capital' and its potential role as a factor of production. These outcomes are summarised in **IMO4.1[knowledge]** based on end-of-workshop short questionnaires.	Complete: See documentation in; • Section 3.2.5 co-design results with producers, advisors, accountants. This also details the Research Adoption and Advisory Committee (RAAC) as chaired by the NFF • Appendix 2 for peer review results • Section 4.3.3.5 documents the natural capital impact summit held

PKO Producer KASA Objectives activity and achievement metrics

PKO1 Measurement

Objective: Establish a measurement/ monitoring program for changes in KASA elements, behavioural intentions, and behavioural change.
Target audience / recipients: Experts, peer-review. Note: Design of KASA monitoring program provided by Heuris (background IP).

<table>
<tr><th>Pathway</th><th>Achievement metric</th><th>FftF status</th></tr>
<tr><td>PKO1.1
Description of behavioural intentions, actions and antecedents models
Outputs:
PKO1.1[review report]</td><td>Provision of PKO1.1[review report]
Note: This feeds into PKO2.1</td><td rowspan="3">Complete: A FftF KASA Framework has been developed – see ‘FftF_KASA framework 05_07_2022.docx.’ This covers:
• The pathways and metrics in PKO1.1 and PKO1.2 – including a Theory of Intended Behaviour.
• The development of a multiple social/behavioural-analysis surveys as a method to monitor and evaluate KASA of project participants (covering PKO1.3).

For additional information the following sections of this report, documents behaviour change considerations;
• 3.1.5 Systems activation
• 4.1 Producer motivations to invest in natural capital
• Section 3.4 Modelling landholder adoption</td></tr>
<tr><td>PKO1.2
Description of concepts regarding behavioural interventions from PKO1.1 and their linkages to increasing natural capital
Outputs:
PKO1.2[concepts report]</td><td>Provision of PKO1.2[concepts report]
Note: This feeds into PKO2.2 & PKO2.3</td></tr>
<tr><td>PKO1.3
Description of concepts and approaches to using the behavioural intentions/expected behaviours model to generate project evaluation tools.
Outputs:
PKO1.3[evaluation concepts]</td><td>Provision of PKO1.3[evaluation concepts]
Note: This feeds into PKO3.X</td></tr>
</table>

PKO2 Behaviour

Objective: Apply the KASA program to measure and describe KASA elements and changes in those elements including potential intervention 'control points' to identify pathways to increasing farm-based natural capital.
Target audience / recipients: Producers, FAFA

Pathway	Achievement metric	FftF status
PKO2.1 Estimation of behavioural intentions/change models and collation of results into a summary report **Outputs:** **PEO2.1[summary report]**	Accepted models (reviewer and/or peer-review) estimated and reported on for the KASA component (e.g. a working paper with review) Provision of **PEO5.3[summary report]**	Complete: The following KASA social/behaviour surveys have undergone expert review namely: • Management practice data collection and compilation methods reviewed by FAFA (see Section 3.2.5 and 4.3.1) and peer review panel (Appendix 2) • Optional wellbeing survey reviewed and approved by the University of Canberra Regional Well Being survey team.
PKO2.2 Identification of key 'control points' for implementation of natural-capital increasing farm management activities by farm managers. This will be in the form of a summary report that seeks to feed into PKO2.3 (below). **Outputs:** **PKO2.2[summary report]**	Provision of a working paper/journal paper (reviewed) that seeks to establish the validity of treating the chosen KASA model as a tool allowing identification of behavioural 'control points' for assisting producers to increase their intentions regarding increasing natural capital.	• • We provide a working paper that summarises our KASA approach in Supplementary document I.

PKO3 Learning

Objective: Develop a program learning, adaptation and impact evaluation program focused on KASA elements
Target audience / recipients: FftF project operations

Pathway	Achievement metric	FftF status
PKO3.1 Trial of a program learning, adaptation and impact evaluation tool. This tool will support descriptions of project impact including potential linkages to formal impact evaluation methods for establishing the causal validity of estimates of relationship between natural capital and farm performance. **Outputs:** **PKO3.1[summary report]** **PKO3.1[evaluation concepts working paper]**	Provision of **PKO3.1[summary report]** Provision of **PKO3.1[evaluation concepts working paper]** Review of **PKO3.1[evaluation concepts WP]** by a small set of invited expert reviewers.	Complete**:** Management practice data collected in PKO3 has been analysed as part of benchmarking results. See related preliminary results in Section 4.2.4. Preliminary results have been reviewed by an invited set of experts. See: • Section 3.2.5 for co-design results with producers, advisors, accountants. This also details the Research Adoption and Advisory Committee (RAAC) as chaired by the NFF. • Appendix 2 for peer review results • Section 4.3.3.5 documents the natural capital impact summit held which included presentation and discussion of management practice results.
PKO3.2 Design of a project-specific framework for ongoing evaluation of KASA components. **Outputs:** **PKO3.2[design framework]**	Provision of the **PKO3.2[design framework]** report. Review of the **PKO3.2[design framework]** report by a range of experts and stakeholders.	Complete**:** The documented KASA Framework, benchmarking methods and outputs, as well as the respective social/behavioural surveys collectively allow for ongoing evaluation and reporting of KASA elements.