Project Report

Natural Capital Accounting Learning Case Studies Phase 1

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Executive Summary

Agricultural enterprises produce food and other benefits to society by using and managing natural capital including water, soil, fungi, plants, animals, bacteria, minerals (see Figure 1 for an illustration). The quality, productive capacity, dependability, and sustainability of natural capital is significantly influenced by its inherent qualities, seasonal quality and variability, the effect of invasive pests and diseases and how farmers manage it. It is well-accepted that the quality of natural capital influences the productivity and profitability of farms and the quality of agricultural products, but ‘you can’t manage what you can’t measure’. At present, we have no systems to measure and record the quality of agricultural natural capital to help farmers manage it.

Measurement systems should be designed and implemented to help farmers detect whether they are ‘consuming’ their natural capital or whether they are improving it. They should also be designed to associate this information with farm financial performance so that farmers can make judgements about the type and configuration of natural capital that best supports their personal and business goals and to assess the potential returns from investment in or maintenance of natural capital.

Natural Capital Accounting[1] (NCA) is being developed to provide a solution. In the same way that financial accounting helps businesses to account for financial and produced capital, NCA aims to provide a way for farms to account for their natural capital as assets of their business. It aims to give them:

- information about the contribution of these assets to the enterprise,
- information about changes to natural capital that might affect the future productivity and profitability of the enterprise, and
- a way to communicate their management of natural capital, the value of investments they make in it, and their contribution to the public good (including resources for future generations).

NCA describes a set of concepts, guidelines, and systems to record information about natural capital and account for (explain) how natural capital contributes to economic (financial and non-financial) outcomes. It is founded on an understanding of the different elements of agricultural natural capital that supports the operation of commercial producers and is not confined to ‘regenerative’ or ‘ecologically intensive’ agriculture.

To date, much of the research and development in NCA is occurring ‘top down’ by national accountants, economists, ecologists and academics with a priority for compiling accounts at sub-national and national level under guidance by the United Nations’ endorsed System of Environmental Accounting – Experimental Ecosystem

1 Also known as environmental-economic accounting (EEA).

Accounting standard (2021) (UN SEEA EEA 2021). The Natural Capital Accounting Learning Case Studies (NCALCS) project aims to complement the top-down work with information needs analysis and accounting designs for use by farmers.

The NCACLS program gives farmers and their advice networks (including their financial accountants and farm advisors) and opportunity to contribute to the development of NCA.

This report describes the activities of phase 1 of the NCALCS project. It summarises the methods used to capture information requirements and accounts designs and blend these with the concepts and standards described in the UN SEEA EEA (2021). The results from farmer interviews and workshops are described along with summaries of literature reviews and other analysis. A set of reports and accounts was designed to help farmers to assess and report their natural capital position, their natural capital performance since the prior period and natural capital stewardship. These were populated with data compiled from financial and operational records that are already collected for management purposes, and from spatial analysis (mapping) and field observations. Data collection was designed to help the project team to provide feedback on the design of the reports and accounts and the processes of data collection and compilation. In other words, the data collection was designed to maximise the learning about natural capital accounting at farm level, not to provide a comprehensive or high confidence evaluation of the quality of natural capital of each farm.

Phase 1 of the NCALCS program has generated some significant insights for future development of natural capital accounting. These include that the concepts in the UN SEEA EEA can be applied and have the potential to work quite well to reflect the multiple economic benefits being generated by farms, but some adjustment should be made to provide information at the scale required by farm enterprises. The delineation of ecosystem assets and the methods for accounting for ecosystem condition also work well but may need a combination of adaptation and new technology to make them cost-effective to apply. We suggest that the coverage of information suggested by the UN SEEA EEA has good alignment with the generalised requirements of agricultural sustainability programs reviewed for this project.

We observe that there is significant potential for monetary valuations of ecosystem assets to help farmers plan their use of natural capital and for citizens to learn about the economic value of the public goods generated by farmers and the private cost to farmers of this generation. We therefore make the strong recommendation that research aimed at developing methods for monetary valuation of ecosystem assets includes an explicit aim to generate information for natural capital management and investment at farm level.

NCACLS Phase 1 experience suggests that many of the foundational elements of

Ecosystem Asset Accounts (type and condition of natural capital in physical terms) for Farm-level NCA can be compiled from existing data by someone with GIS and ecological skills. Further, with the present speed of development of technologies, we anticipate that in the near term, the range of information that can be compiled using remote sensing and GIS systems will increase dramatically. However, despite NCA mostly just requiring information that would be reasonably expected to be collected and retained by farm managers, we found that it was not as simple as it should be for farmers to produce this information. The operational information required to quantify the natural capital (environmental) performance reports such as GHG emissions and resource-use efficiency is mostly already collected, but presently requires manual collation and calculation. However, we speculate that agricultural management and accounting packages could be modified to automate more of this to make it less onerous to collect and more useful.

In the absence of standards for presentation of NCA, the designs presented in NCALCS are loosely based on financial performance reports and the published outputs of other SEEA EEA projects. Accordingly, we recommend that future phases of this project (and other projects working in this field) should apply human-centred design and other techniques to work out how to present the information make it most useful to farmers and their stakeholders. This should include the development of engaging summaries to be incorporated into the presentation of farm NCA and NC Reports.

Finally, the project was determined to realise the opportunity presented by identifying 'empty-cells' – information that would be desirable in NCA, but which presently cannot be compiled either due to budget, scientific, or technological reasons. Empty cells include quantification of ecosystem service delivery and the estimation, in monetary terms, of the benefits ecosystems generate for farm financial performance and to public goods. These are particularly important to achieving the farmer-consumer reciprocity sought by this program. Other empty cells include information about private benefits to production, or private benefits to farm enterprises that are important inputs to decisions farmers make about their natural capital in the short and the medium term. While the coverage of ecosystem services in the UN SEEA EEA broadly reflects the farmers' perception of the services they generate as part of their enterprises, farm accountants and farmers will need to be able to draw on methods to quantify the values in monetary terms as well as physical terms. These should probably be designed to help farmers estimate the monetary values of ecosystem services in terms of their contribution to income or costs to the enterprise and also to consider the monetary value of the broader economic benefit to society.

The key learnings and feedback from our farmer participants are summarised in Table I, along with future research and investigations suggested for future programs.

Table I: Key learnings from the farmer participants

Key Learnings	Future actions / investigations
There are still plenty of 'empty cells'	Ongoing research to fill the gaps
Measurement and reporting of the NC condition raised the farmers' awareness, which can then feed into ongoing decision making	Continue to evolve the presentation of the information in the accounts to maximise this
Accounting for soil condition is complex and the existing methods are not satisfactory for the purposes of NCA compilation	More work to identify pragmatic and appropriate representative soil measurements for the purposes of NCA, along with methods for compilation to condition scores for cropping assets
The use of ground cover metrics as a proxy for soil regulation and protection services does not necessarily reflect the functions where high biological activity lead to rapid composting of litter	Further investigation of the balance between higher biological activity (leading to lower groundcover) and the impact on protection and regulation functions. Inclusion of farms which characterise this as part of spatial analytics models using biomass to predict soil functions
Historical data collection for farm production and financial information is time consuming and can be a barrier to participation by a farmer.	Documentation of data requirements for farmers/farm accountants so that the information can be recorded at the time of data generation (throughout the year). The required level of detail is recorded in the financial accounts. See Appendix.
State & Transition Models appear to be a pragmatic and useful way of characterising ecosystem type and state	Development of additional S&TM models for a broader range of biomes
Resource Use Intensity reporting limited usefulness without a benchmark for comparison	Ongoing development of industry and regional specific benchmarks for metrics such as GHG emissions, Nitrogen and Phosphorus use, water use
The methods to assess nutritional quality of foods produced under different management regimes is lacking.	Further work to identify key measures for nutritional density of different food types, along with a method to compile this information into the accounts

Subsequent phases of NCALCS will build on the work in Phase 1 to increase the participation of farmers, accountants, advisors, ecologists, and researchers in the development of farm-level NCA. Due to informal agreements for cooperation with other projects working on similar projects, subsequent phases will be able to learn from and with experts in other states of Australia and from countries overseas

Acknowledgements

This report and the learning case studies associated with it have been developed with a collaborative effort by Perth NRM, Stuart McAlpine, Tom Mitchell, Di & Ian Haggerty, Warren Pensini, Michelle McManus and Integrated Futures (IFPL). In turn, we have drawn on a wonderful body of work by academics and practice leaders in agriculture, ecology and NCA. We particularly acknowledge the collaboration and support provided by the La Trobe University Farm-scale Natural Capital Accounting project in terms of methods sampling. IFPL would like to express our appreciation for the opportunity to work with collaborators who have contributed so much of their time, expertise and passion to agriculture and to acknowledge the funding from CommonLand and Perth

NRM that made this project possible. We hope to see a number of projects address the opportunities we outline in this report and to expanding the number of collaborators working on NCA.

Disclaimer

This report has been prepared to enable people to learn about NCA and how it is emerging to assist people to manage and invest in natural capital and to participate in its further development. The report is written as far as possible in plain English, with active voice to make participation in NCA development, preparation and use accessible to many people - especially farmers, farm accountants and farm advisors. As a result, it doesn't conform to the style that might be expected of a peer-reviewed published journal article. Citations for references used are provided to enable interested parties to access resources for further study.

Phase 1 (this report) of the NCALCS project aimed to maximise learning about natural capital accounting at farm level but not to form a detailed view of the natural capital of each farm or its relative environment-economic performance.

This report has been prepared by Integrated Futures Pty Ltd (IFPL) for the purpose of demonstrating how natural capital accounting principles may be applied to individual farms. IFPL advises that the information and recommendations contained in this publication comprises general statements based on informal research and published and other literature. IFPL advises that such information may be incomplete or unable to be used in any specific situation. This report and case studies associated with it uses simulated data and data provided to IPFL by third parties, and whilst IFPL has exercised due care, skill, and diligence in preparing this report IFPL does not warrant the accuracy of data provided to it, or the accuracy of any conclusions drawn in reliance on the data. This report does not constitute financial or investment advice and should not be relied upon for this purpose. To the extent permitted by law IFPL accepts no responsibility for any loss, claim or liability incurred by any party in connection with this report.

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Introduction

Natural Capital in agriculture

Natural Capital is the stock of renewable resources including soils, plants, animals, air, water, and minerals that provide goods and services that humans use to meet their needs. In agriculture, natural capital includes the soils, pasturelands, croplands, woodlands, forests, riparian areas as well as the above and below ground water resources used in production of agricultural products and services (Figure 1). Agriculture uses natural capital to produce products (private goods) such as crops, wool, and livestock for sale. Depending on the type, extent, location, and condition of different elements of natural capital, farm businesses have different production options and different potential for productivity, reliability, profitability, and sustainability.

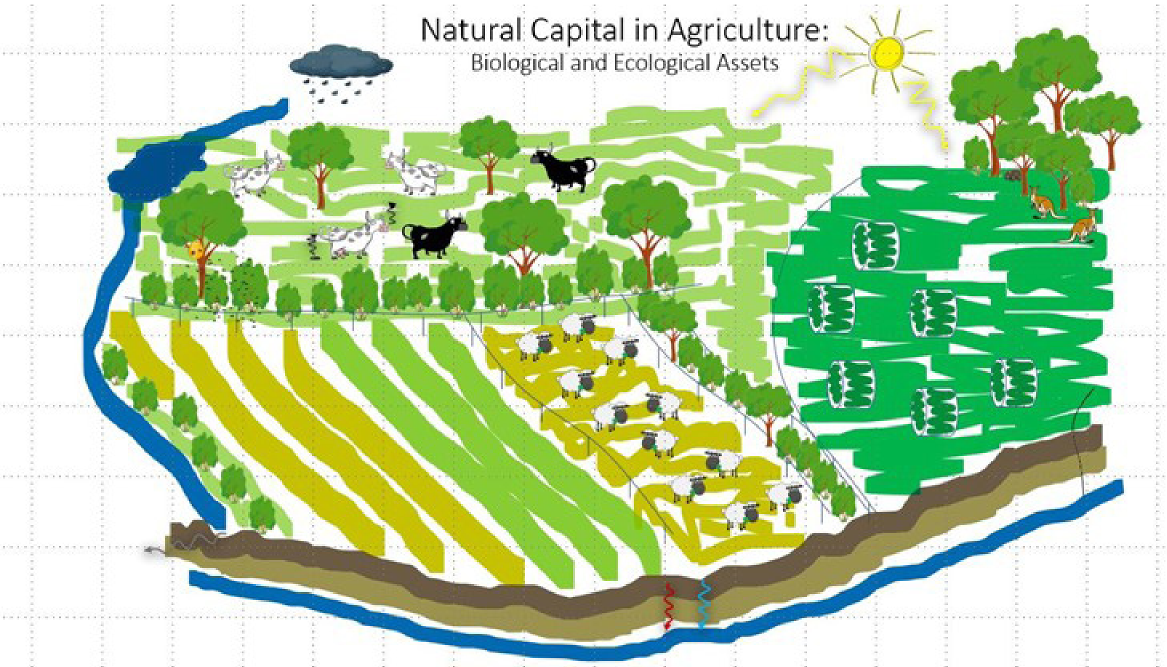

Figure 1: Illustrative view of Natural Capital in Agriculture. In this project, a farm's natural capital includes its productive or intensively managed areas such as orchards, vineyards, croplands and pasturelands.

In many cases, good management of natural capital produces both private and public benefit. For example, maintenance of productive capacity of land has benefits for today's farmers as well as future generations of farmers. Good grazing practice can increase productivity and dependability of pastures as well as increase pasture and soil biodiversity, increase soil carbon, and avoid soil erosion and air and water pollution. However, sometimes the maintenance of natural capital causes a short-term reduction of the farmer's income from agricultural goods.

Under the present Australian accounting standards (AAS)[2], agricultural businesses tend to only account for biological assets like livestock, harvested crops, orchard trees, vines and timber plantations. These standards don't presently provide guidance for how to account for other forms of natural capital such as pastures, soils, shelterbelts, wetlands and woodlands. This means that the contribution they make to the environmental, social and financial performance of an agricultural enterprise is only informally recognised. In this situation, farmer investments to maintain or improve natural capital appears to reduce the financial performance of the business.

NCA is emerging to correct this situation. In multiple projects in Australia and around the world, people are drawing on the United Nations System of Environmental-Economic Accounting (UN SEEA EEA)[3] which is being developed to enable countries to include natural capital in their national accounts and consider them in analysis and planning for economic and social wellbeing. NCA applies the concepts and principles developed in the UN SEEA EEA (2020) and adapts these to the appropriate scale to be useful to farmers and their stakeholders. It also draws on the financial reporting concepts and standards already used by agricultural accountants and the knowledge farmers and farm advisors hold about agri-ecological systems and good management practice.

In addition to natural capital accounting approaches, many organisations around the world are applying integrated reporting frameworks to help them to measure, manage and improve their business and supply chains interactions with natural capital and communicate non-financial information about environmental factors. These frameworks include the Natural Capital Protocol (NCP) and the Environmental Profit & Loss (EP&L) (and many others).

Objectives of the learning case study program

To date, most of the activity in sustainability accounting, reporting and certification is being driven 'top down' from by business leaders, economists, statisticians, researchers, and large corporations. In contrast, the Natural Capital Accounting Learning Case Studies (NCALCS) program is a farmer-centric program that aims to establish a Natural Capital Accounting framework and data platform that meets farmers' needs for information to help them measure and manage natural capital. This includes the aspiration of supporting farmers to negotiate with their supply chains for more equitable sharing of the cost and responsibility for environmental performance, and a share of any consumer premiums for better environmental performance. Associated with measurement and management of natural capital, NCALCS also aims to support informed public and industry investment into good land-stewardship in agriculture

2 AAS 141 – Agriculture, AAS 161 Property, Plant and Equipment, AAS 13 – Fair Value Measurement, AAS 137 – Impairment. Available from www.aasb.gov.au

3 UNSD, "System of Environmental-Economic Accounting - Ecosystem Accounting: Draft for the Global Consultation on the Complete Document," (New York2020).

Accordingly, the objectives of the NCA Learning Case Studies (NCALCS) program are to establish a natural capital accounting framework and data platform to:

- measure and manage natural capital,
- increase farmer benefits from investment and management of natural capital,
- improve resilience and productive capacity,
- assure sustainability of farming systems,
- support informed public and industry investment into good land stewardship,
- build farmer-consumer reciprocity,
- link natural capital qualities to food qualities.

The NCALCS program has three phases:

- Phase 1: Pilot (this report) – aimed to develop a set of 'learning case studies' for NCA to learn:
    - about what happens when we apply the guidelines in the UN SEEA EEA at farm-scale,
    - how NCA might be designed to support farm managers to measure and manage their natural capital and to detect and avoid degradation of natural capital, or make investments in it and to assess the sustainability of their enterprises,
    - how to communicate the environmental-economic benefits delivered by the natural capital of a farm in combination with the stewardship of the farmer,
    - about needs for research and technology development to enable accounting information that is useful to farmers and cost-effective to collect and compile.
- Phase 2 – to use the pilot to develop an agreed-to NCA framework. This will involve engaging with 30 farming entities (including horticulture, grains, livestock, pasture, pastoral and if possible First Nations farms). These participants will build on the learnings from the pilot phase by testing and refining the framework.
- Phase 3 – aims to extend this broadly to agriculture in Western Australia and other states and territories.

Methods

This section describes the approach we used for the Phase 1.

The Phase 1 project team consisted of:

- Broadacre and horticulture farmers who are deliberately investing in natural capital that underpins their operations to produce healthy, high quality

products for food, fibre, and beverages,
- Natural Resource Management leaders who aim to support improvements in natural capital management and investment to assure natural resources for continued food quality and security,
- Consultants who are researching and developing ways of adapting the corporate financial accounting standards and the UN SEEA EEA to satisfy the natural capital information needs of farmers and their stakeholders.

To contribute to the objectives of the NCALCS program, Phase 1 aimed to design a natural capital accounting and reporting system that supports management and stakeholder decisions about the natural capital of a farm enterprise and that aligns with the UN SEEA EEA (2020) and the structure described by the Natural Capital Protocol (NCP)[4].

The approach to farmer-centric NCA designs drew from principles of several frameworks including human-centred design, the value proposition canvas[5], the notion of the whole product[6] and on substantial ecological-economic, natural capital accounting and sustainability reporting literature.

We took the view that a farmer-centric approach to NCA would design it to solve problems farmers are having with relating how the natural capital of their farms and their management of it relates to the financial, environmental, and social performance of their businesses and how to communicate their stewardship of natural capital to external stakeholders. These problems and questions were described by the participants in co-design workshops and individual interviews and supplemented by reviews of published literature and case studies. In addition to scientific publications, case studies of farms considered as environmental leaders and reviews of the requirements of agricultural sustainability certification programs were used to indicate the types of information that were considered relevant for reporting.

Two co-design workshops were held over a period of three weeks. Additional individual consultations were used to supplement these. These explored:

1. The types and characteristics of natural capital on the case study farms and why the farmers manage it to have these characteristics,

4 Capitals Coalition, "Draft Teeb for Agriculture and Food: Operational Guidelines for Business," (Online2020).

5 Described in Steve Blank et al., "Value Proposition Canvas," (2013); Sarah Nolet and Cass Mao, "Challenges and Opportunities for Effective Value Proposition Design in Australian Agtech," (Sydney, Australia: AgriFutures National Rural Issues, 2018); Cara Stitzlein et al., "Participatory Design of Digital Agriculture Technologies: Bridging Gaps between Science and Practice," *Rural Extension & Innovation Systems Journal* 16, no. 1 (2020); Cara Stitzlein and Martijn Mooij, "Design for Discovery: Helping Australian Farmers Explore Their Options in a Government Sustainability Program through User Centred Design" (paper presented at the Human Factors and Ergonomics Society 2019 Annual Meeting, Seattle, Washington, USA, 2019)..

6 Jeffrey Schmidt, "Whole-Product Concept," (2010).

2. The role that natural capital plays in generating economic benefit for the farmers and for society more broadly.
3. The purpose that NCA should serve in supporting farmers to manage natural capital and be recognised for good management.

Workshops encouraged participants to describe the logic of how the different types of natural capital supports their businesses and generates benefits for society more broadly. The workshops and interviews included:

- describing the natural capital types and their role in production and land stewardship,
- proposing some possible ways that the value of natural capital could be quantified, and
- proposing ways in which the information may be presented to make it useful to producers, including making it useful to producers when engaging with their stakeholders.

These were synthesised into logic tables[7] that mapped the types of natural capital to the economic benefit to farmers and to society more broadly. This exploration helped to capture some features and value propositions for natural capital accounting and reporting so that it could be designed to successfully communicate the way in which natural capital contributes to agricultural production and environmental protection and what farmers are doing to manage it.

Some initial design ideas for the scope and design of the natural capital accounting and reporting system were presented to participants for comment. It was emphasised that the tables and ideas presented were initial ideas and that feedback and critiques were welcomed in the context of the objectives of this project. These were incorporated into the individual case studies prepared by farmers which in turn were used for further feedback.

The team resolved to embrace the spirit of the project to promote learning about natural capital accounting. The project was conceptualised as not so much an exercise in quantifying natural capital but learning about natural capital accounting for Australian farms. This involved learning about:

- the purpose of farm-level NCA, who prepares them, who uses them, how are they used,
- the scope of them, who owns the data, where should it be stored,
- how to (practically) produce estimates to fill the accounts including how to use farm information systems and publicly available data, how to brief ecologists and other consultants for field observations,

7 Following UN SEEA EEA (2020) Table 6.2

- how to assess whether natural capital is being sustained or consumed,
- how to quantify and communicate the contribution that natural capital makes to farm enterprise and to society more broadly.

The project team resolved to promote further learning by being transparent about what the project exposed as requirements for future research and technology so that other teams with complementary skills and resources can contribute to the development of NCA. Accordingly, we decided we would include accounts and tables that exposed the 'empty cells' - cells that we couldn't fill in this project because measurement concepts and methods haven't been defined, data was too expensive to collect, or that required statistical analysis of large datasets to provide estimates.

Results & Discussion

This section reports on the findings from the interviews and co-design workshops about the purpose that NCA needs to fulfil, and the information required to fulfil this purpose. These incorporate requirements derived from literature about what the farmers' stakeholders[8] need.

The findings and insights for the design of NCA to meet the objectives of the program are described in three sections:

- Designing NCA to be useful – to help farmers measure and manage natural capital, increase farmer benefits from investment and management of natural capital including by helping farmers to identify opportunities to improve business resilience and farm productive capacity,
- Conceptualising sustainability for a farm enterprise so that strategies to assure it can be developed by the farmer and the advisory network,
- Supporting farmer-consumer reciprocity and public and industry investment into good land stewardship
- Methods for measurement of natural capital that are cost-effective and useful in making decisions.

Designing NCA to be useful

Considerable discussion in workshops and individual interviews focused on the notion that NCA should be designed to provide information that is useful for farm management and planning:

- It should help the farmer understand the effect their management and use of natural capital is having on its condition and its capacity to produce dependably and profitably into the future,
- It should provide information that helps famers to identify how they might adjust farm natural capital or operational activities to reduce the risk of environmental damage e.g., soil erosion, leaching to aquifers, salinity, and acidification.
- It should provide information that helps farmers identify how they might use changes to natural capital to improve resource use and avoid overuse.
- It should help the farm manager and their advisory network of farm accountant, agronomists, and environmental consultants to understand, detect, predict, and influence or respond to natural capital change. NCA should communicate whether natural capital change is positive or negative given the production and environmental goals of the business. It should also communicate the adaptive measures taken by the farmer to manage risks associated with the change or take advantage of it.

8 Stakeholders include consumers, supply chains, financial services suppliers and governments.

- It should communicate that the farmer is applying good management practice such as assessing the productive capacity of the coming season as part of decisions about livestock numbers and crop/cover crop strategies to regenerate or remediate soil functions and fertility.

To enable the quantification of natural capital contribution to agricultural operations and society more broadly, NCA should also be able to provide information in a way that is:

- Capable of reflecting causal pathways between management practice (operational policy and activities), natural capital type/condition, resource use efficiency, generation of societal benefits.
- Capable of contributing to the development and application of methods to estimate the monetary value of natural capital's contribution to farm enterprises and the economic benefits received by society more broadly,
- Capable of contributing to natural capital related research projects that aim to understand relationships between natural capital qualities and the qualities of food, meat and fibre.
- Capable of generating useful outputs to inform external stakeholders including:
    - Financial service providers to assess natural capital related lending risk,
    - to enable supply chains to use these to measure their own environmental performance more accurately,
    - information for land/business owners to use in supporting farm managers to manage natural capital and balance this with business goals,
    - Relative quality of food produced and environmental performance so that they can be recognised as attributes of the products they produce.

The requirements and purpose of NCA derived from the workshops and interviews align well with central objective of NCA (consistent with the UN SEEA EEA). This is to estimate the contribution natural capital makes to the performance of a farm business, whether by supplying resources that are sold directly to markets, by contributing to livestock performance and crop quality, or improving access to desirable markets by communicating the environmental performance of a farm operation.

In agriculture, there is a very tight relationship between the management practices used, the type and condition of natural capital and the yields and gross margins of crops and livestock products. This suggests that NCA should be designed to associate the type and condition of natural capital with its use and management and the yields of product and the gross margins. This should assist farmers to understand how natural capital affects yields and profits (and vice versa).

Conceptualising Sustainability for a farm enterprise

In deciding (for this project) what sustainability means and how NCA might help to assess it, the project team conceptualised a couple of 'factors of sustainability'[9]:

- Sustaining and/or regenerating natural capital (ecosystem assets)[10]
- Eliminating dependence on inputs derived from non-renewable resources,
- Matching the rate of resource use to the rate of resource generation
- Using a fair share of resources (including considerations of emissions to the environment)

If these are useful concepts for agricultural sustainability, NCA should be designed to provide information about all these factors.

We also considered that these issues seemed to suggest that sustainability in agriculture might be framed in three ways; biophysical sustainability, financial sustainability[11], and social sustainability (the social licence to operate).

Biophysical sustainability of agriculture can be assessed by the following questions:

- Is privately owned natural capital being maintained?
- Is publicly owned natural capital (air (atmospheric carbon stocks), water (quality and quantity of above ground and below ground water resources), and biodiversity) being maintained,
- Are inputs to maintain natural capital and generate ecosystem services and economic benefits from agriculture being sourced from finite stocks.

Social sustainability can be related to:

- agriculture's contribution to the sustainability of publicly owned natural

9 The requirement to be financially sustainable (i.e., not to consume your financial capital) is self-evident. The techniques to measure and account for this are well known and not addressed in this project.

10 Unless proscribed by legislation (e.g., native vegetation management, or soil protection legislation) farmers have the right to convert ecosystem assets (natural capital) to different types. They may do so to change their product mix in response to changing market needs and to meet their business and personal goals. For example, farmers can convert crops to pastures, or parts of croplands to timbered areas for production or environmental outcomes. This does not (necessarily) indicate unsustainability. It is conceptually the same as a city-based business having the right to change the products they produce and sell and the forms of produced capital they use to do so. However, due to the unique role of agriculture in managing irreplaceable assets such as soils, it may be appropriate to regard any degradation of natural capital to a state where it cannot (economically) produce a reasonable quantity and quality of any type of vegetation as an indication of unsustainability. The framing of 'strong' and 'weak' sustainability may be helpful. See Jerome Pelenc and Jerome Ballet, "Weak Sustainability Versus Strong Sustainability," in *Brief for GSDR* 2015 (France 2015).

11 Financial sustainability is well understood as a concept and not covered in this work. This work focuses on how natural capital might affect the productivity and profitability of an enterprise and its access to markets.

capital – how much is agriculture allowed to use or drawn down on publicly owned natural capital[12].
- whether agriculture is using a reasonable amount of resources or its fair share of resources

With respect to financial sustainability of enterprises dependent on natural capital, we note that rainfall declines in Western Australia are already considerable. Accordingly, as climate continues to change (and rainfall continues to decline, or shift in its timing and intensity), it may be difficult to maintain both present production (and financial returns) and also apportion sufficient annual vegetation growth to regenerate pastures and soils and maintain natural capital. Future designs of NCA will need to provide information about the expected decline in natural capital due to changes in resources such as rainfall so that farmers can adjust their financial arrangements to assure financial sustainability.

Supporting farmer-consumer reciprocity

In addition to helping to describe and to quantify the contribution that natural capital makes to farm enterprises and to contribute knowledge about where an investment in natural capital is in the interests of a farm business, NCA needs to be designed to help to identify situations where a change to natural capital that might be desired by consumers and citizens may not be in the interests of a farm business. In these situations, citizens and consumers need to reciprocate in some manner and share the cost and responsibility for the maintenance of natural capital.

The section describes some of the activities and approaches citizens and consumers (via brands that represent them) are taking to communicate their desires for different natural capital outcomes in agriculture. It briefly mentions the Sustainable Development Goals (SDG) because these are providing an important context for government and business aspirations for natural capital related to agriculture. It then provides an interpretation of the needs that are emerging from the business community for information about agricultural natural capital and its management. These are drawn from a review of publicly available information about agricultural sustainability certification programs. It finishes with a brief discussion of the purpose of NCA in contributing to analysis and quantification of situations where farmers management of natural capital is contributing significant public good.

12 We note that corporate sustainability reporting is settling on this being measured in terms of greenhouse gas emissions (from livestock, fertilisers, and operational energy use), pollution of air and water, generation of waste. See Science Based Targets, "The Science Based Targets Initiative," CDP, UN Global Compact, WRI, WWF, https://sciencebasedtargets.org/about-the-science-based-targets-initiative/; C. T. Van der Lugt, P. P. van de Wijs, and D. Petrovics, "Carrots & Sticks. Sustainability Reporting Policy: Global Trends in Disclosure as the Esg Agenda Goes Mainstream," (Stellenbosch, Sweden2020). (The Kering EP&L is a good example.)

Sustainable Development Goals

The Sustainable Development Goals (SDG[13]) are at the heart of a blueprint for peace and prosperity for people and the planet, now and into the future. There are 17 SDGs including goals for no poverty (Goal 1), Zero hunger (Goal 2), Gender Equality (Goal 15), Responsible Consumption and Production (Goal 12), Climate Action (Goal 13), Life on the Land[14] (Goal 15) and Partnerships for the Goals (Goal 17) https://sdgs.un.org/goals.

A recent report about the use of NCA for the SDG describes its potential to measure several of the SDG indicators related to natural capital such as SDG 6, 13, 14 & 15 as well as sustainable production and consumption (such as SDG 2 and 12) and to support implementation strategies to achieve them. This potential is provided by the coherent, structured, and systems-based framework NCA (following guidance in the UN SEEA EEA) that provide the potential to show interlinkages between the economy, the environment and society[15].

The 'bottom' up NCA designed for application and use at farm level have kept the SDG indicators in mind and (described in the previous section) been designed to enable linkages between information about natural capital, and economic performance (financial performance and non-financial).

Information required by sustainable agriculture certification and incentive programs

Many initiatives have emerged over the decades in the natural capital space to develop incentives for better farm environmental performance. Some of these try to enable consumers to consider a farm's environmental (and animal welfare) performance as an attribute of the product they purchase. Others require farms to report their performance as a condition of supply, whilst others take the approach of recognising farm performance by paying for environmental stewardship.

We reviewed a selection of the contemporary initiatives that are active in dairy, beef, wool and perennial horticulture to identify the information that they have in common. The farm-level NCA have been designed to provide a pathway to provide it. Initiatives that have been reviewed include:

- Dirty Clean Food (Wide Open Agriculture)

13 United Nations, 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development*. New York: UN Publishing.

14 Protect, restore and promote sustainable use of terrestrial ecosystems and halt and reverse land degradation and halt biodiversity loss

15 For a discussion about natural capital accounting's role in supporting the SDG see A. Ruijs, M. van der Heide, and J. van den Berg, "Natural Capital Accounting for the Sustainable Development Goals. Current and Potential Users and Steps Forward," (The Hague: PBL Netherlands Environmental Assessment Agency, 2018).

- Responsible Wool Standard
- SustainaWool
- Nativa Precious Fibre
- Kering Environmental Profit & Loss
- Fashion Pact
- Ecological Outcomes Verification (Land to Market)
- Accounting for Nature
- Australian Beef Sustainability Framework
- Australian Dairy Sustainability Framework
- Unilever Sustainable Sourcing Programme for Agricultural Raw Materials

While the review was not a formal metastudy of the standards, we suggest that there are some common elements between them that indicate some general agreement about the management practice or outcomes they encourage and the information they require to evaluate whether these are being achieved. These are summarised in Table 2.

Table 2: summary synthesis of common themes of agricultural sustainability certification programs.

Natural Capital or Environmental Issue	Information required
Land used for grazing	Evidence via monitoring that land is not becoming degraded for example due to overgrazing (including total grazing pressure)
Biodiversity conservation	Evidence via farm maps and goal setting that native vegetation is preserved and managed and that feral plants and animals are controlled.
Waterway protection	Evidence via farm maps of exclusion of livestock from riparian areas, evidence of an appropriate ‘buffer’ to protect waterways from agricultural pollution.
Soil protection	Evidence via practice statement and/or monitoring that best practice management related to things like fertiliser, cultivation and stubbles or other ground cover are being used to maintain or enhance soil health.
Greenhouse gas emissions	Quantification per approved methods
Deforestation/Land Clearing	Evidence that native systems have not been converted to another type of natural capital
Management of pollution	Evidence that people are appropriately trained to use farm chemicals

We also observed that most programs relied heavily on reported management practice (instead of direct measures) as an indicator of natural capital outcomes. The most prominent ones are summarised in the bullets below:

- A key indicator in many of the initiatives reviewed was the presence of a detailed and spatially explicit farm plan that specifies management practices being used to improve aspects like soil health and biodiversity,
- There seemed to be a general acceptance that training and assignment of responsibilities for environmental outcomes are useful indicators of farm

performance,
- Regarding management practices, the initiatives are generally supportive of the use of locally appropriate management activities as recommended by trusted/expert sources,
- Responsible use of resources such as water are encouraged, but there were no clear specifications of ways to quantify this.
- Evidence that people are appropriately trained to use farm chemicals.

We noted that self-assessment was acceptable for a number of environmental factors, but that in most cases the initiatives encouraged farmers to engage appropriate experts.

Finally, we tried to determine whether there was any evidence of cost-sharing of collection of the information required for certification, or of payments from suppliers that were tied to natural capital outcomes. We weren't able to identify clear evidence of these in any of the programs we reviewed but we have anecdotal evidence from personal communications with farmers that price premiums may be achieved as a result of participation in some schemes.

Quantifying the value of public good generated by farmers

The methods for valuing ecosystem services and assets described in the UN SEEA EEA present the potential for the exploration of a final aspect of farmer-consumer (society) reciprocity – where farm activities generate considerable benefit for households, businesses, and governments.

Three examples are provided to illustrate:

1. In managing their land to avoid wind erosion of soil, farmers help other businesses and organisations avoid the cost of cleaning dust from buildings and roads.
2. In managing fertiliser use and soil health, farmers can avoid leaching of nutrients into aquifers. If governments and other businesses wish to use ground water, these activities help them to avoid costs associated with desalination.
3. In managing natural capital and farm operations to maintain quality and safety of food, farmers make considerable contribution to avoided costs to society related to food-related health problems. *"The food you eat can either be the safest and most powerful form of medicine or the slowest form of poison."* – Ann Wigmore

In these examples, the benefits to citizens of avoiding these costs can be considerable. Accordingly, it seems desirable that NCA should be designed to communicate the activities of the farm that provide these benefits and whether these activities have negative or positive implications for farm financial performance. To design for these, this project drew on concepts of ecosystem services developed in the UN SEEA EEA. While methods for valuation are not yet developed, the concepts suggest the potential to quantify the activities that farmers undertake to deliver public good ecosystem services and to value the public benefits generated by these activities.

Natural Capital Measurement

One of the critical issues that needs to be addressed to improve natural capital management is the identification or development of measures that provide useful information about natural capital and the services it provides, and that are cost-effective to compile, update and use[16]. We contend that measures of natural capital in agriculture should also align well with the measures suggested in industry Best Management Practice (BMP). NCA provides a way to organise this information and associate it with financial, environmental, and social benefits generated by a farm business.

The workshops and interviews with the participating farmers confirmed the generally held view that measures of natural capital, especially the measurement of natural capital condition, need to be (but presently may not be) reliable and fit-for-purpose, and they need to be verifiable, cost-effective, and comparable. We suggest that it might be useful to consider that fit-for-purpose may be different for different types of natural capital at different times and that measurement strategies should be responsive to these differences.

We suggest that a fit-for-purpose measurement would be one that represents the concept being measured and satisfies the purpose of measurement. It should also help to align the cost to collect and compile the data with the proportional 'value' of the information.

An important consideration with respect to the 'value' of information is to assure that the confidence required of the information is proportional to the risks associated with decisions made with respect to it (this aligns well with the qualitative characteristics of useful information applied in financial accounting[17]). Finally, an important principle in management and in accounting is the principle of materiality[18] - information is material if it has the power to change a decision.

This suggests that NCA should be designed to accommodate a range of strategies

16 Climateworks Australia, with support from NAB, aims to create an open source catalogue of metrics of natural capital for people to use when designing natural capital investment incentive programs.

17 IASB, "The Conceptual Framework for Financial Reporting," in IAS 1 (IFRS, 2018). Information is useful when it is relevant and is a faithful representation of what it purports to represent. Information is faithful when it is reliable (another equivalent expert would make the same judgement), neutral (independent) and free from error (can be corroborated by other data).

18 Information is material (relevant – see below) if it has the power to change a decision. In other words, information is material if its inclusion or omission would result in different decisions. Materiality is decided by the enterprise when it considers the things that are important to it.

for natural capital measurement. Three main strategies may be employed – 1) direct measures which may be via technological sensors or field observations, 2) inferences from scientifically established models, and 3) proxies of direct measures (which may be via technological sensors or field observations).

Proxy measures of Natural Capital

It is acceptable in the UN SEEA EEA, and in ecology and management more broadly, to use proxies in circumstances where a direct measure is impractical, but a proxy provides a faithful representation. In agriculture and in ecology, proxies for measurements of ecosystem services such as habitat maintenance and soil quality regulation can include management practices where it has been robustly established that management activities have characteristic ecological or agronomic outcomes. For example:

- There is extensive description of relationships of groundcover that are robustly established with maintenance of soil quality. Consequently, the use of remotely-sense groundcover estimates is generally accepted as good proxy to indicate that natural capital contributions to soil quality maintenance are being delivered,
- it has been robustly established that the avoidance of fertilisers helps to maintain the ecological integrity of a grassy woodland to maintain habitat for the associated species[19]. Consequently, information about fertiliser use in grassy woodland ecosystems may be a good proxy to indicate if habitat is being maintained (for species conservation).

Modelled (inferred) information about natural capital

Inferences of ecosystem services generation can also be made by drawing on scientifically established models. For example, a commonly used model FullCAM[20] has been developed to enable people to estimate the quantities of carbon stocks and sequestration rates associated with their natural capital and management activities. It established empirical measures of bio-carbon in trees and soils associated with different species and management practices.

It is likely that estimation of quantities of ecosystem services such as shelter for crops and livestock, pest-control and pollination will also require modelled information to associate the services with the characteristics of natural capital that govern their generation.

19 See S. McIntyre, J. G. McIvor, and K. M. Heard, *Managing & Conserving Grassy Woodlands*, ed. S. McIntyre, J. G. McIvor, and K. M. Heard (Canberra: CSIRO Publishing, 2002).

20 FullCAM (Full Carbon Accounting Model) is a freely available software system for estimating greenhouse gas emissions and changes in carbon stocks associated with land use and management in Australian agricultural and forest systems. It is applied at the national scale for land sector greenhouse gas emissions accounting (Australian Government 2018), and at the local scale for monitoring and reporting carbon sequestration projects, such as revegetation and the management of regrowth.

Aligning the robustness of direct measurements to the measurement purpose

With respect to the selection of direct measures, the literature and farmer observations suggests that it may be useful to be able to draw on measures that have different levels of 'robustness' depending on the context or purpose of measurement. The range of 'robustness' we decided to explore in the NCA design included:

- Informal observational assessments, e.g., used as input to immediate management decisions, or serendipitous observations of species that are normally difficult to observe,
- Rapid, (independent) expert[21] assessments as part of a rapid, but fairly formal evaluation of natural capital
- Formal, rigorous assessments such as would be used by researchers in scientifically designed experiments to assess the effectiveness of an intervention[22], or may be imposed by a contract to supply ecosystem services or biodiversity.

Whether direct measures or proxies are used and the 'robustness' of the measurement method should be disclosed in explanatory notes to the accounts so that users of the information can make their own assessment of how they should use the information. The NCA Designs demonstrate some possibilities for these.

Natural Capital Accounting Sampling Scheme

In order to ensure that the sampling scheme for collection of natural capital measurements creates information that is fit-for-purpose, it is recommended that NCA for each farm includes an explicit description of the sampling scheme. This would describe the approach to selecting representative samples and the protocols for sampling. It would allow all three levels of 'robustness' to be used and provide a way for these inputs to valuation to be communicated to users and would be a form of long-term monitoring that is aligned to the purpose of NCA. The scheme would be updated in response to changes to natural capital type and use and in response to changing information needs.

The sampling scheme used for the NCALCS Phase 1 project has evolved during the project, leveraging approaches used in other NCA projects (specifically the La Trobe University Farm-scale Natural Capital Accounting project). This project has provided an opportunity to trial new methods and technologies for the on-farm natural capital measurement, providing a more systematic and efficient assessment process, which in turn will reduce the cost of on-farm data collection and compilation over time.

21 These don't always have to be done by independent (external) experts. Farmers seem to have acute observational skills and may be very adept at rapid assessments.

22 Note that farmers may perform these experiments.

Anecdotes to evidence[23]

Farmers are in a unique position to capture rare observations of species or phenomena that may otherwise go unobserved. NCA and the science and technology that supports it should incorporate ways in which farmers can capture these in a way that enables them to be used in some way in science.

23 A beautiful concept introduced by Di Haggerty.

Learnings and insights

This section describes some of the learnings and insights gained in Phase 1 of the NCALCS project. These are described to inform the approach to Phase 2 and to initiate collaborations with research and practice teams who may be able to develop solution responses and methods to fill the 'empty cells'. There are five main areas of learning and insights:

- The degree to which farmer information requirements are already incorporated into the UN SEEA EEA and NCP frameworks,
- The degree to which the requirements of agricultural sustainability certifications are incorporated into the UN SEEA EEA and NCP frameworks,
- How difficult/easy is it to compile NCA at farm level,
- Making the NCA Reports and Accounts useful and worth the effort of compilation,
- The empty cells that need filling.

The coverage of farmer information requirements in SEEA EEA and NCP

Provisional conclusions from Phase 1 of NCALCS indicates that the concepts in the UN SEEA EEA can be applied and have the potential to work quite well to reflect the multiple economic benefits being generated by farms, but some adjustment should be made to provide information at the scale required by farm enterprises. These are outlined below.

Subject to the Ecosystem Accounting Area (EAA) being a farm, the guidelines in the UN SEEA EEA for the delineation of ecosystem assets work well at farm level and are fairly easily applied by combining vegetation maps with paddock maps that include information about the land use of each paddock.

The methods for condition accounting described in the UN SEEA EEA (Chapter 5) are also applicable for use at farm level but may need some adaptation to make them cost-effective to apply. We make the following suggestions:

1. The capture of variables as described in the UN SEEA EEA is relatively expensive, may not provide material information and may not be cost-effective for many purposes at farm level. The methods of use of remotely sensed information (proxy measures) of ecosystem condition and services plus rapid expert categorisation of ecosystem condition described in this report and demonstrated in the case studies should be tested as potential solutions to this problem.
2. The UN SEEA EEA (2020) emphasises the use of the natural state (ecosystem condition in the absence of major human modification) as the reference

by which ecosystem condition is measured. However, farmers manage agriculturally modified ecosystems and require information that helps them to assure the maintenance of the integrity, productivity, and ability of them to persist as agriculturally modified and productive ecosystems. This reveals a need for publicly available reference condition indicators and indicators of degradation thresholds for NCA preparers to use that are aligned to crop type and location and are reliable indicators of whether agricultural natural capital is being sustained, improved, or consumed.

An observation emerging from NCALCS Phase 1 is the potential for monetary valuations of ecosystem assets to help farmers plan their use of natural capital and for citizens to learn about the economic value of the public goods generated by farmers and the private cost to farmers of this generation. We therefore make the strong recommendation that research aimed at developing methods for monetary valuation of ecosystem assets includes an explicit aim to generate information for natural capital management and investment at farm level. The UN SEEA EEA (2020) suggests that ecosystem asset valuations in monetary terms may be estimated as the Net Present Value (NPV) of the sum of net cash flows from the ecosystem services generated. Discussed further in the ecosystem services section below, detailed methods to apply this approach have not been developed yet making them out of scope for NCALCS Phase 1. However, this is an area of active research and we look forward to methods emerging in the near term.

The present list of ecosystem services suggested in the UN SEEA EEA (2020) provides good coverage of the material issues nominated by the participants in the co-design sessions. However, the scale of the information that is useful for analysis at sub-national and national scales is likely to be too coarse or not cover the variables that farmers need when making management decisions. We recommend that methods being developed for NCA at farm level are designed to satisfy a farmer's needs for information that has the power to change a management decision. For example, while groundcover relative to an erosion threshold is a good proxy to use to indicate whether ecosystem services are being provided to protect soil health, a farmer is likely to need require information about soil physics, chemistry, or biology in order to select the most appropriate intervention to overcome soil limitations that constrain ground cover development.

Information about land capability is important in agriculture. Land capability assessments can give important guidance to landholders and governments about the capacity of the land to support sustainable production of different types of crops. This helps landholders to develop well-informed views of productivity and profitability for agricultural enterprises and avoid financial difficulty associated with unrealistic expectations. The UN SEEA EEA (2020) suggests the potential to record information about land capability via concepts such as potential ecosystem services but does not explicitly provide guidance for how ecosystem asset accounts might organise and communicate this information. Future research related to design of natural capital accounts and reports is desirable to test whether this information may be included in NCA and if so, how it should be included.

The coverage of information required by agricultural sustainability certification programs

Although this project didn't do a formal metastudy of present agricultural sustainability certification programs, our overview of these led us to perceive that there were plenty of common elements. We further suggest that the guidance provided in the SEEA EEA for ecosystem asset and service accounts and NCP as applied in this phase enables the information required by these certifications and standards to be compiled in a standardised way. It seems desirable that negotiations between the different certifications and standards developed and used by Brands should commence to work towards establishing commonality.

How difficult/easy is NCA to compile at farm level

NCACLS Phase 1 experience suggests that many of the foundational elements of Ecosystem Asset Accounts (type and condition of natural capital in physical terms) for Farm-level NCA can be compiled from existing data by someone with GIS and ecological skills. Further, with the present speed of development of technologies, we anticipate that in the near term, the range of information that can be compiled using remote sensing and GIS systems will increase dramatically. We anticipate that field observations for ecosystem condition (including soil condition) will be always required. Related to field observations and measurement methods for NCA, we make two suggestions:

1. When setting up a NCA system for a farm enterprise, it would be wise to describe the sampling scheme (sampling strategy and protocols) for the different measurement approaches for the different types of ecosystems and economic purposes of them. This would provide useful context for users of the accounts to make judgements on how to use the information. It would also form the logic for the long-term monitoring that NCA suggests.
2. Protocols used by field ecologists for field observations of ecosystem condition need to be aligned to satisfy the measurement purpose of NCA, especially for modified ecosystems. Additionally, the rapid assessments (such as pasture condition categories, or assessments of where woodlands might sit in a state & transition model) may be uncomfortable for professional ecologists who might be more comfortable with a more rigorous approach to condition assessment strategies that use indicators developed from variables. It would be desirable to align the protocols to the purpose of measurement to resolve this discomfort.

In addition to this, the compilation of the biophysical, operational, and financial information necessary to estimate the contribution natural capital makes to a farm enterprise in production and monetary terms is quite complex and will require some technology and some methods development to be practical. The estimation of the monetary value of ecosystem assets (and ecosystem services) is likely to require fine-scale data about expenditure and yields at a paddock scale but may be founded on estimations similar in style to gross margin calculations already used by some farmers to assess performance of paddocks and so may in future be relatively easy to perform. This is discussed further in the section discussing ‘Filling the ‘empty’ cells.

The operational information required to quantify the natural capital (environmental) performance reports such as GHG emissions and resource-use efficiency is mostly already collected, but presently requires manual collation and calculation. However, we speculate that, agricultural management and accounting packages could be modified to automate more of this to make it less onerous to collect and more useful.

Subject to these developments, we expect that it is not unlikely that, given some guidelines, farmers, farm advisors and farm accountants may be able to compile their own NCA for farms. However, it is likely that some training and further development to integrate emerging technologies will be required.

Making the NCA useful

Two main insights from Phase 1 of NCALCS; firstly, the information reported by NCA has to be useful for farmers and this includes supporting farmers to engage external stakeholders especially the supply chain. In response, we designed reports and accounts to provide the fine-scale data about ecosystem condition that is needed for management purposes and demonstrate how ecosystem services accounts may be compiled for each type of ecosystem asset. The designs also demonstrate the potential to supply the information required by sustainability-certifications developed by brands.

Noted earlier, with present technologies and need for field observations, the cost of applying the condition accounting under the SEEA EEA and NCP is quite high. We speculate that at present, in the early days of NCA where its utility for management and marketing are unproven, people would only be prepared to pay a modest amount for accounts and reports to be prepared and this would constrain the breadth and depth of the information. This would limit its ability to provide reliable information about the condition of natural capital resulting in a self-defeating cycle.

However, if NCA becomes useful and widely used by agricultural economists, supply chains, governments and financial service providers, there would likely be appetite to increase the coverage and depth of NCA. This might lead to mechanisms by which stakeholders external to a farm can share the cost of preparation of the information.

In addition to the impact of coverage of material information and the data definitions, the ways in which NCA are presented are also important to making it useful. In the absence of standards for presentation of NCA, the designs presented in NCALCS are loosely based on financial performance reports and the published outputs of other SEEA EEA projects. This may make them a bit dense and technical for readers who are unfamiliar with them. We acknowledge that the way information is presented can be significant in people being able to use it effectively. Accordingly, we recommend that future phases of this project (and other projects working in this field) should formally explore the development of engaging infographics to be incorporated into the presentation of farm NCA and NC Reports and work out how to present the information make it most useful to farmers and their stakeholders.

Filling the 'empty' cells – research and technology requirements

This report and the case studies developed illustrate a number of 'empty cells' that we suggest would be useful in achieving the goals of the project. These are generally with respect to the quantification of ecosystem service delivery and the estimation, in monetary terms, of the benefits ecosystems generate for farm financial performance and to public goods. These are particularly important to achieving the farmer-consumer reciprocity sought by this program.

Information about private benefits to production, or private benefits to farm enterprises are important inputs to decisions farmers make about their natural capital in the short and the medium term. While the coverage of ecosystem services in the UN SEEA EEA broadly reflects the farmers' perception of the services they generate as part of their enterprises, farm accountants and farmers will need to be able to draw on methods to quantify the values in monetary terms as well as physical terms. These should probably be designed to help farmers estimate the monetary values of ecosystem services in terms of their contribution to income or costs to the enterprise and also to consider the monetary value of the broader economic benefit to society.

Methods to fill this gap in future may be able to draw on existing agricultural economic science. NCA at farm-level has strong alignment with the well-studied functions and processes of natural resources in agriculture. Accordingly, we suggest that, as a result of extensive research and development of best practice management in agriculture, potential solutions to quantification of ecosystem services and the value of changes to condition of natural capital may already exist or require moderate adaptation to meet the need.

For example, we note that the Soil Quality website (www.soilquality.org.au) has developed calculators for farmers to use when considering management activities or practices that will protect, maintain, or regenerate soil health. These are conceptually equivalent to the ecosystem services of soil quality regulation and soil erosion control described in the UN SEEA EEA (2020). Since management activities and practices are essentially tied to the condition of natural capital, these calculators may be able to be adapted to develop a method that might provide satisfactory estimates in monetary terms for two important ecosystem services – soil erosion control and soil quality regulation. For example:

- Retaining crop stubble instead of burning it is an example of ecosystem services - soil quality regulation and erosion protection services. Crop stubble is widely accepted as being important to maintenance of soil health and avoidance of erosion via its protection of the soil surface and the biological functions associated with its decomposition. The soilquality.org.au calculator suggests that (under certain circumstances) the economic value of these services may be estimated as $14.80/ha.
- In a similar vein, green manure rotations are an excellent example of soil quality regulation and erosion protection services. The soilquality.org.au calculators suggest that, under certain circumstances, the use of green manure rotations compared to break crop rotations suggests these may be worth $77/ha[24].

We note however, that the development of industry accepted best management practice is likely to lag behind leading edge innovation. Accordingly, we recommend that methods of measurement of natural capital and ecosystem services in NCA can incorporate formal experimental designs that would provide information about the effect of innovative practice and accelerate further testing and development of farmer-discovered innovations.

As an addition to the private benefits farmers generate for their own enterprises by providing soil erosion control and soil quality regulation services, the generating of these services has benefits for other members of the community. It is well accepted that, by preventing soil erosion from creating dust storms, they help local governments and other businesses to avoid cleaning costs for roads and buildings. These costs can be considerable, and a farm enterprise may wish to quantify the proportion of these benefits it has generated for other citizens.

There are other examples of where farmers jointly produce public good as well as private good ecosystem services. Some types of Natural Capital, such as native grasslands and shrublands used to provide feed for sheep, have a wide biodiversity of grasses, forbs, and forage shrubs. In addition to supporting native plants and animals, they provide a dependable supply and useful diversity of high protein, high sulphur, and high tannin forages. These have been demonstrated to provide nutritional elements important to good wool quality and strength, improved digestive function

24 http://www.soilquality.org.au/calculators/green_manure

for livestock including reducing enteric emissions and intestinal parasite burdens[25]. In this way, the natural capital qualities can be seen to contribute positively to biodiversity conservation, sustainable landscape management, animal performance as well as premiums for high quality wool.

Some situations are less clear. For example, a need exists for quantification of the public and private benefit (in monetary terms) for farmers' maintenance of vegetation that might provide private goods to the enterprise such as shade and shelter as well as habitat for pollinators and pest-predators but might represent a trade-off to production. At present, while general inklings from research suggest that these types of natural capital might contribute benefits to a farm enterprise, methods are not available to enable an individual farm to quantify the additional (or reduced) crop and livestock production that can be attributed to habitat maintenance. Neither are methods available for farmers and governments to evaluate needs for these types of services in the future so they can make an informed decision about whether to (and how to) share the investment in these types of natural capital on farms.

Finally, many farms produce considerable public good by conserving native vegetation for conservation and cultural reasons. This may entail a modest cost to the enterprise either as an opportunity cost of not using productive areas, or in expenditure to maintain the area. The public benefit of this in preserving species and landforms and providing access to these may be considerable. It seems desirable for farmers to be able to estimate the total economic value of the public benefits they generate, even if they do not wish to be formally compensated for the opportunity cost or maintenance expenditure.

As a general comment on monetary valuations of ecosystem services, discussions with farm accountants have indicated that they are comfortable in providing valuation of the ecosystem services in monetary terms if a reliable estimates of the physical quantities of those services. As a related observation, we have investigated the possibility of providing the monetary valuations for ecosystem service provision within the accounts and found that a possible hurdle to doing this is the willingness of insurers to provide professional indemnity insurance to NCA compilers (without a full financial services certification process). The reluctance of the insurance industry to provide coverage for the compilation of NCA with respect to monetary valuations will need to be resolved in order to support this component of the NCA compilation.

25 See for example D K Revell, "Sustainably Meeting the Nutrient Requirements of Grazing Sheep," in *Achieving Sustainable Production of Sheep* (Burleigh Dodds Science Publishing Limited, 2017); Revell et al..

NCA Designs

This section describes the designs for Natural Capital Reports and Accounts to satisfy the purpose and fulfill the requirements identified in the co-design workshops. It is followed by a discussion of the 'empty cells' that emerge from the design and the requirements for research and technology needed to fill these. An accompanying document will provide more detailed NCA concepts and designs in a framework to help farmers, farm accountants and farm advisors compile their own experimental Natural Capital Reports and Accounts.

The design for the NCA for Phase 1 for the NCALCS draws on research exploring how to extend the guidelines used by farm accountants when preparing financial statements and reports for agriculture so that they can include natural capital[26]. For ecosystem accounting standards and concepts, it draws on the UN SEEA EEA because of the guidance it provides on accounting for natural capital and ecosystem services. It also draws on examples of applications of the Natural Capital Protocol (NCP) for examples of how to quantify agriculture's dependence and impact on natural capital. Most importantly, the approach to designing ways to account for natural capital in agriculture draws on the input from farmers and literature describing agriculture ecology and best management practice.

To recap, four main priorities were identified for exploration in Phase 1 of NCALCS. We seek to compile and present information to learn about:

1. applying the guidelines in the UN SEEA EEA (2020) at farm-scale,
2. how NCA might be designed to support farm managers to:
    a. measure and manage their natural capital and
    b. to detect and avoid degradation of natural capital, or
    c. make investments in it and
    d. to assess the sustainability of their enterprises,
3. how to communicate the environmental-economic benefits delivered by the natural capital of a farm and the stewardship of the farmer,
4. about needs for research and technology development to enable accounting information that is useful to farmers, cost-effective to collect and compile and that will support the emergence of farmer-consumer reciprocity in responsibility for natural capital.

We propose that these requirements can be satisfied by a presentation of farm scale NCA that has a Natural Capital Reporting section, which provides a summary of the current position, performance and stewardship activities on the farm, followed by a summary set of natural capital accounts which provide the supporting detail for the performance reports. This would be used by members of the supply chain and maybe

26 Including S. Ogilvy, "Toward a Methodology for Incorporating Ecological Capital into the Accounts of Individual Entities." (ANU, 2020). Applications of the Natural Capital Protocol Paola Ovando, "Application of the Natural Capital Protocol at Glensaugh Farm. Living Document Version 1.0," (Scotland, UK2020).

also by financial services providers. An additional report (or digital platform) containing a very detailed set of Natural Capital Accounts – Management Accounting, may be needed to provide the level of detail required for managers and their advisors for goal setting, performance monitoring and farm budgeting.

Natural Capital Reporting

Natural Capital Reports (NC reports) presented here draw on the analogue of general-purpose financial reports used by companies to report their performance to shareholders. These communicate annual reports of key information that has been derived from the enterprise's accounts. The objectives of NCALCS make clear that stakeholders of the NCA reports are the farmer (and their advice network) and consumers of agricultural products (although financial services providers will also be important). Accordingly, the NC Reports should provide information as described in the prior section (headed 'Information required by sustainable agriculture certifications'). The designs proposed here aim to provide a way that a farmer can draw on information compiled in their financial accounts, their operational records (agricultural management systems) and their natural capital accounts (described in the next section) to summarise key aspects of their natural capital and its contribution to the enterprise and society. The designs also accommodate reporting of a farmer's stewardship of natural capital and other resources.

Described in the NCA purpose section (recapped here for convenience), the farmers required a design that enabled them to communicate the quality of their natural capital and how it has changed over time. They also require a way to communicate the quality of their management of natural capital and how it contributes to their business and to society more broadly. To meet these requirements, we suggest that the natural capital reports include three statements followed by a selection of ecosystem asset accounts. The statements would report on the ecosystem assets and the ecosystem services that they are generating. We suggest the following three statements could form the basis of experimental natural capital reports:

1. Natural Capital Position
2. Natural Capital Performance
3. Natural Capital Stewardship
    - Information about the natural capital management practices, production and maintenance activities and the affect this is likely to have on natural capital type and condition in future,
    - Information about the resource-use efficiency of the enterprise and its generation of environmental impacts
    - Information about the dependence the enterprise has on finite resources,
    - Information about whether the enterprise is satisfying legal and other

obligations related to natural capital.

These are described further in the next sections and illustrated in a 'sample' Natural Capital Report (separately). 'Empty cells'[27] that could not be filled in this phase are identified with grey shading. These are discussed in this document in the section titled 'Filling the 'empty' cells.

Note: the designs presented here are very detailed and elaborate with repetition of some measures to illustrate the potential of presenting different material to different audiences. If a simple report is preferred, the information can be selected from the elaborate set.

Natural Capital Position

The Natural Capital Position Statement provides information that summarises the natural capital of the farm and the enterprise's policy position on its management. This is accompanied by a summary of the types of Natural Capital on the property and their condition and explains changes since the last reporting period. A natural capital position statement may ideally provide information about natural capital in both physical terms and monetary terms with the monetary value of each type of ecosystem asset being estimated as a net present value (NPV) of the net cash flows from each asset[28]. This summary would be designed to provide the information needed to judge whether the enterprise is sustaining and/or regenerating natural capital (ecosystem assets) and biodiversity or if it has seen any degradation of its natural capital and therefore whether it is sustainable in biophysical terms.

The statement would also summarise the current capacity of natural capital to produce ecosystem services in the forthcoming period given the quality of the season (for example forage available for livestock in the coming year[29]) and whether some types of natural capital will have 'maintenance activities' (for example a break crop or extra growing season rest) and as a result will produce lower quantities of provisioning services than usual. This information would provide evidence that the farmer is applying good stewardship practice and provide information relevant to estimating the production capacity, for financial budgeting for the coming year.

Finally, the Natural Capital Position statement might report on any 'leading indicators'[30] of natural capital change that might have implications for the future environmental, social or financial performance of the farm and be important for the stakeholders of the

27 Values (in physical or monetary terms) that could not be estimated by the project because methods did not exist, or data was too expensive to collect, or was out of scope for the case studies approach.

28 Methods for monetary valuations of individual ecosystem assets are an active area of research

29 It may be useful to design NCA to report at dates aligned with seasons, instead of at 30 June as is conventional in financial accounting. Due to the different timings of growing seasons, NC reporting dates may be different for enterprises in monsoonal/tropical compared to temperate environments.

30 'Leading Indicators' are ecological phenomena or variables that change before a change to type or condition of an ecosystem asset (See "Checking for Change" CSIRO for an example).

farm.

Three components of the statement are summarised:

1. Natural Capital overview – a commentary about the natural capital types of the farm and the environmental, social and production purposes these serve for the enterprise.
2. A summary of the production capacity of the ecosystem assets with respect to the forthcoming year. This might be useful as part of farm budgeting for the coming year and to communicate the long-term production capacity of the farm.
3. This may also enable communication that natural capital 'maintenance' activities are being performed. Good management practices for agricultural ecosystems tend to include activities or interventions that should be applied periodically (e.g., using break crops in Wheat rotations) or when condition assessments indicate they are needed (e.g., reducing livestock numbers to match the annual pasture growth or allowing extra growing-season rest to allow pastures to regenerate).
4. A summary of the type and condition of the long-term ecosystem assets that underpin the business and comments on any changes.

Natural Capital Performance

The Natural Capital Performance Statement describes the natural capital performance over the prior period since last 'revaluation' (which might be five or more years prior). It includes information about the types and quantities of ecosystem services generated by the enterprise, including public good services such as carbon storage, avoidance of soil erosion. It may also report on the biodiversity of the property and habitat protection services. Note that livestock, wool, grains, fruit, and other crops harvested are already reported under existing farm accounts. The tables suggested here communicate information not presently covered in farm accounting. A brief narrative is also provided to illustrate how these might be used. (A detailed definition of each ecosystem service is provided in the later section headed "Ecosystem Service Accounting" (p 29)

Three main tables are proposed:

1. A statement of the carbon position of the enterprise. This would communicate the greenhouse gas emissions (GHG) and the bio-carbon stored and being sequestered by the enterprise,
2. Ecosystem contribution to farm production,
3. Ecosystem services produced for societal benefit (public goods).

<u>Greenhouse Gas Position</u> – the GHG emissions related to general farm operations,

livestock, and crop production. This would include Scope 1, 2 and 3 emissions, including pre-farm emissions associated with farm inputs and purchased livestock, but not include emissions related to provision of financial services to the farm. The bio-carbon being stored and sequestered by the enterprise would be summarised in this statement with more detail about the carbon stocks provided in thematic 'carbon' accounts.

Ecosystem contribution to farm production – this section would communicate some of the contributions that natural capital is making to the farm's productivity. For example, it would summarise the provisioning services (forage for livestock, annual plants for grain harvest, mallee for harvest etc) and intermediate services that support the generation of provisioning services and final products for market. These include shelter for crops and livestock, insect pest-control and pollination and soil quality regulation services. The list of services that can be quantified is expected to increase over time as science and technology is developed.

Ecosystem services produced for societal benefit (public good) - This table communicates the ecosystem services generated by the farm that provide benefits to society. These should present information about:

- GHG sequestration in physical (sum of GHG position figures from earlier) and monetary terms and perhaps should also include an estimate of the total economic value to citizens in addition to an estimate of the payment made to the farmer for producing the services.
- Other public goods such as cultural ecosystem services such as ecosystems that are interesting for research and that are valued for spiritual and recreational purposes.

This list is presently constrained to the ecosystem services listed in the UN SEEA EEA (2021). Accounting for broad benefits to society is a rapidly developing area and we expect to be able to increase and refine this list over time.

Natural Capital Stewardship

This statement is designed to provide information about the farmers' stewardship of natural capital and public resources and whether it is 'socially sustainable'. It describes the management and operational choices being used to protect or invest in natural capital including information about how management is responding to natural capital change either to avoid negative economic implications or realise economic opportunities. Stewardship has four interrelated aspects:

Natural Capital Management – the production activities and practices involved in the use and maintenance of natural capital and the effect this is expected to have on its type and condition. How these may affect the capacity of the business to meet its financial and non-financial goals. How management is adapting to the changes.

Resource Use Efficiency – to assess whether the enterprise using its fair and efficient use of public resources such as water, GHG sinks (fair GHG emissions 'allowance'), finite minerals, energy, and community infrastructure such as landfill for non-biodegradable materials[31] and maintenance of roads. The information captured for these assessments can also be used to assess the degree of dependence the enterprise has on finite resources (part of the assessment of biophysical sustainability).

Environmental Protection Specific Services (EPSS) – to communicate the farm's activities to protect the environment[32] that it undertakes alongside agricultural production[33]. EPSS can be conceptualised as:

- maintenance of natural capital e.g. soil health for future generations
- conservation of biodiversity e.g. by managing grazing in such a way that a diverse native pasture is maintained
- avoidance of soil erosion and leaching of inputs into waterways and aquifers
- greenhouse gas sequestration where there is no carbon sequestration contract or payment. If there is a contract or payment, then the entity is providing a service, not an externality – similar with biodiversity.

Natural Capital Obligations – the satisfaction of legal obligations under the State and Commonwealth land and environmental protection Acts and the satisfaction of environmental performance obligations to clients. In WA legal obligations for land holders are described in the Land Act and the Soil Protection Act as well as the EPBC Act. These require ecologically sustainable management and protection of soil as well as no intensification of land use where threatened species are located. Some farmers will have environmental performance obligations described in supply contracts or sustainability certification requirements. Note: this project does not address this issue.

31 Some agricultural properties maintain their own landfill sites. Presumably these become exhausted at some point and new ones need to be established. Accordingly, they are considered a finite resource and future generations' needs for this resource should be considered.

32 Environmental Protection Specific Services are environmental protection services produced by economic units for sale or own use EC, "System of Environmental-Economic Accounting 2012: Applications and Extentions. White Cover Publication, Pre-Edited Text Subject to Official Editing," (New York: European Commission, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, United Nations, World Bank, 2012).

33 Situations where public benefits are generated alongside private goods, at no cost to the producer, are sometimes described as positive externalities or joint products.

Natural Capital Accounting – Ecosystem Asset and Services Accounts

The accounts described in this section are designed to provide the supporting detail and other evidence to support the interpretations provided in the Natural Capital Reports. The summary accounts described here would be complemented with detailed accounts and different views of information designed to provide a way for farmers to diagnose the causes of changes to natural capital and to identify appropriate interventions and monitor the effect of their implementation

Ecosystem asset accounts (physical terms)

Ecosystem asset accounts in physical terms are the foundational information for natural capital accounting and reporting. They are the main vehicle for information about the types of natural capital on the property and the capacity of natural capital to contribute to the farm's production, environmental and social goals. Different types of ecosystem asset accounts are used to communicate different types of information about natural capital:

- Ecosystem Extent Accounts are used to record changes to the types of natural capital of the property and communicate whether the changes were due to conversions or condition improvements or other factors including a natural disaster.
- Ecosystem Condition Accounts are used to communicate information about the condition of the natural capital with respect to the economic purpose it serves for the farm. For example, condition accounts can be prepared to communicate the condition of ecosystems with respect to desirable pasture characteristics.
- Thematic Accounts can also be prepared to communicate information of interest to stakeholders. For example:
    - Carbon Accounts can be used to communicate the stocks of bio-carbon on the property and how these stocks are changing over time (e.g., by sequestration of carbon or by emissions events such as fire or clearing).
    - Biodiversity Accounts can be used to communicate changes to biodiversity that are associated with changes to the type and condition of ecosystem assets.
    - Water Accounts can be used to communicate the sources and uses of water resources.
- Accounts can also be prepared to provide information about the capacity of the property to generate ecosystem services that contribute to production. For example, that provide shelter for crops and livestock, habitat for pollinators and pest-predators and filtration of agricultural runoff to prevent pollution of waterways.

Ecosystem Extent Accounts

The UN SEEA EEA recommends that natural capital accounting uses typologies of ecosystems (categories of ecosystem types) and typologies of change (categories of reasons for natural capital change) to make the accounting process tractable. We recommend that the approach to farm-level NCA applies this principle, but extends it to a finer scale for two reasons:

1. It was clear from the workshops and interviews (and is evident in the literature) that information about the condition of a farm's natural capital forms an important input to decisions about its management and use.
2. We expect that information about the ecosystem services that provide support for production will be valuable in helping farmers design their natural capital to optimise their use of 'free inputs from nature' as part of their operations.

An example of an ecosystem asset account that incorporates some condition characteristics is provided in Table 3. It demonstrates the way that changes to natural capital can be recorded and explained[34]. See the next section for further information about condition categories. The table shows the area of each type of ecosystem in each condition category on the date of valuation. Changes between dates are accounted for by recording the amount of each ecosystem that has changed and the reason for the change. This information is used to communicate farmers' investment in or consumption of natural capital and provide context for the ecosystem services and benefits being generated.

34 The classifications of different types of ecosystems and the categories of explanations provided here are designed to be relevant to farmers and are slightly different to those used in the UN SEEA EEA. A concordance between these will need to be established to enable individual farm accounts to be aggregated to sub-national and national accounts.

Table 3: Example ecosystem asset account (ha)

Ecosystem Type	Date 1	Additions (ha)				Reductions (ha)				Date 2
		Conversions[35]	Condition change[36]	Natural Increase[37]	Reappraisal	Conversions	Condition change	Reappraisal	Catastrophic loss	
Grassy Woodland[38]										
State 1	100		10							110
State 2	100						10			90
Shrubland	100									100
Environmental Plantings	23									23
Woodlot	10									10
Pasturelands[39]										
V. Good	12		15							27
Good	40		9				15			34
Fair	41						41			0
Poor	0		32							0
Croplands[40]										
V. Good										
Good	25		20							45
Fair	25						20			5
Property Total	**476**									**476**
Biodiversity	**0.36**									**0.42**

35 Used to communicate that a spatial area has been converted from one type of ecosystem to another. For example, the conversion of a part of forest to cropland or conversion of crop land to environmental plantings.

36 Used when the explanation for a change is due to improvement (deterioration) in condition. For example, a grassy woodland that was assessed on Date 1 as being in S1 and on Date 2 as being in State 2, or a pasture assessed on Date 1 as being in Fair Condition, being assessed on Date 2 as being in Good Condition.

37 Natural Increase is used when growth of vegetation explains a change of capacity to deliver ecosystem services. Used mainly for timber assets or environmental plantings when increased biodiversity or carbon storage is directly associated with growth (natural increase).

38 Condition assessment with respect to the potential for the ecosystem to persist as a grassy woodland (also described as ecological integrity).

39 Condition assessment with respect to forage quality for livestock. See for example DAFWA, "Pasture Condition Descriptions and Photos 'Black' Soil Group: Mitchell Grass Upland Pastures, Mitchell Grass Alluvial Plain Pastures, Blue Grass Alluvial Plain Pastures, Ribbon Grass Alluvial Plain Pastures," in *Pasture condition guide for the Kimberley* (Perth, Western Australia: Department of Agriculture and Food Western Australia, 2018).

40 Condition assessment with respect to cereal crop production. Classifications could be aligned with the Traffic Light Indicator system (www.soilquality.org.au) using the method described in UN SEEA EEA Chapter 5).

Ecosystem Condition Accounts

Condition accounting can be used to provide information that helps managers identify areas for improvement and to select an appropriate intervention (e.g., extra wet season rest to improve the condition of a pasture). They can also be used to assess and communicate the outcome of an intervention applied during the prior period. There are two approaches to condition accounting:

1. Condition categories that use classes of condition to communicate information about the quality of the natural capital and its capacity to supply ecosystem services. In the same way as a 'picture is worth a thousand words' a condition category can convey a great deal of information about an ecosystem and the basket of ecosystem services it generates. Table 3 used in the example Ecosystem Extent Account above illustrate how these are used. These are well-suited to rapid observational or expert assessment.
2. Condition indicators can be calculated from a set of selected individual variables and used to provide an overall condition index for the ecosystem[41,42]. This strategy aligns well with assessment methods that quantify selected variables that reflect ecosystem condition. For example, the Victorian Habitat Hectares framework requires collection of data about different variables[43]. These can be converted to an index such as the ECond[44] developed by Accounting for Nature. Likewise, the variables collected in soil tests might be an appropriate approach to produce an index that represents the condition of soil with respect to the crop to be produced. It may also be useful to use variables suggested in the 'Ecological Outcomes Verification' (EOV) program[45] to create an index of the health of a pasture.

With consideration of the requirement for measures to be fit-for-purpose, we suggest that the two approaches are not mutually exclusive and can be used in combination.

A set of condition categories has already been developed by scientists to assess and manage the health of important Australian ecosystems such as Grassy Woodlands[46] and grasslands[47]. These have drawn on existing state and transition models (STM). (STM are

41 Described in detail in UN SEEA EEA (Chapter 5)
42 Patchkey – a system developed by CSIRO to measure pasture condition is an example of this.
43 David Parkes, Graeme Newell, and David Cheal, "Assessing the Quality of Native Vegetation: The 'Habitat Hectares' Approach," Ecological Management & Restoration 4 (2003).
44 https://www.accountingfornature.org/
45 See Land to Market Ecological Outcomes Verification program.
46 S. Lavorel et al., "Ecological Mechanisms Underpinning Climate Adaptation Services," Global Change Biology 21, no. 1 (2015); P. G. Spooner and K. G. Allcock, "Using a State-and-Transition Approach to Manage Endangered Eucalyptus Albens (White Box) Woodlands," *Environmental Management* 38, no. 5 (2006).
47 Steve. J. Sinclair et al., "A State-and-Transition Model to Guide Grassland Management," *Australian Journal of Botany* 67 (2019).

already used widely in the USA[48].)

STM have not been described for all ecosystems yet, but the Federal Government and CSIRO are developing a set of ecological models for Australian ecosystems that should enable NCA preparation on farms to describe their health and ability to persist and to reflect changes in ecosystems that are due to climate change and distinguish these from natural disturbances. Categories of condition are suitable for either informal observational (self) assessment[49], or rapid expert assessment[50] which may enable the cost of condition assessment to be reasonable.

A categories-based approach to ecosystem condition accounting for vegetation, as demonstrated in the ecosystem extent accounts in Table 3, produces easy to interpret information about the condition of a farm ecosystem with the accuracy of the information aligned to the management purpose.

The approach to pasture condition in NCA can leverage the approach taken in good grazing practice to categorise the condition of a land system or pasture and use this information as an input to management[51]. In making their assessment, the observer would decide which category the ecosystem asset fits using the description provided[52] (Table 4). Geolocated and time-stamped photographs taken by farmers or ecologists while making observations provide valuable evidence or artefacts of the observation that enable independent corroboration of the assessment. Table 4 illustrates categories of pasture condition already familiar in rangelands management. Tables 3 and 2 provide example of accounts and a summary table using pasture condition categories to communicate changes to the condition of paddocks.

We suggest that assessment of pasture condition can be done by farmers using informal observations for their own management information, and/or by independent experts preparing reports that need a higher level of assurance. Furthermore, remote sensing technologies are evolving that may be able to accurately assess pasture condition from satellite imagery (CIBO Labs PastureKey, Digital Agriculture Services).

48 USGS, “Geo Global Ecosystem Mapping Process,” United States Geological Survey https://seea.un.org/sites/seea.un.org/files/documents/Forum_2018/s12_area_1_sayreunseeaexpertsforum2018.pdf.

49 This may be used by farmers to self-assess their natural capital for their own information. Geo-located photographs may enable an independent expert to corroborate (or disagree) with the assessment.

50 Observed by Tongway in (Tongway and Hindley (2004), once one has performed several detailed surveys, one appears to develop the capacity to use observations to form the same view as that provided by the measurements. Also see S.M. Whitten et al., “Multiple Ecological Communities Conservation Value Metric. Final Report to the Australian Government Department of the Environment, Water, Heritage and the Arts,” (Canberra, Australia: CSIRO Sustainable Ecosystems, 2010).

51 E.g., MLA, “Grazing Fundamentals Edge Workshop Notes,” (Sydney, Australia: MLA Edge Network, 2016).

52 Observers would need to make sure they are gaining observations over a sufficiently large area to be confident that their assessment represents the ecosystem unit.

Table 4: Provisional categories of pasture condition for ecosystem accounting. Adapted from Ogilvy et al. (in preparation). We assume that the thresholds described here will need to be adapted to be appropriate different rainfall zones.

Category	Description
A (Very Good)	Pasture or grasslands that have high levels of groundcover (90%), including large perennial tussock species and litter that contribute to landscape functioning (soil protection and water and nutrient cycling), a diverse mix of perennial, palatable and persistent species. A good amount of biomass is retained (>1500 kg/ha). Few weeds are present and soil erosion is absent.
B (Good)	Pasture that has high levels of groundcover (>70% & <90%). There is a slight decline in perennial, palatable and persistent species and larger tussock species that contribute to ongoing high levels of landscape functioning are less abundant than for class A. Reasonable biomass (approximately 1000-1500kg/ha) is retained and there may be some signs of previous erosion as well as potential for current erosion in some areas. Likely to be a minor presence of weeds.
C (Fair)	There are reasonable levels of groundcover (up to 70%), a moderate diversity of palatable and perennial species but persistent native species that protect soil assets, including tussock species, in poor times are missing. Weeds (annual or invasive perennial) are present and conspicuous. Bare ground may be significant (>50%) in some years and there are obvious signs of erosion with current susceptibility to erosion high.
D (Poor)	A fair proportion of bare ground (>30%), low biomass most of the time and (likely to very low in extended dry times). A low diversity of perennials and dominated by unpalatable perennials and annual weedy species.
E (Very Poor)	Few perennial species are present and a severe and hostile environment for plant growth (i.e. scalding, salinity, severe and continuing gullying in susceptible areas). Potential and likelihood of weed invasion is high.

We suggest that condition categories described above create useful information for farm management by providing a way to report on the condition of individual paddocks and link this information with management activities and other factors. An example summary (Table 5) is provided to illustrate a potential use of this information.

Table 5: Illustration of a pasture condition summary table using condition categories.

Paddock Name	Size (ha)	Condition (Date 1)	Condition (Date 2)	Improvement (deterioration)
Top Paddock	15	Good	Very Good	Improvement
Tank Paddock	25	Good	Good	-
Back Paddock	12	Very Good	Very Good	-
Land's End	9	Fair	Good	Improvement
Dam Paddock	32	Fair	Poor	Deterioration
Etc...				
Etc...				

If the Condition Indicator approach (option 2 above) is preferred, the variables that underpin the descriptions in Table 3 can be quantified individually e.g., using Landscape

Function Analysis[53], or Patchkey[54] to form Condition Indicator Accounts. An example of this is provided in a proposed experimental approach to accounting for soil condition accounts (Table 6).

Accounting for the condition of soil - EXPERIMENTAL

At present, the framing of soil health and the relationship of management practices to different soil characteristics and to the productivity and resilience of a soil is contested due to the complex, dynamic nature of agriculture[55]. Mentioned briefly earlier, no standard has been yet developed for accounting for soil health, but we expect that, due to extensive agronomic expertise and a new federal focus on a national soil strategy will yield a practical solution.

For the NCALCS program Phase 2 and beyond, we suggest an experimental approach working with soil scientists to adapt and test the Condition Indicator Accounts approach suggested in the UN SEEA EEA (Chapter 5). We suggest that while the condition category approach (using pasture condition categories or state & transition models) is useful for vegetation, approach 2 – Condition Indicator Accounts should be considered for soil[56,57]. The main reason for this is so that the information in the NCA can inform the different interventions that are selected to change soil variables (such as SOM or pH).

The farmer interviews suggested that, at present the cost of soil sampling is high and most farmers don't use soil test information in their crop and management planning, although leaf tests were extensively used. Instead, farmer practice was to perform the activities such as no-till, stubble retention, mulching, partial budgeting, and biology-friendly inputs that their research and own observation and experience suggests will provide the functions and processes necessary to keep the soil in good condition.

However, the absence of information about key soil functions and processes may be preventing detection of emerging soil degradation before cost-effective interventions can take place. It seems desirable for information about soil health to be collected and communicated in a useful way.

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53 David J Tongway and Norman L Hindley, *Landscape Function Analysis: Procedures for Monitoring and Assessing Landscapes* (Canberra: CSIRO Sustainable Ecosystems, 2004).

54 B Abbott and J Corfield, "Patchkey - a Patch Based Land Condition Framework for Rangeland Assessment and Monitoring. Background Information and Users Guide," (Canberra Australia: CSIRO, 2012).

55 See for an excellent discussion JA Kirkegaard et al., "Sense and Nonsense in Conservation Agriculture: Principles, Pracmatism and Productivity in Australian Mixed Farming Systems," *Agriculture, Ecosystems & Environment* 187 (2014); Grace L. Miner et al., "Soil Health Management Practices and Crop Productivity," *Agricultural & Environmental Letters* 5, no. 1 (2020).

56 Accounting for the condition of soil is desirable in NCA, but methods to do this haven't been developed.

57 We note that, while soil is not considered an ecosystem in the UN SEEA EEA, we suggest that methods for condition accounting described in the UN SEEA EEA (Chapter 5) may be adapted to provide a standardised way for accounting for soil.

The UN SEEA EEA (2020) describes methods for establishing ecosystem condition indicator accounts where each variable is related to a reference condition and a threshold amount that indicates degradation (or collapse) of the ecosystem. This could support the adoption of standardised methods for accounting for soil health in a manner that aligned with the familiar approaches used by agronomists and farm advisors for example by reflecting the 'traffic light' system in www.soilquality.org.au. An illustration of how this might be adapted for soil is provided in Table 6.

Table 6: Example of adaptation of ecosystem condition indicator accounting to provide a soil condition (indicator) account that may be used to indicate soil health. List of variables selected to illustrate the concept.

Soil Health Variable	Indicators[58]	Variable Values		Reference Level Values		Indicator Values (rescaled)	
	Descriptor	Variable Date 1	Variable Date 2	Upper Level	Lower Level	Value - Date 1	Value - Date 2
Functional Property	Ground Cover[59]	0.60	0.60	0.90	0.50		
Physical Property	Bulk Density						
Chemical Property	pH						
	SOC						
	EC						
Biological Property	Microbial Biomass						
Other	Other						

Thematic Accounts

Ecosystems and natural capital have attributes that have importance to citizens, businesses, and governments because they indicate the capacity of the ecosystem to supply important services and functions. Four of these are:

- Carbon – the current stocks of carbon in the biosphere, the potential to store carbon, the trade-offs of carbon storage with other important resources such as water use and food production.
- Biodiversity – the biological diversity of farm properties, and the degree to which farm properties conserve biodiversity. The SEEA EEA suggests species accounts, but these may not reflect biodiversity. King et al (2021) explain how biodiversity is reflected in national accounts, but farmers or their stakeholders may need an additional output designed to satisfy their information needs.
- Water – the use of water from different sources and whether the quality and quantity of these resources is being sustained (maintained) (i.e., water use is less than or equal to water supply/recharge and emissions to water

58 The column headings in this adaptation of the UN SEEA EEA use points in time to reflect the fact that these are measurement of stock characteristics at a point in time.

59 This might be average through the year or minimum of the year.

(e.g., leaching of fertilisers to aquifers) at levels that exceed the capacity of purification services (e.g., those provided by above ground vegetation and subsoil geology etc).

- Quality of food, fibre & beverages – the relationship between characteristics of natural capital and its management (e.g., farm chemical use) and the nutritional qualities and safety (e.g., farm chemical residuals). By providing guidance for a standardised approach to data collection, NCA may be able to help develop information about associations between natural capital characteristics and resource-use with independent measurements of compounds such as sucrose, flavonoids, carotenoids, stilbenes (resveratrol), curvumin, and residual chemical. If relationships can be established, the information would provide valuable insights for farmers and consumers[60].

The national accounting approach to thematic accounts is described in the UN SEEA EEA (2020) and in the UN SEEA Central Framework (CF) (2012). In considering whether these need to be adapted or extended to provide information useful to farmers, we should consider:

- the scale of information – for example, the consideration of whether information about differences in carbon stocks and sequestration rates of each type of ecosystem on the property is useful for management and other stakeholder decisions,
- whether farmers need additional information to help them manage their resources effectively – for example:
    - with respect to carbon and the provision of global climate regulation services, farmers may find information about their sequestration potential[61] to be useful in considering how to plan and manage the ecosystem types of their properties,
    - with respect to water in the context of sustainability, farmers who use groundwater in their operations may be interested in:
        - estimating the ratio of their extraction from above and below ground water resources to the recharge of these resources from rainfall. They may also be interested to distinguish their use of fossil aquifers (essentially a finite resource) from recharging aquifers (a renewable resource given appropriate above ground management)
        - They may also be interested in understanding whether characteristics of their natural capital (for example soil characteristics) are making it more likely that nutrients will be leached though their soil to aquifers so they can respond and

60 Note that establishing these relationships will require an appropriate experimental design and is likely to require a very large dataset and partnerships between soil and ecological science and food and nutrition science.

61 The amount of future sequestration given their present ecosystem assets.

reduce this.

- With respect to relationships between food and fibre product quality and soil and ecosystem health, farmers may be interested in:
  - Understanding how natural capital characteristics such as soil functions and processes affect the nutritional characteristics of the food and beverage products they produce.
  - Tracking and communicating this.

Ecosystem services accounting (physical terms)

Ecosystem services are defined as the contributions of ecosystems to the benefits that are used in economic and other human activity. Benefits in natural capital accounting are the goods and services that are ultimately used and enjoyed by people and society. Each ecosystem asset (piece of natural capital) supplies a set (bundle) of ecosystem services to users (including society more broadly). Ecosystem services make contributions to other goods and services[62] that are used and enjoyed by people.

- Provisioning services are the material contributions an ecosystem makes to goods and services traded between businesses, governments, and households. Every final ecosystem service flow represents a transaction between an ecosystem asset and an economic unit.
- Regulating services are the ability of ecosystems to regulate and maintain climate, hydrological and biochemical cycles, and a variety of biological processes in ranges that benefit individuals and society.
- Cultural services are experiential and non-material services related to the perceived or realised qualities of ecosystem assets whose existence and functioning contributes to a range of cultural benefits derived by individuals,

Ecosystem services are used in two main stages in production of goods and services used in the economy. Where the ecosystem service is used by a business (including a farm business), government or household[63] it is classified as a 'final' (provisioning, regulating or cultural) service. Where the ecosystem service is used by an ecosystem asset and this asset is producing other ecosystem services that are being used by business, government, or households, it is classified as an intermediate service.

In agriculture, the farm business (a type of economic unit) is the user of most ecosystem services provided by agricultural natural capital, and on farms there are considerable intermediate services[64] that different ecosystems provide to each other that contribute

62 The amount of future sequestration given their present ecosystem assets.
63 Described as 'economic units' in the UN SEEA EEA
64 The concept of intermediate services is not equivalent to the wide array of biophysical flows within and between ecosystems that reflect ongoing ecological processes and are important to ongoing functioning of ecosystems. These are considered in the measurement of ecosystem condition, ecosystem capacity (to provide ecosystem services) and biodiversity.

to production. For example, shelter provided by trees to pasturelands and croplands can increase the productivity of these ecosystems. Other businesses, governments and households also use ecosystem services generated by farms, even if they don't have to pay for them. If farms operate sustainably (and don't consume their natural capital), then we might consider that future generations are users of regulating ecosystem services generated by farms to preserve their productive capacity.

The UN SEEA EEA (2021) describes the purpose of ecosystem service accounting as being to estimate the contributions that ecosystems make to the goods and services used and enjoyed by people. The designs for ecosystem service accounting developed for the NCACLS program (with other projects) draws on the definitions and lists of ecosystem services in the UN SEEA EEA and proposes ways in which these can be adapted to farm level. These designs aim to provide ways to estimate the contribution ecosystems make to achieving the environmental, social, and financial performance objectives of the farm and the ecosystem services that the farm and the farmer generates for society.

A reference list of internationally agreed classifications of ecosystem services has not yet been finalised by the UN and methods of measurement or estimation of many of them are still being developed. The present guidance suggests that the primary criterion for inclusion in the reference list of selected ecosystem services is that the service is considered to constitute a relevant and material ecosystem service in many countries and contexts . Applying the principle of materiality to the objectives of NCALCS, we selected a set of ecosystem services presently described in the SEEA EEA that we considered to be most relevant to these goals. We explored the literature (including agricultural practice literature) that described how these ecosystem services can be quantified.

To practice ecosystem service accounting, a physical metric of the ecosystem service is needed. The UN SEEA EEA acknowledges the considerable measurement challenges in either identifying all the ecosystem services provided or accurately measuring the contribution of these. Some ecosystem services (e.g., provisioning) can be directly measured. It is more practical to measure others using a proxy e.g., bare ground with reference to a threshold for water and wind erosion. The SEEA EEA advises that a proxy for a direct metric is acceptable in cases where data for direct measures cannot be collected. Also due to the complexity and expense of direct measurement, it is likely that some ecosystem services have to be (at present) inferred from ecosystem asset characteristics. Examples of these include shelter, pollination, pest predation, water purification.

Once a measure of the ecosystem service in physical terms is established, this information can be combined with other information (such as income or expenditure information from farm financial accounts, or information about livestock or crop performance from operational sources) to estimate a monetary value for the service[65].

The NCALCS program applied these principles to propose a list of ecosystem services that would provide useful information to farmers to:

- Help them estimate the contributions ecosystems make to the health of their natural capital and through this to the capacity of their enterprise to meet its financial, environmental and social goals,
- Help them assess and communicate their contribution to benefits for society.

Where they were defined, we used the measures suggested in the UN SEEA EEA. Where measurement concepts and measures were not defined, we drew on agricultural and ecological literature to propose some concepts and measures that we could use in NCALCS Phase 1. The list of ecosystem services exposed some measurement challenges that need to be overcome if the ‘empty cells' are to be filled in future. The ecosystem services we included in the project are summarised in the next section along with the measurement concepts, units along with the measurement methods and data sources that were judged to be practical for this project. The ‘empty cells' are shaded in grey along with notes about related projects that may assist with their filling.

Provisioning services

Provisioning services are the ecosystem contributions to the growth of plant, animal and other biomass that are subsequently harvested by economic units including the production of food, fibre, energy, medicines, and cosmetics. Table 7 provides some examples commonly seen in broadacre agriculture. Note that many of these already appear in the farm financial accounts.

Table 7: Estimating the generation of provisioning services (agricultural ecosystem inputs to agricultural production)

Provisioning services[66]	Description	Measure (phyisical terms)
Biomass - Forage	Forage for livestock The quantity of forage produced annually from all types of ecosystems on the property that are used by livestock for grazing	Direct Estimate: Tonnes Forage budgets
		Proxy Estimate: AEDays: Days times number of Adult Equivalent Livestock (or DSE) that can be run without supplementary feed or overgrazing that causes pasture condition to decline.

65 Methods to do this are an active area of research. We expect they will increasingly be available for application and testing during the next few years.

66 The contributions ecosystems make to water supply are also classed as provisioning services under the UN SEEA EEA. These contributions provide water purification and regulation of water flow. They aren't being estimated in this project.

Provisioning services[66]	Description	Measure (phyisical terms)
Biomass - Crops	The quantity of annual plants that have produced grains or seeds for harvest[67]	Direct Estimate: Tonnes Management records
Biomass - Timber	Timber for harvest The quantity of timber available for harvest[68]	Direct Estimate: Tonnes Management records
Biomass - Mallee	Mallee for harvest As for timber	Direct Estimate: Tonnes Management records
Biomass - Floristic resources	Forage for bees[69]	Direct Estimate: Area and quality of Floristic resources Ecosystem Asset Accounts

Regulating services

Regulating services are the ecosystem services that reflect the ability of ecosystems to regulate and maintain climate, hydrological and biochemical cycles, and biological processes. Table 8 summarises the ecosystem services relevant to this project and suggests how they might be quantified. Note that the 'empty cells' are shaded in grey to indicate where methods and technologies are needed to quantify ecosystem services.

Table 8: Regulating services.

Regulating services	Description	Measure (phyisical terms)
Global climate regulation	The contribution of ecosystems to storage of carbon in biomass and avoidance of its release into the atmosphere.	Modelled estimate: Mg[70]C (stored in biomass) Stocks of bio-carbon and estimates of sequestration and emissions can be modelled (e.g., FullCAM[71], FlintProTM[72])
Rainfall pattern regulation services (at sub-continental scale)	The ecosystem contributions to maintaining rainfall patterns through evapotranspiration at the sub-continental scale.	Models yet to be developed

67 Accounting for perennial plants that produce crops for harvest (e.g., fruit trees and vines) is already described in the Corporate Accounting Standards for agriculture.
68 Also described in the Agricultural Accounting Standards.
69 Hosting honeybee hives so they can regenerate between crop pollination season is also considered an ecosystem service but is not estimated in this project.
70 Million grams
71 Can be downloaded from Australian Department of Agriculture, Water and the Environment.
72 The Mullion Group

Regulating services	Description	Measure (phyisical terms)
Soil Erosion Protection	The ecosystem elements, for example vegetation (ground cover), contributions that reduce the loss of soil to water and wind erosion and any consequent damage to buildings and roads.	Direct estimate: not defined Proxy measure: Ground cover above 50%[73] (or Bare ground above 50%) Vegmachine[74,75]
Soil Quality Regulation	The ecosystem contributions to the decomposition of organic and inorganic materials and to the fertility and characteristics of soils (e.g., for input to biomass production).	Direct measures haven't been defined in the UN SEEA EEA[76] Proxy measures: • Ground cover[77] and • Application of good management practice Source: Vegmachine (as above) Management records including those related to nutrient replenishment, style of tillage, strategies for dealing with soil pests.
Meso-Climate Regulation (Shelter for crops and livestock)	The contribution of trees in providing shade and shelter for crops and livestock[78].	Proxy measure: Zone of protection (ha)[79] Methods for direct measurement of additional crops and livestock that can be attributed to shelter are yet to be developed[80]
Pollination	The ecosystem contributions by wild pollinators to the fertilisation of crops that maintains or increases the abundance and/ or diversity of other species (including crops and pastures.	Proxy measure: Zone of pollination (ha) As above, methods for direct measurement are yet to be developed

73 A direct measure of soil erosion protection has not been developed by the UN SEEA EEA yet. A proxy measure that is well-accepted as an indicator of whether soil is protected from erosion is whether the ground cover is above 50%.

74 JRSRP, "Seasonal Fractional Ground Cover for Australia Derived from Usgs Landsat Images," QLD Department of Environment & Science, http://data.auscover.org.au/xwiki/bin/view/Product+pages/Seasonal+Ground+Cover.

75 Other services and packages e.g., FarmMap 4D, CIBO labs.

76 It might be useful to explore whether ways of doing soil condition accounting can be described that can provide a way of quantifying soil quality regulation services.

77 A direct measure of soil erosion protection has not been developed by the UN SEEA EEA yet. Proxy measures that are well-accepted as an indicator of whether soil is likely to be healthy include ground cover and management practices.

78 There is a great deal of literature available that suggests these benefits are considerable. The aim of NCA would be to develop methods so that farmers and farm accountants or advisors can quantify the benefits for each farm.

79 This would try to quantify the capacity of the ecosystem to provide shelter services by quantifying the zone of net benefit taking into account the competition effect close to trees.

80 Ways to include these services (including Pollination, Pest-Predation and Water Purification) in the natural capital accounts are being developed by CSIRO and La Trobe University (among others). An avenue being explored is the development of 'look-up' tables that associate service generation with variables that describe the asset.

Regulating services	Description	Measure (phyisical terms)
Pest-Control (insects)	The ecosystem contributions to the reduction in biological interactions of the incidence of species that may prevent or reduce the output of biomass from ecosystems or affect human health	Proxy measure: Zone of protection (ha) As above, methods for direct measurement are yet to be developed
Water purification	The ecosystem contributions to the restoration and maintenance of the chemical condition of surface and groundwater bodies through the breakdown and storage by ecosystem components that mitigates the harmful effects of the pollutants on human use or health.	Proxy measure: Zone of protection (ha)[81]. GIS analysis. Methods for direct measurement are yet to be developed.

It should be noted that the use of ground cover measurements as a proxy for soil protection and regulation services generated significant discussion amongst the project participants. In particular, the question of how accurately the remote sensed measures predict the health of soil when considering highly active biological systems. In these systems, the high biological function leads to rapid decomposition of litter, potentially resulting in more bare ground (and thus a lower groundcover score) which would indicate poorer soil condition. This is inconsistent with the fact that the high biological function of the soil would suggest that the soil is in good condition. Further work is required to better understand the implications of the biological function of the soil with respect to the soil protection and regulation services.

Cultural Services

Cultural services are the experiential and non-material services related to the perceived or realised qualities of ecosystem assets whose existence and functioning contributes to a range of cultural benefits derived by individuals. Table 9 lists these along with the measures we suggest might be appropriate during NCALCS to quantify these at farm-level.

Table 9: Cultural services

Cultural services	Description	Measure (phyisical terms)
Education, scientific and research services	The ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems that enable intellectual and representative interactions with the environment	Direct Measure: The number of people attending field days and studying the farms' ecosystems and operations Records of visits for field days and research

81 B. Hansen et al., "Challenges in Applying Scientific Evidence to Width Recommendations for Riparian Management in Agricultural Australia," *Ecological management & restoration* 16, no. 1 (2015).

Cultural services	Description	Measure (phyisical terms)
Recreation-related services and Aesthetic enjoyment services	The contribution of the ecosystem in particular through the biophysical characteristics and qualities of ecosystems that enable people to use and enjoy the environment through physical and experiential interactions with it.	Direct Measure: The number of people visiting the farm for recreation and sight-seeing. Records of visits for recreation and sight-seeing.
Spiritual, symbolic and artistic services	The ecosystem contributions, in particular through the biophysical characteristics and qualities of ecosystems that are recognised by people for their cultural, historical, sacred or religious significance.	Direct Measure: The number of people-days of indigenous people (Traditional Owners) accessing spiritually significant sites on the farm Records of visits
Habitat maintenance services (for ecosystem and species appreciation)	The ecosystem contributions necessary for sustaining populations of species that businesses, governments and households use or enjoy.	Direct Measure: Area of each type of habitat maintained to support populations of culturally important plants and animals. Ecosystem extent accounts

Biodiversity

Note that the UN SEEA EEA (2020) doesn't consider biodiversity as an ecosystem service. It incorporates biodiversity as an emerging property of a set of ecosystem assets and the community assemblages within them. It considers that biodiversity:

- Provides a greater range of ecosystem service options,
- Is essential for cycling energy, nutrients and other materials through the environment and is fundamental for maintaining the various ecosystem processes and functions that underpin ecosystem service supply,
- Is essential to non-use values that people hold with respect to the environment,
- Assures greater dependability of ecosystem service supply.

Example ecosystem service account

Following the understanding of the role of accounting to account for or explain things and the farmers requirement for an understanding of how natural capital contributes to the farm, we suggest the following approach towards an ecosystem service account suitable at farm level. It is coherent with the SEEA EEA logic tables. ('Empty cells' shaded in grey.)

Table 10: Example ecosystem services account (partial table) for a farm to illustrate the accounting of ecosystem service generation by different ecosystem assets.

Ecosystem type (condition)	Description
Woodland[82]	**Provisioning of Biomass:** • forage • timber • nectar[83]
	Regulating and maintenance: • Bio-carbon sequestration and storage (Global Climate Regulation) • Rainfall pattern regulation services (at sub-continental scale) • Shelter (Meso-climate Regulation) • Pollination • Pest-control (insect) • Water purification • Habitat maintenance/species populations • Soil Quality Regulation • Soil Erosion Control
Shrubland	**Provisioning of Biomass:** • forage
	Regulating and maintenance: • Bio-carbon sequestration and storage (Global Climate Reg'n) • Shelter (Meso-climate Reg'n) • Habitat maintenance/species populations • Soil Quality Regulation • Soil Erosion Control
	Cultural services • Education, scientific and research services[84] • Spiritual, symbolic, and artistic services
Pasturelands	**Provisioning of Biomass:** • forage
	Regulating and maintenance: • Bio-carbon sequestration and storage (Global Climate Reg'n) • Soil Quality Regulation • Soil Erosion Control
Croplands[85]	**Provisioning of Biomass:** • Plants for harvest • Forage for livestock (stubble)
	Regulating and maintenance: • Bio-carbon sequestration and storage (Global Climate Reg'n) • Soil Quality Regulation

82 Grassy Woodlands generate a wide range of ecosystem services that contribute to farm productivity and resilience and to society more broadly Lavorel et al. (2015)

83 For honey-bee forage services. Not included in this project.

84 Illustration - a farm might provide a research opportunity to study whether the ecosystem services that research suggests that shrublands can provide to sheep (filling a feed gap, reducing methane emissions, improving wool quality D. K. Revell et al., "Australian Perennial Shrub Species Add Value to the Feed Base of Grazing Livestock in Low- to Medium-Rainfall Zones," *Animal Production Science* 53, no. 11 (2013). (2013) are observed in the field (and can be quantified).

85 This category includes annual horticulture crops such as pumpkins and other fruit and vegetables.

Ecosystem type (condition)	Description
Perennial Horticulture[86]	**Provisioning of Biomass** • Fruit for harvest
	Regulating and maintenance: • Soil Quality Regulation • Soil Erosion Control • Water purification
Environmental plantings	**Regulating and maintenance:** • Bio-carbon sequestration and storage (Global Climate Reg'n) • Shelter (Meso-climate Reg'n) • Habitat maintenance/species populations • Soil Quality Regulation • Soil Erosion Control • Water Purification Services
Riparian zones	**Regulating and maintenance:** • Water Purification Services

* Cultural services are likely to be associated with individual ecosystem assets as shown in this example but may be generally associated with the whole farm.

Ecosystem services accounting (monetary terms)

Noted earlier, methods for estimation of ecosystem services and benefits from them in monetary terms is an active area of research. We expect methods for application at farm scale to emerge in the next couple of years for testing with farmers. The NCALCS phase 1 project has yielded some insights into the different types of monetary estimations of ecosystem service value that might be useful in natural capital accounting for agriculture. These are mainly that there are significant differences in the measurement concepts and magnitudes of private benefit farms enjoy from ecosystem services and the private benefits other members of society enjoy from farmers delivery of these services. Table 11 suggests some of these for the purpose of providing guidance for methods research for monetary valuations of ecosystem services.

Table 11: Ecosystem Service Accounting in monetary terms

Ecosystem services	Farm Financial Benefits	Other Beneficiaries
Provisioning Services		
Biomass – Fruit, vegetables and grains for harvest, forage for livestock, timber	Measurement concept is the net income from the sale of biomass less the direct operating and input costs associated with production (e.g., fuel, fertiliser, labour and produced capital).	Value to society of reliable, secure sources of good quality food.
Cultural Services		

86 For example citrus, vineyards, almonds, peaches etc.

Ecosystem services	Farm Financial Benefits	Other Beneficiaries
Education, scientific and research services[87]	The measurement concept may be the payment/grant to farmer for hosting events.	There is considerable value to communities and society more broadly from the generation and sharing of knowledge and practice.
Recreation-related services and Aesthetic enjoyment services	The measurement concept may be the payment/grant to farmer for hosting events.	
Spiritual, symbolic and artistic services	The measurement concept may be the payment/grant to farmer for hosting events.	Priceless. However, these may be estimated as the monetary value communities and society more broadly of maintaining ecosystems that are spiritually, and symbolically significant.
Habitat maintenance services (for ecosystem and species appreciation)	The measurement concept may be the payment/grant to farmer for maintaining ecologically significant areas (e.g., environmental stewardship payments).	Priceless. However, these may be estimated as the monetary value to communities and society more broadly of maintaining ecosystems that provide habitat for endangered or threatened species.
Regulating Services		
Global climate regulation (bio-carbon sequestration in vegetation and soil)	The measurement concept may be the payment/grant to the farmer for providing sequestration and storage services (e.g., under the ERF). If the farm is not participating in the ERF, there may not be a private monetary value estimated.	Estimated as the monetary value to society of the farm's contribution to returning atmospheric carbon to safe levels
Rainfall pattern regulation services (at sub-continental scale)	The measurement concept may be the payment/grant to farmer for maintaining treed/forested areas that contribute to these services.	Estimated as the monetary value to society of the farm's contribution to subcontinental rainfall pattern regulation.
Micro-Climate, Meso-Climate Regulation (Shelter for crops)	The measurement concept would be the monetary value of the additional crop and livestock production attributable to shelter.	The value to society of reduced risk of agricultural production failure associated with adverse climatic conditions.
Pollination	The measurement concept would be the monetary value of the additional crop and livestock production attributable to pollination.	Value to society of continued viability and evolutionary adaptation of pollinators.
Pest-Control (insects)	The measurement concept would be the monetary value of the additional crop and livestock production attributable to pest control.	Value to society of reduced pesticides in circulation and increased biodiversity.

87 Estimates of the value of Worrolong contribution to generation of knowledge via field days, scientific research.

Ecosystem services	Farm Financial Benefits	Other Beneficiaries
Soil Erosion Protection	The measurement concept may be the monetary value of avoided loss of the volume of top soil, or perhaps the value of the depth of the A horizon.	Value to society of preserving healthy soils for the future. Value to society of avoiding the costs of cleaning roads and buildings following dust storms.
Soil Quality Regulation	The measurement concept may be the monetary value of soil quality. This may be estimated in a similar way to provisioning services (above).	Value to society of preserving healthy soils for the future.
Aquifer protection services[88]	The measurement concepts for this may include the cost to the farmer to provide aquifer protection. However, the investments to protect the aquifer may provide private benefit to the farmer in productivity and resource use efficiency. The farmer may also avoid costs of treatment of polluted water.	Value to society of avoided cost of desalination of aquifer due to nitrogen leaching. (For example, the estimated rate is between $1 and $4 per kilolitre of water that needs to be treated.)

Corroborating the Natural Capital Reports and Accounts

Financial accounts are usually audited by an independent auditor who checks the lines of evidence and provides a statement indicating that the accounts provide a true and faithful representation of the reported performance. We suggest that some claims in natural capital accounts could be inexpensively and independently corroborated using freely available remote sensing. While these would not corroborate the fine-scale information required for the condition categories reported in these accounts, it would probably be sufficient as form of exception monitoring that would expose a need for a further investigation.

Three corroboration points are suggested. These provide practical independent (remote-sensed) indicators of the farm's protection of soil, bio-carbon stocks, and biodiversity. Annual minimum bare ground indicates the degree to which soil is protected from wind and water erosion. Annual ground cover indicates the degree to which soil quality regulation services are being generated and overgrazing is being avoided. Forest cover indicates the degree to which bio-carbon stocks have been protected and exposes any deforestation. Forest cover change is also an indication of change to biodiversity. These indicators help stakeholders to detect whether there are reasons that further investigation or field observations should be used to assess the veracity of the natural capital accounts.

88 Conceptualised as the contribution of Worrolong's ecosystems and Tom & Emma's management to prevent or minimise leaching of nitrogen into public water resources.

Appendix: Production Data Required for NCA

The following production data is required to process the annual compilation of the Natural Capital Accounts. Most of this information is typically collected in the farm accounts as a matter of course, although there are some elements that are typically not recorded. **These elements are readily available at the time that the management function is undertaken, and the purpose of highlighting them here is to ensure that the information is recorded at the time it is generated rather than requiring forensic effort at the end of the year.**

ENERGY USE		
Use	**Element**	**Data required/Comments**
Calculate GHG emissions & Resource Use Intensities	Electricity used	Ideally: tCO_2e emissions from the bill Option 2: kWh from the bill Option 3: $ spent
	Renewable electricity	Percentage of purchased electricity from renewable sources. Amount exported (local production)
	Electricity allocation across products	Percentage allocated to domestic, livestock, crops, other enterprises
	Diesel used	Ideally: L of diesel purchased Option 2: $ spent
	Diesel allocation across products	Percentage allocated to domestic, livestock, crops, other enterprises
	Petrol used	Ideally: L of petrol purchased Option 2: $ spent
	Petrol allocation across products	Percentage allocated to domestic, livestock, crops, other enterprises
	Gas used	Ideally: L of gas purchased Option 2: $ spent
	Gas allocation across products	Percentage allocated to domestic, livestock, crops, other enterprises
	Contractor fuel use	If contractors are used and they provide their own fuel, then we need to be able to calculate the emissions. Rather than getting their actual fuel use (not typically available to the farm), we calculate the fuel use based on the type of activity (e.g. sowing crop, spraying, cutting hay, baling hay) and the area covered for each activity.

LIVESTOCK		
Use	**Element**	**Data required/Comments**
Calculate GHG emissions & Resource Use Intensities	Number of head, by class of animal, by season (summer, autumn, winter, spring)	**Class for sheep:** rams, maiden ewes, breeding ewes, other ewes, lambs, hoggets, wethers **Classes for cattle:** bulls < 1, bulls > 1, cows < 1, cows 1-2, cows > 2, steers < 1, steers > 1
	Typical weight of animals by class by season	This is used to estimate the feed intake of the animals. Can base the estimates on typical weight of animal at birth, typical weight of ewe/cow at joining.
	Breakdown of lambing/calving by season	Percentage breakdown across the seasons
Calculate pre-farm emissions	#, $ and liveweight of animals purchased by class of animal	# and $ are typically recorded in financial transactions, liveweight less so
Calculate allocation of emissions between products	#, $ and liveweight of animals sold by class of animal	# and $ are typically recorded in financial transactions, liveweight less so
	Greasy wool produced (kg), clean wool yield, $ sold	We are using biophysical allocations between wool and meat products
	Other animal products – physical quantity and $	E.g. If you are specifically selling hides for leather, lambskins for clothing, etc
	Agistment $	Income derived from offering agistment services. Differentiated between cattle and sheep
If the enterprise runs multiple flocks/herds, then we would ideally get this information by flock/herd. Agistment – if agistment is sold to others, then we only need the numbers and typical weights – as any production information ($/lwt purchased/sold) will be assigned to the agisting party. If your animals are agisted off-farm, then they are included in the above stock figures, as the emission are allocated to the products sold.		

CROPS AND INPUTS (Fertiliser, herbicide, pesticides, compost, etc)		
Use	**Element**	**Data required/Comments**
Allocate GHG emissions	Type, area for each crop type	Includes pasture as a 'crop' so that we can track the inputs. Differentiate between areas of types of pasture (native, exotic, irrigated, etc)
	Production (metric tonnes) and $	
Allocate GHG emissions and non-biodegradable waste	Production # bales	By type of product (e.g. round bales, square bales, hay vs silage)
Allocate GHG emissions	Crop amount consumed on farm vs sold (%)	On farm consumption ideally recorded by each flock/herd
Allocate water use	Irrigation per crop	ML per crop
Calculate GHG emissions, potential water pollution	Fert/pest/herbicide/ compost input (kg,L), incl product name (or N:P:K %)	Need this broken down by individual product so that we can understand the N, P, K makeup. This level of detail is often missing in the financial accounts.
Calculate non-biodegradable waste	Packaging of input	Packaging type (no packaging, 20L drum, IBC, 20kg bag, etc) and packaging disposal process (recycled, landfill, drum muster, reused on farm)
Calculate GHG emissions	Allocation of inputs to crops	This can either be an individual list of inputs per crop, or a % allocation of each input to the crops (including pasture/ fodder)

OTHER INPUTS (e.g. Purchased Feed)		
Use	**Element**	**Data required / Comments**
Calculate and allocate GHG emissions	Number of bales, tonnage and type of product purchased	Breakdown by feed type (e.g. silage, lucerne, pasture hay, grain and concentrates, cottonseed, etc)
	Allocation across flock / herds	Allocation of each purchased feed across the various flocks / herds
	Other inputs	Any other major inputs by type, volume and packaging that might be material to the emissions profile of the property.

WATER SOURCES for the property		
Use	**Element**	**Data required / Comments**
Allocate water use	Water sources for livestock	% breakdown of water sources across 4 categories (farm dam, pumped surface water (e.g. from large schemes that collect surface water runoff into dams and then pump to users), recharging aquifers, fossil aquifers (non-recharging). The assumption is that pumped water (from schemes, aquifers, etc) will be supplied to the livestock via troughs. Advise if this is not correct.
	Water sources for irrigation	% breakdown of water sources across 4 categories (farm dam, pumped surface water (e.g. from large schemes that collect surface water runoff into dams and then pump to users), recharging aquifers, fossil aquifers (non-recharging)

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