Final report

Climate and biodiversity credentials for Australian grass-fed beef production

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Abstract

Increasing interest in verification of climate and biodiversity credentials for beef production is evidenced by the proliferation of schemes offering these services. Understandably, producers are uncertain about the value this represents for their businesses and what products will deliver the best return for time and money invested. This project was developed to support entry into credentialling by beef producers and processors, and to build their knowledge to engage with emerging market opportunities associated with credentials. Through formal stakeholder engagement and a review process we identified key metrics and methods for climate and biodiversity credentials in Australian grass-fed beef production. We have suggested how they apply to various types of businesses and at different scales (farm, commodity, and animal cohort). We have recommended the implementation of a 3-tiered approach for entry-level credentialling for beef businesses, which was endorsed by the project steering committee.

The types of methods used in credentialling are diverse, and what we have recommended is essentially a mosaic approach based on our design criteria for entry level credentialling based on time and cost effective, scalable methods, and scientific credibility. We suggested the use of emissions accounting (SB-GAF) and process models (FullCAM – e.g. via FLINTpro) for climate credentials, and a business practice questionnaire and remote sensing (e.g. LOOC-B) approach for biodiversity credentials. These approaches all offer a strong potential for scientific verification and are a pragmatic starting point considering the current state of development in this field, although further work may be needed to achieve this. For example, there will be a need to ensure that questionnaire responses can be linked with biodiversity outcomes. A review paper is being prepared to provide peer-reviewed scientific support to meet the overall objective of scientific verification of methods to support entry level credentialling via an online platform.

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Executive summary

Background

The purpose of this research was to provide underpinning science support to enable verification of the environmental credentials of Australian grassfed beef. We wanted to know what are the key metrics and methods that would support climate and biodiversity credentials for beef producers and processers at different scales (e.g. cohort, enterprise through to multiple business levels). We wanted to identify the most effective ways to obtain the data that is required in credentialling. The work will be used to provide scientific support for the development of a digital platform (ECIT) for entry level credentialling.

Objectives

- Construct a sustainability performance measure that enables validation of climate and biodiversity credentials in the context of the ECIT platform.
- Define the key metrics and methods for a climate standard to enable verification of climate credentials of Australian grassfed beef as they are applied to the production system under examination (farm, feedlot, processor) at different scales (farm, commodity, and animal cohort).
- Prescribe the trusted data sources to provide evidence of meeting the climate and biodiversity standards and which will flow into the ECIT platform.

Methodology

- Conducted a literature review of SCA schemes currently being applied in climate and biodiversity credentialling, and identify key supporting scientific literature
- Developed a systematic framework for entry-level credentialling of climate and biodiversity, and the associated achievement criteria for each level of attainment (a tiered approach)
- Evaluated and recommended tools, metrics and methods for use in climate and biodiversity credentials based on data quality and capacity for scientific verification
- Engaged with stakeholders to receive feedback and guidance on the development of entry level credentialling for the beef industry, through workshops with the Environmental Credentials Advisory Group and the Project Steering Committee

Results/key findings

- An extensive review of SCA schemes revealed that while they are proliferating rapidly, the underpinning metrics and data being used to verify credentials is somewhat limited, due to both the high level of systems complexity and diversity, and likely protection of IP by credentialling businesses.
- The project review identified a wide range of methods and metrics that were being used in SCA schemes, in the areas of GHG emissions, sequestration and biodiversity. For climate credentials, GHG accounting methods are required including metrics such as emissions intensity, net/total emissions, and carbon stores in the soil and vegetation. For biodiversity credentials, the use of habitat condition assessment is a generally accepted proxy for biodiversity.
- We suggest the use of emissions accounting (SB-GAF) and process models (FullCAM – e.g. via FLINTpro) for climate credentials, and a business practice questionnaire and remote sensing

(e.g. LOOC-B) approach for biodiversity credentials. These approaches all offer a strong potential for scientific verification, although further work may be needed to achieve this. We recommend using a tiered approach to provide flexibility for entry level credentialling across the Australian beef industry. The 3-tiered approach and achievement criteria were developed with consistency for climate and biodiversity, i.e. Tier 1 – Aware (Learn and Plan), Tier 2- Actioned (Measure and Manage) and Tier 3-Committed (Monitor and Improve).

Benefits to industry

- This project has developed a scientifically grounded foundation for entry-level credentialling for producers and processors.
- Combined with governance and oversight from an industry representative body such as Meat and Livestock Australia, this should enable consistency and confidence for businesses or entities seeking to credential their products.
- The project supports the ECIT platform build by establishing a scientifically rigorous set of recommendations that can be applied and adapted to meet the practical requirements for credentialling in the beef industry.

Future research and recommendations

- Verification of climate and biodiversity credential outputs of the ECIT platform, and validation of the methods being applied
- Evaluation of the suitability of metrics and methods applied, and the tiered approach, and ensure that perverse incentives are not generated. Assess the potential value of new metrics and methods as they become available, and how credentialling approaches are evolving internationally.
- Improvements in the curation of data used in credentialling, and the possibility of automating data capture and/or avoiding duplication for data entry.

Table of contents

1. Background

1.1 Overview

There is a need for an increased level of coordination for climate and biodiversity credentialling in the Australian beef industry due to the proliferation of credentialling schemes being developed by the private sector. The momentum in credentials has been catalysed by the privatisation of services engaging with Australia's national Emissions Reduction Fund, and an increasing public interest in the sustainable production of food and fibre. With the emergence of many Standards, Certification and Assurance (SCA) schemes that are potentially relevant for grass-fed beef production, this project addresses the need for an entry point to climate and biodiversity credentials at the whole of business level, relevant to producers, lot feeding and processors.

Developing a climate and biodiversity credentialling framework presents a range of challenges, such as its suitability for diverse business structures and how many of the wide range of factors that will influence the credential should be considered. Credentials should be based on a combination of metrics that can be scientifically verified, but also implemented in a time and cost-effective manner. To achieve this, Meat and Livestock Australia (MLA) has proposed developing an entry level digital Environmental Credentials Information Technology (ECIT) Platform for credentialling based on scalable data sources such as existing producer records, ag-tech databases, and remote sensing information. To attract the interest of beef producers and achieve widespread adoption, the tool will require thoughtful and scientifically robust design and close stakeholder engagement due to the complexity of climate and biodiversity credentials. Further, significant rewards and incentives to support the scheme are necessary but must also meet benchmarks for integrity such as peer-reviewed science. Without this, uptake of credentialling schemes is likely to be patchy and the scope of the credentials will be ambiguous and open to domestic and international criticism. This project aims to develop a starting point for scientifically verified methods for climate and biodiversity credentialling in the Australian grass-fed beef industry.

2. Objectives

Project objectives as per the research agreement are:

1. Construct a standard that enables validation of climate and biodiversity credentials in the context of the ECIT platform.

2. Define the key metrics and methods for a climate standard to enable verification of climate credentials of Australian grass-fed beef as they are applied to the production system under examination (farm, feedlot, processor) at different scales (farm, commodity, and animal cohort).

3. Prescribe the trusted data sources to provide evidence of meeting the climate and biodiversity standards and which will flow into the ECIT platform.

3. Methodology

3.2 Overview

The work described in this report was carried out through combined literature review, expert consultation, and stakeholder engagement. The project addressed the development of entry-level climate and biodiversity credentials for grass-fed beef production, which is a challenging problem due to the diversity of grass-fed beef businesses (including farm, feedlot and processor sectors) and the agro-ecosystems used in beef production. To develop useful credentials, a process of accounting for climate and biodiversity is needed along with the capacity for verification of outcomes of management interventions.

The approach taken was to diversify knowledge resources in the project where possible, this included:

- Establishment of a project steering committee
- Ongoing engagement with direct project stakeholders, including MLA, ECIT, and Standards authorities
- Extensive review of the available documentation for SCA schemes
- Targeted review of scientific literature
- Two project workshops, with participation from the Technical Advisory Committee, covering a breadth of farming, technology, ecological and supply systems expertise
- Presentation of and feedback on project from the GFBC Steering Committee
- Presentation of and feedback on project from the Environmental Credentials Advisory Group
- Final report for project

The objectives of the two workshops were as follows:

Workshop 1: Identify design criteria and recommendations for credentials to be applied in the ECIT platform

Workshop 2: Identify and road test key methods and metrics to be applied within the ECIT platform

3.3 Definitions

Definitions applied within the project are described below. As the project has progressed there has been some further refinement of definitions and/or their application. The term 'Standard' was applied in this project to refer to sustainability performance measures. However, given this term is widely used to refer to a structured and authorised collection of rules that are typically overseen by a governing agency we have stepped away from the use of this term and refer to the framework being developed as credentials or credentialling. How carbon credits are considered within a credentialling context was discussed, and it was agreed that these are outside the scope of this project. Achievement of carbon neutrality will likely require carbon offsets or insets through sequestration that should be considered separately to any carbon farming activities.

Biodiversity (Convention on Biological Diversity, 2006)
Biodiversity is defined by the Convention on biological diversity as "the variability of living beings of all origins including, among others, aquatic ecosystems and the ecological complexes they are a part of: this includes diversity within species and the diversity of ecosystems" (art. 2). There are many frameworks for understanding, measuring, and reporting on biodiversity, including species-based,

ecosystem-based, and habitat-based approaches. Habitat-based methods focused on habitat condition is mainly used as the biodiversity assessment approach for this credentialing, as it is possible to obtain estimates of habitat condition from remote sensing, reducing the overheads of on-ground data collection by credentialing participants (see Habitat Condition).

Carbon neutrality (IPCC, 2021)
"Condition in which anthropogenic CO_2 emissions associated with a subject are balanced by anthropogenic CO_2 removals. The subject can be an entity such as a country, an organisation, a district or a commodity, or an activity such as a service and an event. Carbon neutrality is often assessed over the life cycle including indirect ("scope 3") emissions but can also be limited to the emissions and removals, over a specified period, for which the subject has direct control, as determined by the relevant scheme."
"Note 1: Carbon neutrality and net zero CO_2 emissions are overlapping concepts. The concepts can be applied at global or sub-global scales (e.g., regional, national, and sub-national). At a global scale, the terms carbon neutrality and net zero CO_2 emissions are equivalent. At sub-global scales, net zero CO_2 emissions is generally applied to emissions and removals under direct control or territorial responsibility of the reporting entity, while carbon neutrality generally includes emissions and removals within and beyond the direct control or territorial responsibility of the reporting entity. Accounting rules specified by GHG programmes or schemes can have a considerable influence on the quantification of relevant CO_2 emissions and removals."
"Note 2: In some cases achieving carbon neutrality may rely on the supplementary use of offsets to balance emissions that remain after actions by the reporting entity are taken into account"

Carbon negative (EarthOrg, 2021)
"Carbon negative, also called "climate positive," means that an activity goes beyond achieving net zero carbon emissions to create an environmental benefit by removing additional carbon dioxide from the atmosphere"

Climate neutrality (EarthOrg, 2021)
"Climate neutrality is the same concept as carbon neutrality, but it extends to zero net anthropogenic greenhouse gas emissions (including emissions beyond carbon dioxide)". Total GHG emissions are within scope for this project. MLA have an additional definition for climate neutrality that refers to the global warming impacts of an entity or industry. It occurs when the GHG emissions no longer contribute to additional global warming. For long-lived GHGs such as CO_2 and N_2O, this requires that the emissions be balanced to at least zero by the equivalent amount of carbon stored in the landscape within the entities proposed boundary. For short-lived GHGs, such as CH_4, this requires that emissions be reduced to a rate lower than the rate at which they are being removed from the atmosphere.

Carbon dioxide equivalents (CO2e, US EPA)
Carbon dioxide equivalent or CO2e means the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas and is calculated using Equation A-1 in 40 CFR Part 98 (https://www.epa.gov).

ECIT platform
Environmental Credentials Information Technology platform, as developed by Servian Pty Ltd under the MLA-UQ-WWF "Smart Farms" project.

Global warming potential (GWP) (IPCC, 2021)
"GWP is an index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a chosen time horizon, relative to that of the reference substance,

carbon dioxide (CO_2). The GWP thus represents the combined effect of the differing times these substances remain in the atmosphere and their effectiveness in causing radiative forcing."

Global warming potential (GWP100) (from IPCC, 2021)
GWP100 is an index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a 100-year time horizon, relative to that of the reference substance, carbon dioxide (CO2).

Global temperature change potential (GTP) (from Fagodiya et al., 2017)
The GTP is the global average temperature change at time t due to emission of a GHG relative to CO_2 emission. The GTP is directly related to surface temperature changes as a result of GHG emission.

Global temperature change potential (GTP100) (from Fagodiya et al., 2017)
GTP100 is the global average temperature change at 100 years due to emission of a GHG relative to CO_2 emission. The GTP is directly related to surface temperature changes as a result of GHG emission over this period.

Habitat Condition (Williams et al., 2021)
Habitat Condition is defined as the capacity of an area to provide the structures and functions necessary for the persistence of all species naturally expected to occur in that area if it were in an intact (reference) state.

Low carbon beef (USDA (United States Department of Agriculture), described in Henderson, 2021)
"Cattle must demonstrate at least 10 percent lower greenhouse gas emissions than the industry standard baselines based on the Low Carbon Beef Scoring Tables. Cattle are measured across 20 criteria associated with feeds, fuels, fertilizers, and cattle function (performance)"

Net-zero carbon emissions (EarthOrg, 2021)
"Net-zero carbon emissions … refers to reaching net-zero carbon emissions by a selected date"

Net-zero GHG emissions (EarthOrg, 2021)
"Net-zero GHG emissions are achieved when emissions of all greenhouse gases are balanced by greenhouse gas removals. This is the same concept as net zero carbon emissions but conveys a net zero emissions target for CO_2 and all non-CO_2 gases"

Standard
For the purposes of this project, a standard is a 'sustainability performance measure' that is derived from publicly available science research that is evidenced in peer-reviewed literature. It is not the same as a standard developed by a national or international standards organisation (e.g., Standards Australia or International Organization for Standardization). The standard does not provide for audit of the measure or certification of an organisation using it.

Publicly Available Specification (PAS) (from ISO definitions; ISO, n.d.)
A Publicly Available Specification is published to respond to an urgent market need, representing the consensus of the experts within a working group. Publicly Available Specifications are published for immediate use and serve to obtain feedback for an eventual transformation into a standard.

4. Results

4.4 Literature review

4.4.1 Introduction

With the proliferation of SCA schemes for climate and biodiversity credentials in the agricultural industry there is a need for increased coordination to provide clear entry pathways and encourage producer engagement. For example, the Australian Agricultural Sustainability Framework has indicated that it may act as a centralised 'marketplace' for assessing certification schemes (McRobert et al. 2022). However, identifying appropriate indicators and credentials in a space where new digital technologies are developing rapidly is a challenge. In this review we identify some of the key characteristics of the schemes, which include coverage of global regions, industries, supply chain segments, target outcomes, accreditation methods, measures and data sources, and scale. The review explores how the various schemes have approached quantifying key metrics that have been used in credentialling. In applying credentialling metrics, the schemes seek to find a balance that allows confidence that the measure is accurate and verifiable, but at the same time is not so onerous or costly so that stakeholders do not engage. Most schemes rely on voluntary participation and tend to have tiered credentialing to cater for differences in the desire and capacity of producers to be involved.

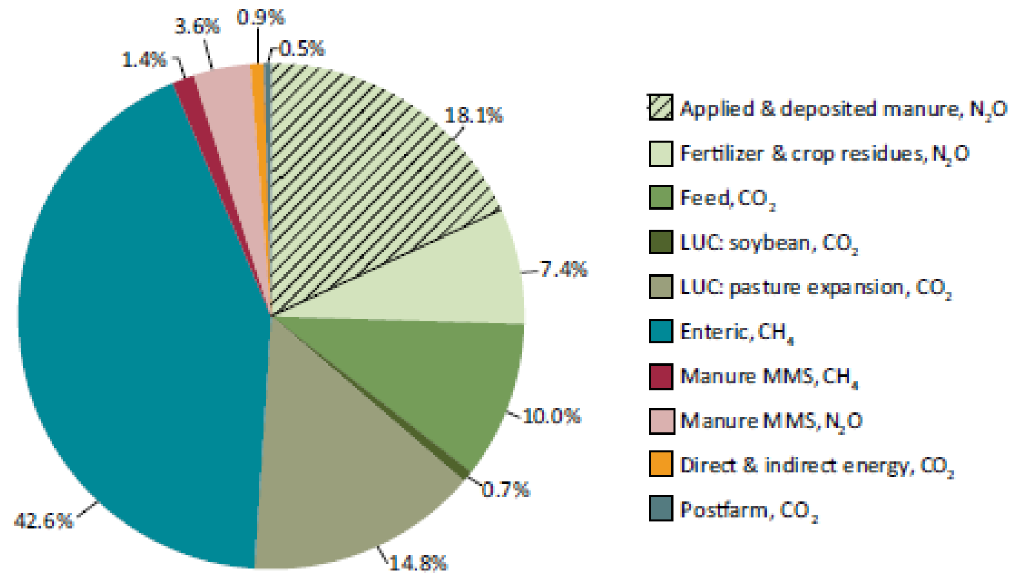
In many cases, there are several potential sources of data associated with various methods or models used to quantify climate and biodiversity indicators. In some cases, as the cost of implementing a method decreases so does the accuracy and confidence in the results. For example, the use of field-based methods that require specialist expertise to implement will carry a high cost whereas remote sensing methods can be applied at scale with the potential to be more cost effective. However, field survey methods will generate a wider range of data that is measured directly, and without the need for the large-scale calibration of models. Generally the value of the credential will be discounted if measures have less certainty. Based on this, the level of error associated with an estimated value should be known, and preferably be verified through peer-reviewed literature.

The structure of the review is based around the range of ways that the beef supply chain engages in credentialling, by moving toward net zero GHG emissions and managing land to support endemic biodiversity. Review sections address the quantification of emissions (total emissions and emissions intensity), sequestration (carbon capture within the agro-ecosystem), and farming of ecosystem services via climate and biodiversity for either credentialing of their own product within the supply chain or on-selling the credits within emerging markets.

4.4.2 Total emissions

Greenhouse gas (GHG) emissions from beef production globally are predominantly from the net production of enteric methane, nitrous oxide (manure and fertilizer application) and carbon dioxide (feed and land use change, particularly deforestation) (Figure 1; Opio et al., 2013_FAO). Estimates for beef production in Australia reflect these emission sources, with an estimated 48% from enteric methane, 40% from land use change and 8% from soil management practices, with the remaining ~4% comprised mostly of energy use, processing emissions and manure management (Mayberry et al. 2018). Based on this, the management of enteric methane emissions and maintaining or increasing on-farm stored carbon stocks should be the primary focus for reducing emissions in grass-fed beef enterprises. Accounting frameworks for the contribution of the different GHG emissions to global warming continue to develop, with ongoing discussion around metrics that are used to establish equivalence between them. The GWP100 climate metric is commonly used, but its validity is questioned because each of the GHGs varies in radiative efficiency and atmospheric lifetime (Ridoutt 2021). The potential for change in GHG emissions accounting methods is a significant challenge to the implementation of SCA schemes and poses a risk that will likely deter take-up of credentialing in the livestock industry.

Figure 1. Source of GHG emissions from global beef cattle production based on the GLEAM LCA model (from Figure 5, Opio et al. 2013)



Source: GLEAM

The purpose of Table 1 is to aggregate metrics and measurements associated with determining total emissions and emissions intensity associated with grassfed beef production within SCA schemes, and to outline the specification of methods and any associated references that provide scientific support and verification.

Table 1. Inventory of items and metrics used by SCA schemes to determine total emissions and emissions intensity for grass-fed beef production.

Metric	Method	Method specification
Livestock		
Livestock numbers by age[12,46,77,84], type[12,46,77,84], standard reference weight[46,60,116]	Farm records[12,46,77,84] Expert tables[60,116]	
Number of cattle purchased and sold[12,46,84]	Farm records/	Total number by weight, class and season[12,46]
Liveweight by class and season[12,46,60,116,84]	Expert tables[60,116]	Liveweight (kg) for each class by state and season[60,116]

Liveweight gain by class and season[12,46,60,84,116]	Expert tables[60,116]	Liveweight gain (kg/d) for each class by state and season[60,116]
Cows calving %		% by season[12,46]
Feed and pasture		
Amount, type, and digestibility of supplementary feed[12,46,77]		
Biomass of forage in pastures		
Quality of forage in pastures[60,77,116]	Based on published data[60,116]	Estimated DMD and CP values (season x location) [46,60,116]
Amount of time livestock were grazed[12,77,84]	Farm records[77]	
Dry matter intake per head[12,46,77]	Calculation [12,46]	Minson and MacDonald (1987) [46]
Type and amount of feed additives[77]	Farm records[77]	
Total seasonal[12,46], annual[84] enteric CH_4 production	Calculation [12,46]	E (g CH_4) = 91.25 x n cattle x (20.7 x Intake)/1000[46]
Total seasonal CH_4 production manure[46]	Calculation[46]	E (g CH_4) = 91.25 x n cattle x Intake x (1 - DMD) x ((Prop Warm Climate x EFWarm [0.021]) + (Prop Temperate climate x EFTemperate [0.003]))[46]
Total seasonal N_2O Urine and Dung during grazing[46]	Calculation[46]	F = 91.25 x n cattle x {(0.3 x (I x CP) x (1 - [((DMD + 10) / 100])) + 0.105 x (ME/kg feed x Intake x 0.008) + (0.0152 x Intake)} / 6.25 + (0.08 (0.032 x Milk Intake Calves) /6.38) [46] U = 91.25 x n cattle x {(Crude Protein Intake / 6.25) + (0.032 x Milk Intake Calves / 6.38) – N Retained – N in Faeces - [(1.1 x 10^-4 x Liveweight^0.75) / 6.25]} [46]
Feedlot (Domestic[46,118], Mid-fed, Long-fed[60,116])		
Livestock factors	Based on published data[60,116]	Days on feed[60,116] daily gain[60,116], mean liveweight[60,116], N retention[60,116]
Diet factors		DMD[60,116], Crude protein[60,116], Net Energy[60,116], Soluble residue[60,116], Hemi-cellulose[60,116], Cellulose[60,116]
Waste factors	Based on published data[60,116]	Allocation: Stockpile[60,116] Composting[60,116] Direct application[60,116] Effluent pond[60,116]
Fertiliser and chemicals (pasture)		
Type of fertilizer (% composition)[46,77]		
Application rate (kg/ha)[77] (t)[46]		
Application method [46,77]		
Dates of applications[46,77]		

N_2O emissions from synthetic fertilizer production[46]	Calculation[32, 46]	kg CO_2e = ($E_{N2O\text{-direct}}$ (kg N_20/ha) + $E_{N2O\text{-indirect}}$ (kg N_2O/ha)) x 298[32] t CO_2e = Mass urea applied x EF [3.67] x N fraction in urea [0.466][46]
Total seasonal urinary and faecal N_2O[46]	Calculation[46]	E (Gg N_20 N) = (seasonal faecal excreted + seasonal urine excreted) x EFUrine/dung [0.004] x molecular conversion factor [1.57] [46]
Fertiliser loss through leaching[46]	Calculation[46]	E = M x EF x Cg[46]
Herbicides/pesticides/animal health[46]		
Fuel and electricity		
Amount of purchased electricity[32,46,77]	Calculation[32]	$EM_{electricity}$[32]
Amount of electricity from on-farm renewable, used on-farm/ sold to the grid[32,46,77]	Calculation[32]	$EM_{electricity}$[32]
Amounts of different types of fuels used[32,46,77]	Calculation[32]	
Transport and distribution[32]	Calculation[32]	e_{td}[32]
Processing[32]	Calculation[3,]	e_P[32]
Soil and vegetation management of emissions		
Land use change and deforestation[32]		e_l (kg CO_2e/t) = CS_R (kg C/ha) – CS_A (kg C/ha)/ (yield raw material (ton/ha*yr) * 20 yr) * 3.664) - eB [32]
Area of residues burned[77]		
Residue biomass[77]		
Savannah burning[46]		Rainfall zone, Vegetation class, Patchiness, Fuel class size[46]

*Method suggests using carbon proportion, 0.2.
Note: superscript values are the reference number for each SCA scheme included in the review, refer to Appendix 8.1.

Individual GHG emissions calculations tend to be considered within the system boundary of a supply chain element, rather than the whole supply chain[32]. In the case of grassfed beef production, this would typically be at the business-level, with grazing, lot feeding and processing businesses or in some cases a combination. Group certification may also be acceptable in cases where units are very similar[32], although this may preclude activities within individual businesses to improve their emissions profile.

The GHG protocol produced by World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) is internationally recognised and used by entities (producer or business) seeking to develop an inventory of agricultural GHG emissions[77]. As shown in Table 1, GHG protocol covers a wide range of metrics within an inventory. Initially launched in 1998, the intention is to identify industry-accepted best practices for GHG accounting. These guidelines do not provide methods for project or product level accounting, the calculator tool that is available is generic and so difficult to adapt to beef production systems.

The SB-GAF tool[46] is the most detailed and peer-review supported tool for estimating GHG emission profiles of beef production for Australia, and there does not appear to be a comparable tool available internationally. However, in the current format the level of complexity may still be too high for business-level adoption.

Some existing SCA schemes are not at all prescriptive regarding the types of activities and assessment metrics that are required. For example, the Canadian Roundtable for Sustainable Beef's Sustainable Beef Production Standard simply states that the highest level of credential is achieved when the "Operation assesses the success of practices that are supporting carbon sequestration or minimizing emissions". No indication of the level of detail for the assessment is suggested, although their documentation also suggests that for production systems deemed to be high risk, a full on-site audit, and then 3 full records assessments are required within 5 years for certification. There is a lot of interconnectedness among the schemes, as has been identified in Appendix 8.1. For example, the FAO SAFA guidelines (2014) refer to an approach based on Environmental LCA within an ISO standard framework. However, this may require ISO standard frameworks to be available or adapted for a wide range of production conditions and sensitive to quantify change in an environmental credential through LCA analyses.

The quality of pasture has been identified as an important factor in total emissions, whereas pasture quantity and intake has not. This may be because indirect methods used to estimate intake are based on LW (e.g., Minson and MacDonald 1987).

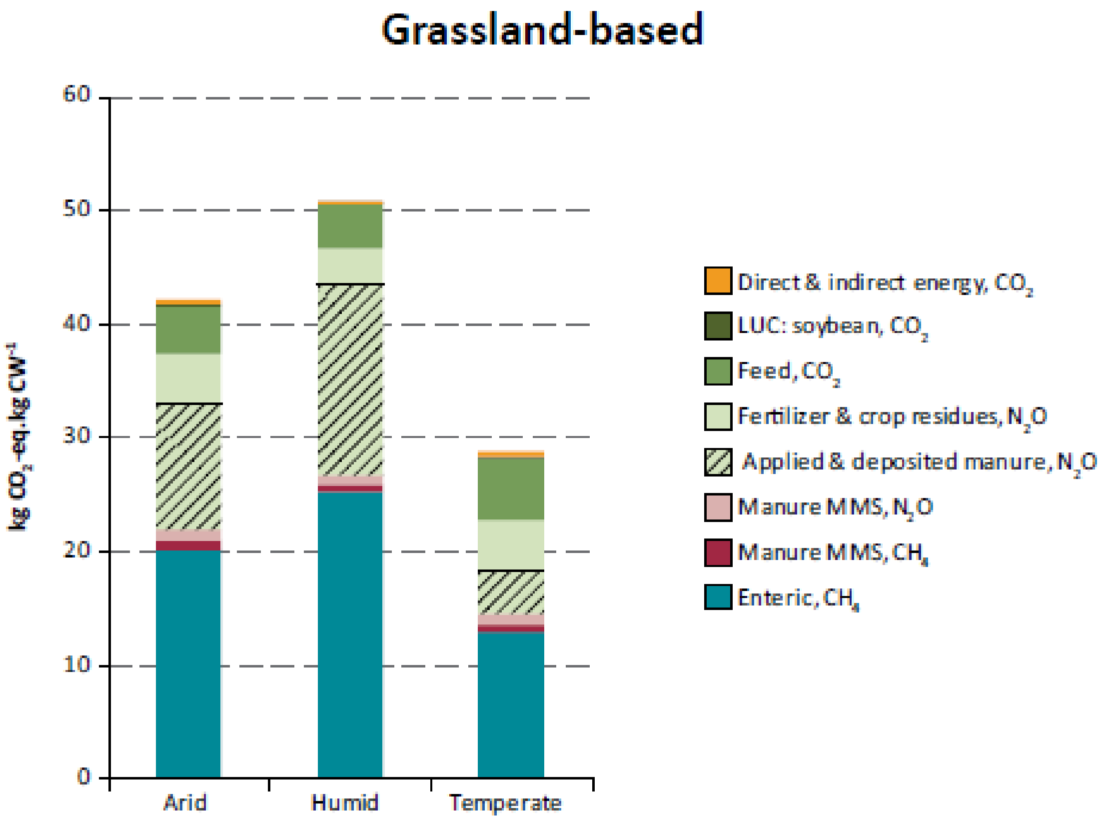
Enteric methane emissions and land use change make up the majority of GHG emissions within livestock systems. Although quantification of emissions from these aren't necessarily explicit in the schemes, prioritising their measurement may be important (Mayberry 2018). Registered Emission Reduction Fund (ERF) projects where approved land use change has been avoided have had a high contract success >90% in this program. However, livestock management projects (e.g., herd management) have not been well taken up (ERF project registry database). Accepted methods for feeding supplements have not been developed so there is not ERF method as this point.

4.4.3 Emissions intensity

Emissions intensity is the level of GHG emissions per unit of product, typically kilograms of live weight or carcase weight produced in the case of beef production. Emissions intensity can vary widely between production systems, due to both the management of inputs and efficiency of production from the herd and general environmental and climatic factors. Emissions intensity values have been reported by Brown et al. (2011) for benchmarked average and top producers for a range of livestock enterprises including cow-calf and steers in temperate systems. As might be expected, emissions intensity of cow calf production was about 3.5 times greater than steer production (22.4 vs 6.7 t CO_2e / t product for benchmark average; Brown et al. 2011). Figure 2 summarises the estimated differences in total GHG emissions intensity and the relative contribution of sources of emissions between three global production zones. This highlights the substantial differences in GHG emissions intensity that exist in different types of production systems. Some assumptions are made in the GLEAM model that was used (e.g., excluding sandy soils) that would likely affect emissions intensity estimates within production zones (FAO 2017).

Applied and deposited manure is the biggest factor varying between production zones (Figure 2), which reflects the nitrous oxide GHG emissions. Enteric methane accounts for about 50% of GHG emissions per unit product in all three cases.

Figure 2. Emissions intensity for grassland-based beef by ecological production zone (from Figure 8, Opio et al. 2013)



Enteric CH_4 is the largest contributor to emission intensity in three grassfed beef systems compared (Opio et al. 2013). However, it is highest in arid and humid zones of both grazing and mixed farming systems where feed, for the most part, is of lower quality. As methane emissions are largely driven by the livestock enterprise and pasture management, biophysical models are useful to investigate finer scale changes to livestock enterprise scenarios (e.g., Gebbels et al. 2022). Changes to reproduction performance and diet quality substantially change the amount and intensity of emissions and the level of production, so are strong drivers of improvement in emissions intensity.

The SB-GAF (Sheep and Beef Greenhouse Accounting Framework) developed by the University of Melbourne is intended for use in sheep and beef cattle grazing businesses, particularly enabling a baseline analysis to compare effects of other scenarios such as changes to land use, livestock enterprise or sequestration opportunities. SB-GAF is used to compare scenarios with different emissions intensity (Ekonomou et al. 2020).

The ERF Beef Cattle Herd Management Calculator must be used to estimate the total Emissions and Emissions intensity of ERF projects using the Beef cattle herd management method (https://www.dcceew.gov.au/climate-change/emissions-reduction/emissions-reduction-fund/methods/beef-cattle-herd-management). The Beef-cattle-herd-management-calculator-Version 3.2.xlsm, appears to be a simplified version of SB-GAF, particularly in the data structure for animal classes and input of numbers, average LW and average LWG on a seasonal basis. It was designed primarily to assist with requirements for reporting to the timeframes of the Beef Herd Management method for reference years and crediting years. It appears to be a simpler tool with hidden and protected formulas giving little opportunity to fine tune data inputs or to clearly understand the calculations. All outputs (enteric CH_4, N_2O) are converted to t CO_2e yr^{-1} and LWG as t yr^{-1}.

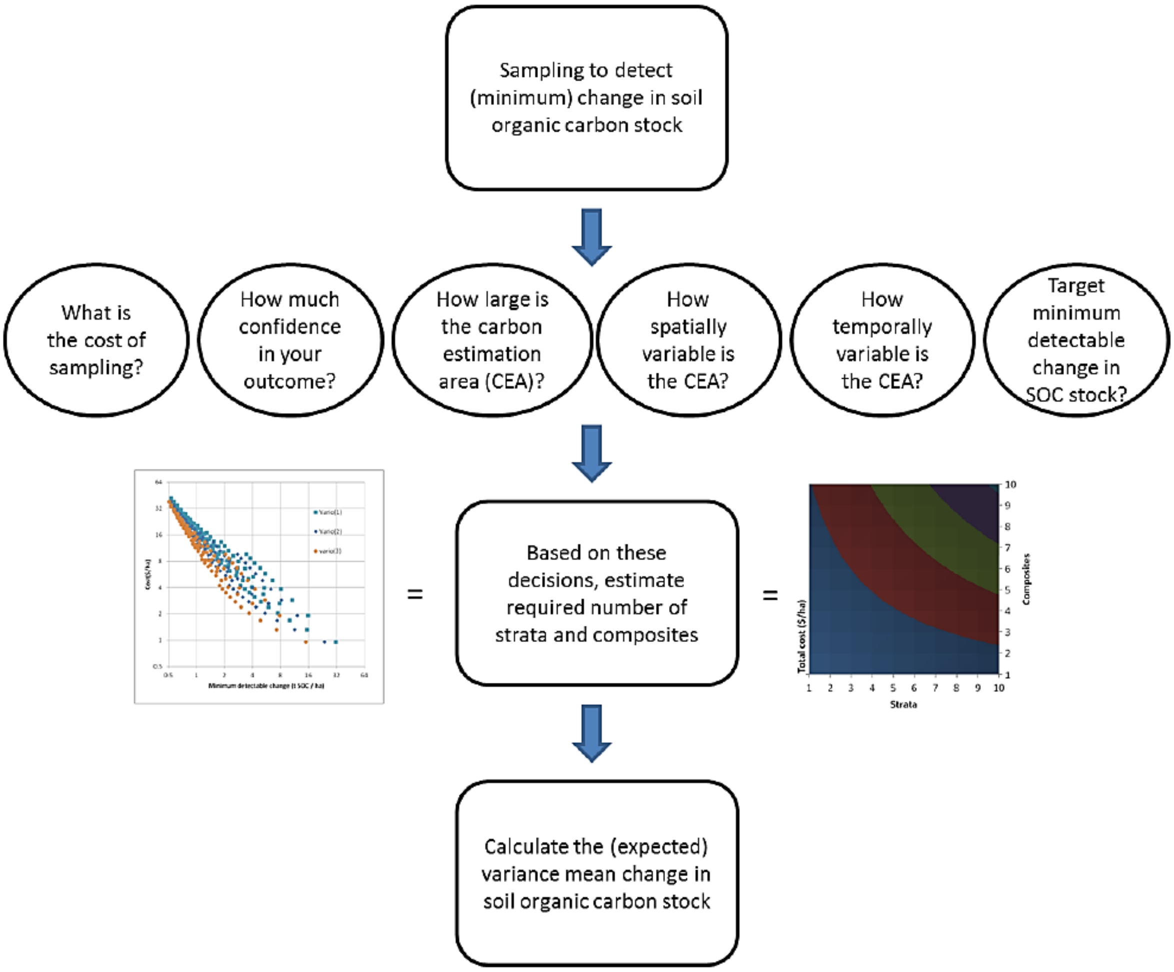
The Australian Government Clean Energy Regulator oversees the ERF, which provides a mechanism to register projects that can earn Australian Carbon Credit Units (ACCUs) for emissions avoidance or carbon storage. Some ERF methods also consider emissions intensity, with producers receiving ACCU's for activities that reduce emissions intensity.

4.4.4 Carbon sequestration

As land custodians and managers, farmers are uniquely placed to implement farming practice change that will increase the storage of carbon within agricultural landscapes. Carbon storage is a product of the area available for sequestration, and the carbon sequestration rate of carbon in soil and vegetation (e.g., $CSi = (SOC + C_{veg}) * A$[32], where CSi is total carbon stored, SOC is soil organic carbon per ha, Cveg is carbon in above-ground biomass per ha, and A is the area of land under consideration).

Perennial plantings, particularly shrubs and trees, are the primary mechanism for carbon sequestration within extensive livestock systems (Flugge and Abadi 2006; Monjardino et al. 2010; George et al. 2012). Similarly, protection of remnant vegetation or allowing regeneration of native flora in some areas of the farm will result in carbon storage. Other practices that can result in carbon sequestration include, conservation tillage, retention of crop residues, reduced use of fallowing, conversion from annual to perennial crops or pasture, improved grazing management, and sowing forage species that produce more biomass (Kragt et al. 2012; Richardson et al. 2019). These mechanisms tend to increase the storage of soil organic carbon, however there is still substantial uncertainty around the achievable rates of soil carbon sequestration, its permanence (Kragt et al. 2012), and effects of soil redistribution (Chappell et al. 2013). A sampling method for the spatio-temporal measurement of soil carbon was described by Chappell et al. (2013), and highlights requirements for determining uncertainty when measuring in changes in soil carbon associated with management practices (Figure 3).

Figure 3. Decision point for calculating the minimum detectable change in soil organic carbon stocks (from Chappell et al. 2013).



Schwenke et al. (2013) concluded that only a complete change in land use from cropping to perennial grass-based pastures has been clearly demonstrated to significantly build total organic carbon in degraded cropping soils, at least on heavy-textured clay soils (Dalal et al. 1995; Chan et al. 1997; Young et al. 2009). However, Meier et al. (2020) suggests all GHG emissions be considered when evaluating the abatement potential of different farming systems and practices, and that these practices need to be tailored to the climate, crops, soils, and management at locations. In their simulation study across 3 contrasting environments in Australia, net emissions from stocked permanent pastures were not always less than those from cropping systems. This was because enteric methane CH_4 emissions from livestock were not consistently offset by increased Soil Organic Carbon (SOC) under permanent pastures relative to the cropped systems. A key influence upon C inputs to soils in two of the case studies reported was that low summer rainfall limits pasture growth in the livestock scenarios over a similar period to the dry fallow period inherent in winter crop growing cycles. And in these predominantly cropping environments, where a key role of the pasture phase is as a disease break in cropping rotations, pastures generally receive little or no fertilizer, limiting pasture growth and carbon sequestration potential. The potential for climate to limit the accumulation of SOC has been recognized in previous studies (Liu et al. 2016, Lawes and Robertson 2012). While the soil-based emission approach and assumptions made in this study, fall short of a life cycle analysis (LCA) approach in which cradle-to-grave emissions are evaluated, a key message from this study is that "Assessment of the emissions from all sources, while complex, is important to ensure that both field-scale and absolute abatement is achieved" when evaluating the abatement potential of different practices (e.g., de Boer et al. 2011).

Table 2 presents the various metrics and measurements associated with determining carbon storage and sequestration for soil management associated with grassfed beef production within SCA schemes and outlines the specification of methods and any associated references that provide scientific support and verification. A range of metrics and measurements for vegetation management relating to carbon sequestration are identified in schemes, including total biomass (kg/ha)[5,17,24], Volume of harvested wood[77,105], Volume of woody detritus left on-site[77,105], Land types and species[77,105], Area of trees[46], Age of trees[46,105], Species of trees[46,105], Year land use change occurred[77] and % Allocated to beef[46].

Table 2. Inventory of items and metrics used by SCA schemes to determine carbon sequestration

Metric	Method	Method specification	Support and Verification	Auditing
Soil management				
Soil organic carbon (SOC)[5,17,32, 77,86,87,105, 112]	Soil sampling[17] Soil sampling and modelling[87]	NATA accredited[17] ERF soil sampling methods. International standards specify that the top 30 cm is measured, although ERF has provisions for measurement below 30 cm [87] .		Producer[17] Carbon scheme[17,87] Independent[17]
Ground cover (%)[4,5,13,15,17]	Field survey			Producer[17] Carbon scheme[17] Independent[17]

Note: superscript values are the reference number for each SCA scheme included in the review, refer to Appendix 8.1.

4.4.5 Carbon neutral credentials

A clear objective of carbon neutrality by 2030 has been set by the Australian red meat industry (MLA 2020). Carbon neutral farming (or carbon neutrality based on CO_2-e) is the point at which the total emissions of a beef enterprise are equivalent to the amount of GHG CO_2-e stored. This is consistent with the aim of the FAO's SAFA guidelines that set out an objective for an enterprises GHG emissions to be contained[25]. The scope of this project includes the on-farm and processor components of the supply chain. Recent research indicates carbon neutrality in beef production is possible but will require clear pathways for producers to embark on persistent options for emissions reduction and vegetation management (Mayberry et al. 2019). These activities will need to be supported by a variety of reporting and certification initiatives (Ridoutt 2021), and these will need to be verified based on quantitative methods, measures, and metrics. Effectively, the options and systems discussed in sections 4.2, 4.3 and 4.4 will require a suitable accounting framework that is verified on an ongoing basis through appropriate credentialling or audit processes.

Over the past several decades, various GHG and carbon accounting systems have been developed to quantify effects on the balance of atmospheric GHGs and associated global warming. Leading examples of this are Overseer[106] (New Zealand), Cool Farm[19] Alliance (United Kingdom), GHG Protocol Agricultural Guidance[77] (Global) and GHG Accounting Frameworks for Australian Primary Industries (GAF; Australia). The SB-GAF[46] (Sheep and Beef) developed by the University of Melbourne is intended for use in grazing sheep and beef cattle businesses, particularly enabling a baseline analysis to compare effects of other scenarios such as changes to land use, livestock enterprise or sequestration opportunities. Carbon sequestration estimates in SB-GAF are based on FullCAM modelling outputs (Ekonomou et al. 2020).

To achieve carbon neutral status for business activities, the following steps are commonly suggested (Climate Active[18])

1) Define the emissions boundary
2) Calculate total emissions
3) Develop and implement an emission reduction strategy, based on an emissions inventory or life cycle assessment, generally by an expert consultant
4) Purchase offsets to balance any emissions that are not able to be reduced or inset within the business

There is currently a guideline undergoing consultation that will enable insetting to be included in baselining calculations for Climate Active certification. This will mean that baselines calculated at step 2 above will be reduced by the amount of carbon dioxide equivalents stored in trees and soil within the system boundary.

Meeting Australia's 2030 target of reducing total emissions by 43% from the 2005 level will require a combination of emissions reduction, and increased carbon storage across many sectors of the economy, particularly the energy sector which produces about two thirds of GHG emissions (ANGGI 2021, Figure 4 below). Agricultural systems, responsible for 15.8% of GHG emissions in Australia (Figure 4), are also considered to have the most potential for carbon sequestration and emission avoidance activities, given their role in land stewardship. However, an inspection of the 1358 projects registered through the ERF shows minimal uptake of methods targeting the reduction of CH_4 emissions from beef. Similarly, projects listed in the Climate Active website target almost entirely "Vegetation" methods rather than "Agricultural" methods (Table 2).

However, if this means reducing the availability or increasing the price of productive agricultural land this will make it more difficult to achieve production and economic targets and global food security. So, incentivising carbon neutral farming needs to be viewed with some caution, particularly if carbon credits are traded to markets outside the agricultural industry/red meat sector. Despite this, it is unlikely that global climate targets will be met for the foreseeable future unless the agriculture sector is able to create strong net negative emissions (Lal 2021).

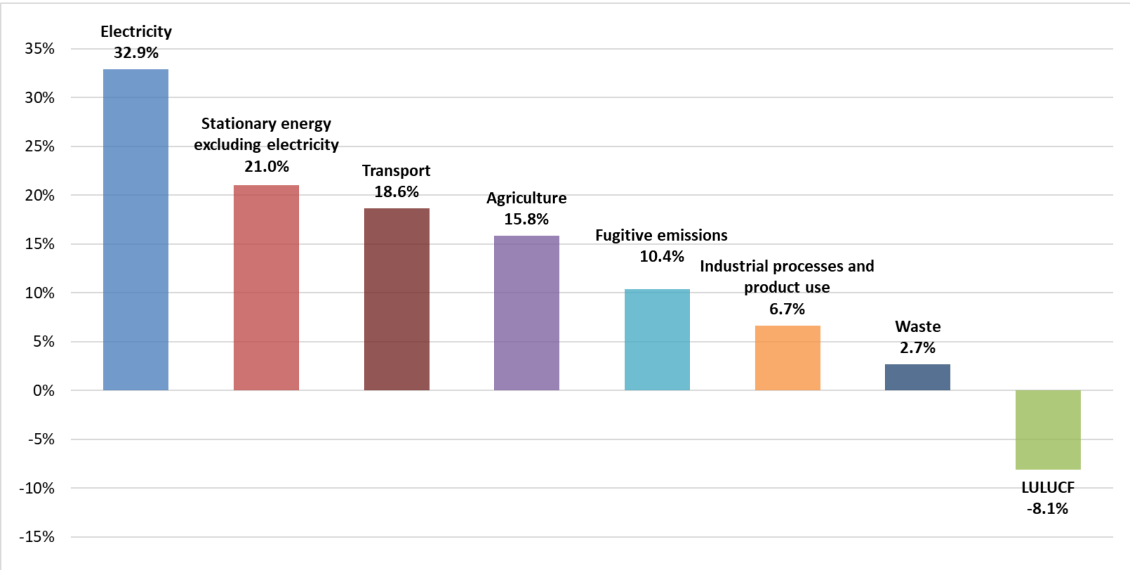
Although agriculture since 2014 has promised 15.2 Mt of abatement, by April 2022 it had delivered only 1.1 Mt (White 2022). Current methods are restrictive, in the single implementation of eligible activities, which may be limiting uptake. A new method "Integrated Farm Management", under development and expected by February 2023, will allow separate land-based activities to be combined or 'stacked' on the same property or aggregated properties. The Integrated Farm Management method aims to increase the carbon pools and activities for which individual projects may receive credits, while reducing the administrative costs associated with registering, reporting, and auditing on multiple projects (Clean Energy Regulator Webpage). An approved method of suppressing CH_4 emissions is not yet available and it would need to be scaled up commercially and proven for grazing animals. The main constraints on soil carbon sequestration (SCS) are the unreliability of Australian rainfall, the high cost of project management relative to the value of a carbon credit, and the opportunity cost of maintaining an approved land management for at least 25 years (Rabbi et al. 2015; White 2022).

Given the economic incentives for carbon farming, primary producers are likely to continue to weigh up their options for carbon farming based on the risks and rewards associated with their business.

The CER (2022) warns potential investors in vegetation or sequestration projects to be aware of expected "Return On Investments" from sequestration projects due to misleading claims (White et al. 2021), particularly about unrealistic minimum returns on investment or returns that are government guaranteed.

Beef production systems in Australia vary widely in their reliance on crop production to support year-round feeding and finishing cattle to meet market specifications. For example, grass-finished cattle required 0.85 tonnes of feed bought into the farm system, compared with 2.25 t for 150-day grain-finished cattle, per tonne of liveweight produced (Thomas et al. 2021). Consistently, an average value of 1.2 tonnes of various crop-produced feeds per tonne of Australian beef produced was used in a recent life cycle assessment, based on national feedlot statistics (Ridoutt and Navarro Garcia 2020).

Figure 4. Share of total emissions, by sector, for the year to December 2021 (ANGGI-2021).



A GHG accounting (climate) standard for Australian grass-fed beef has been suggested to enable centralisation of rules of engagement for product credentialling. Ideally, this is a means to ensure that the various schemes have a common reference point when developing products around GHG accounting frameworks and calculations. This would also enable reporting back on the use of schemes to a central point, potentially a government body such as the clean energy regulator, so that it is possible to track the uptake of the various schemes by the industry. Uptake of schemes will also be driven by their cost effectiveness, ease of implementation and obvious value returned to the producers through reward mechanisms such as branding, and premium prices through market access.

4.4.6 Biodiversity credentials

Producers are responsible for the short and long-term management of vegetation in extensive beef systems, with flow-on effects to ecosystems and biodiversity. Further, land use change associated with agriculture poses a persistent threat to biodiversity globally (Tilman et al. 2017; Cresswell et al. 2021).

As extensive beef systems vary widely across Australia, due to differences in climate (e.g., temperate, tropical, semi-arid), effects of livestock production on biodiversity also vary widely (Ridoutt et al. 2017). Where beef production systems are evaluated in terms of pressure to compete for "land use" with croplands (necessary to feed the world), while limiting further land clearing and habitat segmentation, Ridoutt and Navarro Garcia (2020) show that Australian beef have a low footprint for a) land occupation, b) cropland scarcity footprint, c) cropland malnutrition footprint and d) Cropland biodiversity footprint.

In some instances, well managed pasture and rangeland livestock systems may benefit biodiversity outcomes (Ridoutt et al. 2017; Norton et al. 2022). However, in other cases there may be biodiversity benefits by removing grazing as the area is more likely to return towards its pristine state and support greater biodiversity (Paul and Roxburgh 2020). Management factors that affect biodiversity in grazing systems have been reviewed by Rook et al. (2004), and science-based methods are being developed for the assessment of biodiversity in permanent pasture lands in Australia (e.g. The Wentworth Group 2008) and more broadly for ecological condition (e.g. White et al. 2022). Preserving biodiversity requires both strategies to maintain habitat condition to support existing species, and to assist with the restoration of degraded systems to states that support greater biodiversity, for example through the removal of invasive plant and animal species that threaten biodiversity (Bradshaw et al. 2021). Systems of coordination and the delivery of data to inform control measures will be a key requirement for implementing actions that result in the preservation of biodiversity (e.g. Hardisty et al. 2019; Pirzl et al. 2019).

4.4.7 Quantifying biodiversity

In this review, we are primarily focused on methods used to quantify biodiversity, both as a baseline compared with the land condition pre-European colonisation and how the state of biodiversity is changing over time. Typically, it is not possible to achieve accurate accounting of species abundance and population status (susceptibility to extinction), so habitat condition assessment methods are widely used as an indicator of the capacity of systems to support biodiversity (Williams et al. 2021; Larsen et al. 2021). Biodiversity needs to be considered both independently and as a co-benefit in relation to carbon storage in grazing enterprises, due to effects of grazing, revegetation, and other management practices on vegetation characteristics. For example, remnant vegetation that has been heavily grazed may retain biomass and carbon due to the persistence of trees, woody shrubs, and less palatable grasses etc., but may have reduced capacity to support biodiversity (Pitman 2011; Paul and Roxburgh 2020).

Carbon and biodiversity are considered jointly in many SCA schemes reviewed, with about 20% of schemes considering both. Carbon projects designed to increase vegetation biomass do not necessarily provide support to biodiversity, where those projects rely on carbon production from introduced plant species, or there is a lack of diversity, complexity, or suitability to regional context in native species used (Reside et al. 2017; Standish and Prober 2020). Reside et al. (2017) argue that opportunities for carbon storage should have robust assessments for biodiversity conservation benefits and consider additional incentives for improved biodiversity outcomes.

The purpose of Table 3 is to capture the various metrics and measurements associated with biodiversity assessment within SCA schemes that may be relevant to grassfed beef production, and to outline the specification of methods and any scientific support and verification, and auditing processes that are in place.

Table 3. Inventory of items and metrics used by SCA schemes for biodiversity assessment

Metric	Method	Method specification	Support and verification	Auditing
Habitat assessment				
Conservation value[54,59]	High Conservation Value (HCV) framework[54]	(Rayden 2008) [54]	Peer reviewed publication[54]	
Regional ecosystem assessment[7]	Part of PMAV[7]		Scientific reference panel[7]	Scheme[7]
Regional condition benchmark[9,59]	Assessed against comparable farms, with similar vegetation and land types[9,59] Assessed against comparable pristine vegetation in reference sites, with a habitat condition assessment based on remote sensed and environmental data[59]	Relative condition of native vegetation for biodiversity on the farm. A scale is used between 0 (complete loss of native vegetation) and 100 (undisturbed remnant vegetation) [9] Habitat condition at project sites compared with reference sites[59]	ANU and DAWE[9] Williams et al. (2021)[59]	Accredited[3,4,5,9]
Habitat condition[37,52,54,59]	Time series based on woody vegetation cover[37,59] Time series of habitat condition based on remote sensed biotic data combined with environmental abiotic data[59] Expert site assessment[59]	Observed tree cover compared with 90th percentile cover, 100 km2 tiles[37] Habitat condition at project sites compared with reference sites[59]	Peer reviewed publication[37,52,59] Larsen et al. (2021)[52] Williams et al. (2021)[59] White et al. (2019)[59]	

Metric	Method	Method specification	Support and verification	Auditing
		Condition score between 0 and 1 (1=pristine; 0=natural habitat completely removed)[59]		
Land types and species[7,9,25,37,52,54, 59,77]	Species diversity and abundance[25, 59]	Farm maps[9]	Scientific reference panel[7]	Scheme[7]
Area of land (accounting area) [7,9, 77]	Property extent[7,9]	Farm Records and GIS[7,9]	Scientific reference panel[7]	Scheme[7]
Land set aside for conservation (%)[13,15,25,27,40,54]	Quality and quantity of natural vegetation in the project area[13,15,25, 27, 40,54]	Farm Records and GIS[7,9]		
[a]Extent (%)[3,4,5,9,52]	GIS and vegetation map. Benchmark of 100% taken from surrounding reserves[4] Reference Benchmark[4] Dynamic Reference Benchmark[5]	Indicators can be determined using remote sensing (Bastin et al. 2012)[5]	Peer reviewed publication[3,4,5]	Self-verified[3,4,5] Scheme Accredited[3,4,5, 9]
[b]Configuration (%)[3,4,5,9]	GIS and a current vegetation map and on-ground/aerial photography verification. Benchmark of 100% as the pre-1750 extent of all vegetation types 1 - 5 km from of each sample site. [3,4,5]	Desktop survey[3,4,5, 9]	Peer reviewed publication[3,4]	Self-verified[3,4,5] Scheme Accredited[3,4,5, 9]
[c]Composition[3,4,5,7,37,48, 52, 54]	Native tree canopy height (m, Line Intercept Transect)[3,4,5] Native tree canopy health score (%,50x20 m quadrat (sparse) or	Field survey[3,4,5] Biodiversity models, remote sensing	Peer reviewed publication[3,4,5] State government[48]	Self-verified[3,4,5] Scheme Accredited[3,4,5, 9]

Metric	Method	Method specification	Support and verification	Auditing
	20x20 m quadrat (forest). Standing trees > 10 cm dbh) [3,4] Native tree canopy cover (%, Line Intercept Transect)[3,4,37,54] Native tree density (stems/ha, 50x20 m quadrat)[3,4] Native species count for tree canopy and shrub layer species (number, 50x20 m quadrat)[3,4] Native shrub cover (%, Line Intercept Transect) [3,4] Non-native shrub / tree cover (%, Line Intercept Transect)[3,4] Native herbaceous cover (%, Line Intercept Transect)[3,4] Native species count for herbaceous species (number, 50x20 m quadrat) [3,4] Non-native herbaceous species cover (%, five 1x1 m quadrats) [3,4,] Organic litter ground cover (%, five 1x1 m quadrats)[3,4] Cryptogam cover (%, five 1x1 m quadrats)[3,4,] Fallen timber >100 mm diam. (summed length	products and data analytics[37] Biodiversity questions[48,54] Selecting pictograms[48] Phone App enabled[48] Interviews with residents and experts regarding the history of the local vegetation[54]		Government officer[48]

Metric	Method	Method specification	Support and verification	Auditing
	metres/0.1 ha, one 50 x 20 m quadrat)[3,4] Forage/Grass Cover[3,5] Presence of weeds[5,48,59] Woody Cover[3,5] Pasture Composition[7,48] Pasture quality[48] Erosion[48]			
Ground Cover	Groundcover (% total groundcover)[3,5,6,7,13,48,59] Persistent green cover fraction[59] Recurrent green cover fraction[59] Litter cover fraction[59] Bare ground fraction[59]	Groundcover - CSIRO VegMachine (2021)[6] Donahue et al. (2009)[59] Guerschman and Hill (2018) [59]	Peer reviewed publication[3,6,59]	
Habitat connectedness[9,37,52,59]	Patch-based, Grid-based, Neighbourhood level analysis, System-level analysis[52]		Peer reviewed publication[52]	
Species status[52]	Extinction risk[52]	Direct observation[52] Habitat-based approach[52]	Peer reviewed publication[52]	
Species stocks[52,54]	Opening and closing entry for accounting period[52]		Peer reviewed publication[52]	
Threats to biodiversity[37,54]		Biodiversity questions[54]		

Metric	Method	Method specification	Support and verification	Auditing
Soil condition (Sbrocchi, 2015)[6]	Soil acidification (pH, water $CaCl_2$)[6] Soil organic carbon (% dry weight basis)[6] Soil salinity (EC, dS/m)[6] Extractable phosphorus (Olsen P, mg/kg)[6]	Field and lab measurement of topsoil samples collected[3,6] Field survey[7]		
Catchment health and water quality[20]	Monitoring riparian areas and wetlands[20] Identifying potential sources of contamination to water bodies[20] Cattle nutrient management[20]			Self-verified[20] Accredited[20]
Management measures				
Business plan[7,9,27]	Biodiversity management plan[7,9,27]	Farm records[7,27]	Scientific reference panel[7]	Independent [9] Scheme[7]
Revegetation[37]	Potential habitat condition[37]	Habitat condition predicted using logistic model[37]	Peer reviewed publication[37]	
Certification[7]	BMP Certified[7]		Scientific reference panel[7]	Scheme[7]
Grazing management[7,48]	Rotational grazing[7] Limit grazing pressure[7,48]	Farm records[7]	Scientific reference panel[7]	Scheme[7]
Pasture management[7]	Monitoring/improving species composition[7]	Farm records[7]	Scientific reference panel[7]	Scheme[7]
Weed control[7]	Regular interventions[7]	Farm records[7]	Scientific reference panel[7]	Scheme[7]
Feral animal control[7]	Regular interventions[7]	Farm records[7]	Scientific reference panel[7]	Scheme[7]

Metric	Method	Method specification	Support and verification	Auditing
Water/run-off quality[7]	Monitoring EC, pH, and turbidity downstream	Farm records[7]	Scientific reference panel[7]	Scheme[7]
Drought management[7,48]	Destocking, early weaning[7]	Farm records[7]	Scientific reference panel[7]	Scheme[7]

Note: superscript values are the reference number for each SCA scheme included in the review, refer to Appendix 8.1.
[a] Extent: is the proportion of remnant vegetation remaining within the accounting area compared to the 1750 extent with the area.
[b] Configuration: The configuration of native vegetation relates to its connectivity, context, and patch size within the local landscape (i.e., in the vicinity of the sample site).
[c] Composition: The composition of native vegetation relates to its structure and the assemblage of species.

Biodiversity assessment is a complex area, and a wide range of approaches to assessments are used (e.g. Table 3). However, to achieve broad adoption of assessment methods, the requirements placed on end-users of assessment schemes will need to be minimal with sufficient flexibility to meet a wide range of circumstances in an agile manner, while remaining scientifically robust. This principle has been noted in the development of some of the schemes, for example rules of thumb applied within the Social and Biodiversity Impact Assessment (SBIA; associated with scheme 54) are that biodiversity objectives should be 1) few in number and 2) easy to assess and quantify using practical indicators. It is also critical that assessment approaches are scientifically sound, transparent and assumptions and limitations are made clear, in order to present an accurate view of the biodiversity position of any enterprise or corporation to engender trust and avoid risks associated with 'greenwashing'.

A common theme of biodiversity assessment is the comparison of areas of agricultural land use (e.g., property level) with those of undisturbed or pristine reference sites containing remnant vegetation. To meaningfully represent the diverse range of habitats in condition assessments also requires an extensive collection of field survey data that can be used to calibrate scaleable models. To achieve this, the National Reference Library of Expert Site Condition Assessments project10 (Pirzl et al. 2019; White et al. 2023) piloted a novel, national approach to collecting expert site condition assessments and calibrating participant expertise within a common conceptual framework.

4.4.8 Protecting biodiversity

Multiple organisations use an assessment questionnaire approach to evaluate the admission into and subsequent progress of participants in a biodiversity credentialling scheme. Participants typically undergo a self-assessment of progress against goals by answering standardised questions developed by the scheme. The questions are worded so that the answers may be externally verified. Many schemes require an external audit and the issue of a certificate or other attestation document before participants can claim the credential. Table 4 provides examples of credentialling schemes which use an assessment questionnaire approach.

Table 4. Credentialling schemes which include biodiversity self-assessment at the individual farm level

Scheme name	Administering organisation	External verification required	Assessment questionnaire is the main methodology
Farm Sustainability Assessment (FSA)	Sustainable Agriculture Initiatives (SAI)	Yes	Yes
Sustainable Dairy Partnership (SDP)	Sustainable Agriculture Initiatives (SAI)	Yes	Yes
Australian Sustainable Produce Certification	Certified Sustainable	Yes	No
Cool Farm Tool (CFT)	The Cool Farm Alliance	No	Yes
Sustainability Assessment of Food and Agriculture systems (SAFA)	Food and Agriculture Organisation of the United Nations (FAO)	No	Yes
Global Good Agricultural Practices (GAP)	FoodPLUS GmbH Ltd.	Yes	Yes

Schemes and standards other than those in Table 4 were reviewed, however these either had no self-assessment component, were not aimed at the individual farm level, were discrete projects rather than credentialling schemes or were too hard to review as information was not in the public domain. These other schemes can be seen in Appendix 8.1.

Of the six credentialing schemes listed in Table 4 we were able to access the questionnaires for FSA, SDP, SAFA and CFT. SDP represents a subset of the FSA tool specific for the dairy industry, so we used a comparison of the SFA, SAFA and CFT to derive some principles for an Australian beef industry biodiversity credential questionnaire.

FSA provides a questionnaire for farm self-assessment and delivers a report across eleven areas: Farm Management and Community, Plant Material Selection and Propagation, Soil Management, Nutrient Management, Chemical Control, Integrated Pest Management, Waste Management, Water Management, Biodiversity, Air Quality and Emissions, Labour Conditions. The questions are explicitly divided between biodiversity (11 questions) and the other areas however it is obvious that many questions have relevance to multiple sustainability domains. For example, it is asked whether a stock inventory control system for farm inputs is implemented, which has relevance for biodiversity impacts of input product use, but is also highly relevant for Farm Management, Nutrient Management and Chemical Control. Other examples include proper storage of fuel and chemicals, training of staff in chemical and fertiliser application, maintaining groundcover and increasing soil organic matter. In the biodiversity section, the preservation of primary habitat such as forest, mangroves, wetlands and native grasslands is a high priority. Other suggested practices include returning non-productive land to a natural state, measures to protect and promote natural habitat, creating a plan to protect and promote native species and avoiding the use of “invasive species”. The control of non-native pests and weeds are not explicitly mentioned, but perhaps this is included in the management of invasive species.

SAFA provides a questionnaire guide with 14 suggested general biodiversity questions. It aims to deliver a tool useful in a world-wide context, so suggests concepts that can be adapted to local circumstances. SAFA is divided into four themes, Governance, Environmental Integrity, Economic Resilience and Social Well-Being. The Environmental Integrity theme is divided into six sub-themes, Atmosphere, Water, Land, Biodiversity, Materials and Energy and Animal Welfare. Although biodiversity is considered separately it is clear that aspects of Water, Land and Materials and energy are important for biodiversity. The biodiversity sub theme (E4) has three components: Ecosystem Diversity, Species Diversity and Genetic Diversity. Land Use and Land Cover Change (LULCC) is a central concept for the ecosystem diversity component. Positive biodiversity scores are achieved for practices such as preparing a habitat conservation plan with exact targets and timeframes, ensuring ecological connectivity between all areas of the property and adjacent natural ecosystems and maximising the "structural" diversity of the property (types of vegetation). Negative biodiversity scores are achieved for practices such as the conversion of primary habitats (e.g., wetlands, primary forests, grasslands, protected waterways) for agricultural use. The scheme suggests a target where on at least of 5% of the land "non-utilized plants are growing AND there is a high diversity of wild taxa."

CFT is an assessment tool which uses terminology and describes farming practices in ways that are unsuitable for Australia; the website states that further development goals exist that will enable the tool to be used outside of Europe/North America. Nevertheless, CFT deals with important principles which can be extrapolated to Australian circumstances. The questionnaire has 29 questions divided into Farmed Products (5 questions), Farming Practices (15 questions), Small Habitats (7 questions) and Large Habitats (2 questions). Higher biodiversity scores can be achieved by allowing intervals for plants to flower and set seed, for providing habitat and for setting aside areas of land undisturbed by agricultural activity. Lower scores for failure to adopt positive biodiversity practices, having a low biodiversity production base and poor control of chemical and fertiliser use.

Together, these credentialling schemes suggest some categories of questions which could be included in a farm assessment tool for the ECIT platform:

1. Maintenance and protection of remnant native habitats and species (CFT, FSA, SAFA).
2. Avoiding practices that degrade or endanger remnant native habitats and species (FSA, SAFA).
3. Creating plans to protect and foster native species, including the achievement of greater ecosystem connectivity (FSA, SAFA).
4. Control of input application and storage to minimise impact, including training of personnel (CFT, FSA).
5. Conduct of a diversified enterprise (multiple species and/or more diverse genetics) (CFT, FSA, SAFA).
6. Care of soils and beneficial species (CFT, FSA).

Many of the questions used by CFT, FSA and SAFA are situation specific. The large diversity of beef systems present in Australia means that although most of the questions used by the schemes considered (Appendix 8.1) are applicable for some producers, many are not applicable across all producers. For example, although questions about dealing with blackwater disposal may be relevant for dairy/beef operations, they will not be widely applicable in more extensive systems. Similarly, questions about fodder cropping and fodder conservation will only be applicable where crops and intensive pastures are grown. Therefore, a questionnaire will need to incorporate this diversity and deal with it appropriately.

The best approach for developing a questionnaire would be to undertake a series of stakeholder workshops and allow these discussions to suggest questions and appropriate wording. This report could be used as background reading for participants, introducing the six areas and some information about similar questions that have been formulated by international schemes (Appendix 8.1).

Self-assessment schemes are useful for producers to become involved in biodiversity assessment and become aware of practice changes that foster biodiversity. However, progress against benchmarks and assessment of continuing improvement over time will require either third party assessment and/or image analysis assisted monitoring to quantify changes in biodiversity.

4.5 Recommendations

4.5.1 Design of credentialling methods

Uptake of climate and biodiversity credentials by beef producers will depend on a range of factors related to their business, however the design and implementation of the credentialling system will also be a critical factor. Confidence in the value of the achieving credentials, the ease of implementing the credentialling systems and seeing a strong value proposition as an incentive will all play an important role in the expansion of credentials in grassfed beef production.

Guidelines describing credentials will need to be considered in the context of rapid evolution of climate and biodiversity credential markets. As new technologies become available, the ability for assessment will likely become faster, more accurate and of higher resolution. Incentives for demonstrating climate and biodiversity credentials are likely to increase over coming years, as political, social and market drivers intensify. The project recommends the use of tiered credentials to better enable entry into credentialling within the industry and remove some of the barriers to participation.

The purpose of this document is to detail pathways to participation in climate and biodiversity credentials, while keeping in mind the complexity of this process and the need for ongoing improvement as knowledge and measurement technologies continue to advance. As such the following design criteria were applied in the development of recommendations and methods to achieve Environmental Credentials for grassfed Beef:

1) Flexibility: Markets and policies will continue to develop and change and new credentialling information will become available through digital technologies etc.
2) Clear outcome: Driving practice change to ensure lowering of emissions/emissions intensity toward the goal of industry carbon neutrality. This will help to enable improved social licence and access to markets
3) Not too prescriptive: Need to be able to accommodate a wide range of viable/accepted approaches toward improving climate and biodiversity credentials
4) Ensure positive change is recognised and rewarded
5) Informs the ECIT platform development
6) Focus on scalable methods
7) Science-based measures and metrics using trusted data sources

<u>Project Recommendations</u>

This section outlines recommendations that were developed for the credentialling of grassfed beef production, which was an outcome of the Beef Credentials Synthesis and Recommendation workshop (joint CSIRO and MLA) held at St Lucia, Qld, on 27th October 2022, and two further meetings with MLA project oversight committees. The eight recommendations for climate and biodiversity credentials are:

1. Climate and biodiversity credentials are developed jointly

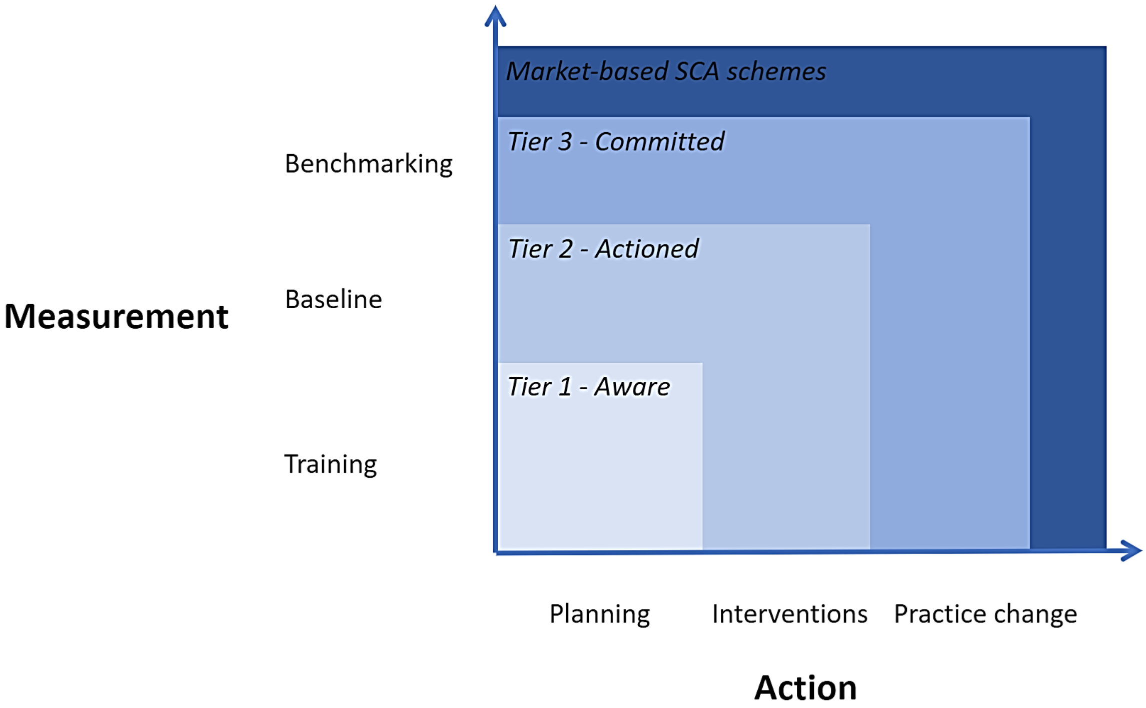
Five learning modules for credentialling within the beef industry have been developed for the Australian Beef Industry by MLA, these being Climate, Biodiversity, Tree Cover, Ground Cover and Drought Resilience. For this project, and credentialling within the grass-fed beef industry generally, the Climate and Biodiversity themes / modules have been prioritised. Climate and biodiversity are considered jointly in many SCA schemes, which supports this recommendation. An overall benefit-cost evaluation of planned activities would need to consider joint impacts on climate, biodiversity, and productivity. For example, in some situations, improved biodiversity may contribute to productivity, but not necessarily.

Several key metrics need to be carefully selected for verification of credentials and benchmarking. Ideally, these credentials would follow a defined protocol based on information specific to the credential domain. For biodiversity credentials, the use of habitat condition assessment is a generally accepted proxy for biodiversity. According to the Habitat Condition Assessment Scheme for Australia (HCAS), the definition of 'Habitat Condition' is: "the capacity of an area to provide the structures and functions necessary for the persistence of all species naturally expected to occur in that area if it were in a reference state." For climate, GHG accounting methods are required including metrics such as emissions intensity, net/total emissions, and carbon stores in the soil and vegetation. Producers will have varying production recording and account keeping procedures that are needed to inform climate and biodiversity standards, and so a tiered approach will provide flexibility for entry level credentialling across the Australian beef industry. There will be a need to ensure flexibility and updatability in measurement methods and analytical approaches from the initial starting position. For example, applying a framework where several data sources can be linked with a parent metric when calculating a benchmarking value for credentialling.

2. Each priority theme is based on three tiers of credentialling

Three tiers of credentialling are proposed, as illustrated in Figure 5. Credentials based on training (Tier 1), implementation (Tier 2) and benchmarking (Tier 3), which captures the intent for carbon and biodiversity assessments between comparable enterprises with similar land types within agro-ecological regions. Appropriate training material (Tier 1), on-farm assessment metrics and opportunities for improvement based on a defined SMART (Specific, Measurable, Achievable, Relevant and Time-Bound) management plan (Tier 2) and benchmarking metrics are to be identified for climate and biodiversity credential tiers.

Figure 5. Proposed 3-tiered framework that identifies the level of action and achievement measure for climate and biodiversity credentials



Benchmarking periods across 5 years of data are suggested to consider variability in seasonal conditions that may affect GHG emissions, carbon sequestration and biodiversity indicators. A benchmarking approach such as that developed by FarmPrint (Sevenster 2020) could be considered. Alternatively, benchmark values for some credentials measures (e.g., emissions intensity) taken from research publications or other industry data may be suitable. Beef enterprises may initially use standardised or normalised values for the region (e.g., a Gross Margin template, or ABS data) for benchmarking, but with the possibility of using "Credentialled" aggregated data from neighbouring farms within regions, where credentials have been achieved, as this becomes available. Further scientific verification of the effectiveness of credentialling for biodiversity and climate outcomes should be considered once the details of the tiered credentials have been established. That is, what are the environmental, production and social outcomes resulting from each tier? The outcomes could potentially be linked with the greater incentives that will be needed to encourage producers to advance between tiers. The upper limit for credentials in beef businesses can be established once credentialling metrics are routinely collected.

The platform should be designed with entry level users in mind, with useable/interpretable input values that can be adapted to a range of grass-fed beef production systems. A higher-level description of the 3 climate and biodiversity tiers is shown in Table 5. A consistent approach was taken with the design of the 3 tiers for climate and biodiversity. While ongoing improvement is encouraged with progression through the tiers, we wanted to include a mechanism that rewarded businesses demonstrating existing high levels of climate and biodiversity credentials. For this reason, Tier 3 includes both scope for demonstrating ongoing improvement, but also the option to achieve the credential by being in the top 25% relative to the benchmark. It could be reasonably expected that the initial participants in credentialling might have at least average, or above average, credentials compared with whole of industry. As the overall level of the beef industries climate and biodiversity credentials improve, by definition the top 25% of producers would need to continue to improve to meet this target.

Table 5. Climate and Biodiversity criteria associated with the three tiers of credentials proposed.

Tier	Level	Criteria
Climate		
Tier 1	**Aware** (Learn and plan)	• Trained in basics of on-farm emissions accounting for beef production. Familiar with credentials platform and basic data inputs • Have a basic management plan for own business, with change options identified
Tier 2	**Actioned** (Measure and manage)	• Conducted an on-farm assessment of GHG emissions/emissions intensity and carbon sequestration • Implemented changes toward improving net emissions/emissions intensity.
Tier 3	**Committed** (Monitor and improve)	• Net GHG emissions and emissions intensity benchmarked with other similarly sized and operated businesses • Trend for continuous improvement or top 25% relative to benchmark for net GHG emissions/intensity over the previous 5 years
Biodiversity		
Tier 1	**Aware** (Learn and plan)	• Trained in basics of on-farm habitat condition (biodiversity) assessment for beef production. Familiar with credentials platform and basic data inputs • Have a basic management plan for own business, with change options identified
Tier 2	**Actioned** (Measure and manage)	• Implemented an ongoing system for assessment of habitat condition (biodiversity) • Implemented changes toward improving habitat condition or biodiversity.
Tier 3	**Committed** (Monitor and improve)	• Habitat condition (biodiversity) benchmarked with other businesses with the same agroecological attributes/limitations • Trend for continuous improvement or top 25% relative to benchmark in habitat condition or biodiversity over the previous 5 years

3. Fewer priority focus areas

Due to the complexity of greenhouse gas and biodiversity accounts, there are many activities that might be undertaken to improve credentials. This is where it is important to get the balance between positive interventions that are easy to implement and not detrimental to business productivity (low hanging fruit) and targeting areas where there is greater potential for substantive emissions reduction and biodiversity benefits (e.g., beef herd management, methane reducing supplements, habitat connectivity). Implementing synergistic interventions to accelerate progress e.g., establish environmental plantings to improve habitat connectivity by selecting topography that will improve shade/shelter or revert the impacts of salinity.Small positive changes may contribute to creating momentum around credentialling activities but might also be diverted toward unsubstantiated claims and greenwashing in terms of enabling the gap between "symbolic" and "substantive" corporate social actions (Walker and Wan 2011). A focus of fewer priority areas for credentialling will likely lead to a less confusing operating environment and produce improved sustainability outcomes.

These are suggested areas of priority for;

- Climate: Enteric emissions, land use change, methane management, and energy

  It might be useful to look to the set of principles outlined in the recently published Verified Carbon Standard (VCS) v4.3 by Verra (https://verra.org/programs/verified-carbon-standard/). These are based on ISO 14064-2:2006 and espouse:

  - Relevance (of GHG source, sinks, methodologies)
  - Completeness (of GHG sources, sinks)
  - Consistency (methodology and definitions)
  - Accuracy (as far as possible)
  - Transparency (disclosure of GHG relevant information)
  - Conservativeness (of assumptions)
- Biodiversity: Actions to reduce degradation of habitat condition, loss of native flora and fauna species due to invasive species or anthropogenic perturbations and improve connectedness of habitat.

4. Provide clarity and certainty in relation to implementing credentialing pathways

A centrally coordinated platform, with defined tiers and methods, will provide the grassfed beef industry with greater clarity around what is required for businesses to achieve Environmental Credentials for Grassfed Beef. This is becoming an expectation in society and will help to ensure social licence domestically and ongoing market access, particularly international. The challenges and limitations of SCA schemes can impact the adoption of these schemes by livestock businesses by creating barriers to entry, increasing complexity, and reducing relevance and perceived value. Currently, the fluid nature of schemes and rules around credentialling, and their implementation (e.g., changes in interpretation of emissions factors) adds complexity and requires greater understanding and management skills, which reduces the value proposition for producers (McCarthy et al. 2018). Addressing these challenges will require efforts to reduce costs, increase transparency, improve standardization, and simplify compliance requirements. Having a centralised industry-led credentialling framework that is designed to be adaptable and updateable in a well-defined and expected manner will build confidence in its use by the Australian grass-fed beef industry. Governance of the framework, managed by MLA, would need to consider data management, conflict resolution, security, and privacy requirements and how data is used in functional processes such as benchmarking.

5. Developed to use digital technologies and scaleable methods

The methods, measurements and metrics used in the credentialling platform should be selected keeping in mind ease of use and cost-effectiveness as much as possible, but also need to be accurate (with defined uncertainty), verifiable and operational. Defining uncertainty for remotely sensed data sources tends to be time-consuming and expensive, but there has been continual development and application of scientifically verified and published protocols relevant to climate and biodiversity (e.g. Donald et al. 2010; Li et al. 2020; Guo et al. 2023). Potential options that align with these criteria are remote sensing or integration with existing record keeping software and databases (e.g., Agtech products). New data layers and products based on remote sensing, are being developed to meet demand for cost-effective, credentialling metrics. For the current ECIT platform build, the metrics will have to be operational, sustainable, and preferably accessible via an API. The accuracy and uncertainty of metrics should be understood through scientific verification and higher uncertainties may need to be discounted accordingly. Some potential candidate tools are currently under development, or at proof of concept, and/or are not yet commercially available products. Identifying and capturing supporting data likely to be used in future credentialling methods should be considered.

6. Based on trusted sources of data, informed by scientific evidence

Within the scope of the CSIRO review of SCA schemes, we have identified methods, measurements and metrics that are currently used, and associated verification for emissions accounting and sequestration, and biodiversity (particularly whole of business habitat condition assessment). The level of uncertainty around the various metrics has been evaluated.

7. Applied with centralised governance

Recognised role of centralised coordination of climate and biodiversity credentialling. In the case of the Australian grass-fed beef industry, Meat and Livestock Australia (MLA), as the red meat industry Research and Development service provider, may be the logical choice, provided a suitable level of independence can be demonstrated (acceptable to target markets) and appropriate coordination with other interested parties such as federal agencies and conservation groups. Getting credentialling governance right will ensure greater acceptance by international markets for grass-fed beef.

For climate, protocols for credentials should be consistent with IPCC accepted standards, approved peer reviewed scientific literature, ERF methods and/or other approved published guidelines (such as Climate Active and the Draft Minimum Standards for Carbon Accounting and Carbon Footprints for Sheep and Beef Farm). Similar to climate, biodiversity approaches should be consistent with peer-reviewed literature and global best practice (such as the Australian Farm Biodiversity Certification scheme, Accounting for Nature, or the underpinning framework used in LOOC-B). However, for biodiversity it is also important to enable farmers to demonstrate how they're managing biodiversity on farm via the use of questionnaires similar to those discussed in Section 4.4.8.

8. Aligned with business objectives and a strong value proposition

Uptake of credentials by the grass-fed beef industry will rely on a clear value proposition aligned with business objectives, or compliance with regulation. The benefits to credentialling for the industry are around market access, access to capital, social license and recognition of producer stewardship, product marketing, improved production efficiency and better knowledge to engage with opportunities and scheme providers. However, the objective of supporting profitable cattle production needs to be kept in mind, as maintaining productivity is part of the value proposition.

A tiered approach to credentials will enable flexibility for a broader segment of the industry to engage. However, for cattle producers to be motivated to engage and continue working through the tiers to meet the requirements of the 2nd and 3rd tiers and then to consider other SCA schemes that may fit with business objectives, credentialling must be supported by an increasing value proposition to warrant putting in the extra effort. The messaging and language used in communicating the tiered credentials approach will be critical in adoption.

4.5.2 Credentialling methods and metrics

A concurrent review of systems of measurements that have been applied within existing SCA schemes for climate and biodiversity has provided a basis to identify the methods, measures and metrics that could be used within the three tiers of credentials that have been developed in our recommendations. Candidate measures identified to support tiered credentialling for the areas of emissions/emissions intensity, sequestration and biodiversity are outlined in Table's 6, 7 and 8. The metrics identified are prioritised based on achieving a substantive impact for the credential, being an important assessment point for entry-level credentials, and being ready for use in credentialling.

Emissions and Emissions Intensity

Enteric methane emissions and land use change are key activities that account for much of the GHG emissions from beef production. Determining a basic estimate of enteric emissions can be achieved based on farm production records, as enteric emissions are closely related to the size and number of cattle, and the quality of their diet. The SB-GAF tool has been identified as one of few tools that are publicly available tools for integrating production data to calculate total emissions and emissions intensity for sheep and beef businesses (Table 6). SB-GAF is a reasonably comprehensive carbon accounting tool and reducing input requirements to focus on direct emissions from cattle (enteric, manure and urine) should be considered for entry-level credentials. The quality of data used to calculate emissions and emissions intensity should be medium-high, depending on record keeping systems, while scientific confidence in some farm records (e.g. livestock numbers, liveweight and growth to estimate enteric emissions) and the SB-GAF tool, which are supported by peer reviewed publication, is high. Data quality refers to aspects of accuracy, reliability, verification, and governance of base data sources. For, example some farm records need to be accurate for purposes such as compliance audits, legal transactions (e.g. LPA documents for livestock transport and sale) and taxation. Recommended measured for emissions and emissions intensity for beef production are whole of business CO2e and CO2e/kg LW sold.

Table 6. Candidate measures identified to support tiered credentialling for emissions/emissions intensity

Emissions/E. intensity	Measure	Methods	Data quality	Scientific confidence	Tier(s)
Learning	Course completion	Carbon accounting technical manual MLA e-learning modules Carbon EDGE,		MLA pre-approved	
Monitoring & Benchmarking	Herd structure Animal numbers Liveweight gain Sale numbers Sale weights Pasture quality	Farm Records SB GAF Ruminati AgCare	Med-High Medium ? ?	High High MLA pre-approved MLA pre-approved	Tier 2/3
Management	Increased weaning/marking rate. Reduce numbers while maintaining output. Increase weaning to slaughter growth rate. Breeding for improved feed conversion efficiency. Join heifers at an earlier age. Feed additives.	Farm Records/ Statutory dec.	Med-High	High	Tier ½3

	Anti-methanogenic pastures and supplements. Fertiliser/Pesticide use				

Sequestration

Carbon storage is a product of the area available for sequestration, and the carbon sequestration rate of organic soil and vegetation. Perennial plantings, particularly shrubs and trees, are the primary mechanism to sequester carbon within extensive livestock systems. Carbon storage in landscapes is a function of complex processes, and is affected by factors such as soil characteristics, climate, vegetation, seasonal conditions and systems management. Carbon stores and fluxes tend to be measured as components (e.g., soil organic carbon) and integrated with models. Suggested measures for entry-level credentialling are listed in Table 7. Data used for monitoring and benchmarking of carbon stores is generally considered to be of medium quality, given that the models are typically based on complex assumptions and some IP restriction have prevented assessment. Methods and accounting systems that can be verified for data quality and scientific confidence are suitable for monitoring and/or benchmarking. For example, FlintPro is based on the FullCAM model, which is supported by peer reviewed science this product should be suitable for entry-level credentialling. Measurement of revegetation areas based on farm maps has a higher level of confidence, and measurement of carbon stock could be consistent with established protocols, such as ERF. Recommended measures for carbon stores (CO_2e as soil organic carbon and vegetation) for beef production are at the business level, but this could be for a subset of the business, property, whole of business, or combined businesses or properties .

Table 7. Candidate measures identified to support tiered credentialling for sequestration

Sequestration	Measure	Methods	Data quality	Scientific confidence	Tier(s)
Learning	Course completion	Carbon E-learning Carbon 101 Trees on farm and shelterbelts		MLA pre-approved High	
Monitoring & Benchmarking	Soil Organic Carbon Vegetation Carbon	Baseline sampling (ERF method) FlintPro FullCAM LOOC-C CIBO Labs FlintPro FullCAM LOOC-C SB-GAF Proximal and remote sensing methods	High Medium? Medium Medium? Medium? Medium? Medium Medium? Medium ? ?	High High? High High High MLA pre-approved High? High High High MLA pre-approved	Tier 2/3
Management	Paddock trees area Remnant veg. area Enviro. Plantings area Inputs Grazing management/Rotations	Farm map/FlintPro Farm map/FlintPro Farm map/FlintPro Farm Records CIBO Labs	High High High High Medium?	High High High High MLA pre-approved	Tier ½3

Biodiversity

Producers are responsible for the short and long-term management of vegetation in extensive beef systems, with flow-on effects to ecosystem biodiversity. Further, land use change associated with agriculture poses a persistent threat to biodiversity globally. A practical assessment of species for the purpose of quantifying biodiversity is extremely difficult, and a common approach is to evaluate the condition of habitat, predominantly associated with the amount and quality of vegetation (Table 8). The use of remote sensing products for the scaleable assessment of habitat condition is an area that is rapidly developing. However, such tools required extensive calibration before they can be available. Farm management practices, and the area of natural or improved habitat that is available, may also be a good indication of support for biodiversity. A survey of practises can provide an efficient entry-level indication of biodiversity credentials, however scientific confidence in outcomes may be uncertain. For example, activities to control feral animals could be easily recorded, but the associated impacts on biodiversity will be more difficult to assess and must be made over longer timeframes. Recommended measured for biodiversity is whole of business habitat condition as a percentage of pristine habitat, and assessment of biodiversity persistence, which is the likelihood that species can maintain their population into the future. Biodiversity persistence is reported as the number of species maintaining their population (Species No).

Table 8. Candidate measures identified to support tiered credentialling for biodiversity

Biodiversity	Measure	Methods	Data quality	Scientific confidence	Tier(s)
Training	Farm biodiversity awareness Biodiversity software awareness Course completion	Accounting for Nature Birdcast SEEA		MLA Pre-approved	Tier 1
Questionnaire	Qualitative/Quantitative business details	Survey	Medium	Verification should continue over time	Tier ½3
Monitoring & Benchmarking	Habitat condition# Biodiversity persistence# Habitat connectivity# Threatened species habitat provision Balance tree/grass cover	LOOC-B LOOC-B LOOC-B LOOC-B CIBO Labs Field survey	Medium Medium Medium Medium Medium? High?	High High High High High High	Tier 2/3 Next step

Management	Paddock trees area and trend	Farm map/FlintPro	High	Medium	Tier ½3
	Remnant veg. area	Farm map/FlintPro	High	High	
	Runoff/riparian management	Farm map/Field survey/LOOC-B	Medium	Low	
	Fenced exclusion area	Farm map	High	Medium	
	Enviro. Plantings area	Farm map	High	Medium	
	Feral animal control	Statutory decl.	High	Low	
	Weed control	Statutory decl.	High	Low	
	Erosion control/Cover	Fractional cover/CIBO labs/LOOC-B	Medium	High	
	Fertiliser/Pesticide use	Statutory decl.	High	Low	

#Weighted average monitoring and management methods

4.5.3 Recommended tools for climate and biodiversity credentialling

A wide range of tools and methods that can be applied to climate and biodiversity credentials have been identified through our review of literature. These have been assessed and prioritised based on the project design criteria and recommendations through consultation with MLA, the project steering committee and CN30 oversight committee. Key criteria are that the methods are scaleable, can be used for benchmarking, are suited to the diverse business structures in the beef industry, and not too onerous so to support entry-level credentialling. The ECIT platform will require flexibility to adapt to new data products as they emerge, and able to be adapted in the case that any perverse incentives emerge. There are IP considerations around the integration of new products within the ECIT platform, as current and new methods have differences in their market maturity, and knowledge about the uncertainty of metrics (Table 9). It is suggested that there be a process in place for the approval of new methods, perhaps similar to that of the ERF, but targeted at entry level credentials for climate and biodiversity.

Table 9. Maturity/availability of credentialling tools and documentation

Platform	Maturity	Confidence

SB GAF	Commercial, publicly available	Peer reviewed publication support
LOOC-C	Pre-commercial, CSIRO IP, API Evaluation license	Based on FullCAM (peer reviewed)
LOOC-B	Pre-commercial, CSIRO IP	Reported evaluation of error estimates Peer reviewed publications
ECIT questionnaire	To be developed by ECIT team	Based on international credential systems and stakeholder engagement
FLINTPro	Commercial, privately owned	Based on FullCAM (peer reviewed), but little information regarding its adaptation
FullCAM	Publicly available	Peer reviewed publication support
CIBOLabs	Commercial, privately owned	Uses ML algorithms with satellite and privately sourced ground-truth data. Fractional cover analysis using remote sensing is based on peer reviewed research.

SB-GAF

The SB-GAF (Sheep and Beef – Greenhouse Accounting Framework) developed by the University of Melbourne is intended for use in sheep and beef cattle grazing businesses, particularly enabling a baseline analysis to compare effects of other scenarios such as changes to land use, livestock enterprise or sequestration opportunities. SB-GAF is used to compare scenarios with different emissions intensity (Ekonomou et al. 2020). The SB-GAF tool is the most detailed and peer-review supported tool for estimating GHG emission profiles of beef production for Australia, and there does not appear to be a comparable tool available internationally. However, in the current format the level of complexity may still be too high for business-level adoption. Entry-level credentialling means that tools should remain accessible to business owners and managers, rather than relying on specialists in order to engage. A reduced version, based on requirements for an entry level assessment of GHG emissions for each of the tiers would be a reasonable starting point for the application of this tool.

Some limitations of the SB-GAF tool were identified in its capacity to represent beef enterprise scenarios. For example, ability to define changes or management of pasture quality, options to define livestock genetic merit and relevant soil and tree options may not be available in some regions. An example of inputs/outputs for a beef enterprise scenario are shown in Figures 6 and 7.

Figure 6. SB-GAF input template and example livestock and pasture data for a beef enterprise in the SW region of WA.

Enter your farm data for each animal class and season

Farm name	Breed herd 100	Is your property north of the Tropic of Cap	No	2
Choose your region in Australia	SW WA	Is your property in orange zone? (Ref Map	No	2
	4			

Livestock inventory		Breeder cattle and owner bred cattle								Traded cattle			
		Bulls >1	Steers <1	Steers 1-2	Steers >2	Cows >2	Heifers< 1	Heifers 1-2	Heifers >2 (not calving)	Steers >2	Steers 1-2	Steers <1	Units
Livestock Numbers	Spring	3	45			100	45	37					head
	Summer	3	45			100	45	37					head
	Autumn	3	45			100	45	37					head
	Winter	3				100	45	37					head
	Average	3	45			100	45	37					head
Liveweight	Spring	800	300			550	260	420					kg/head
	Summer	780	340			530	300	450					kg/head
	Autumn	680	100			480	80	320					kg/head
	Winter	700	170			490	150	330					kg/head
	Average	740	228			513	198	380					kg/head
Liveweight gain (LWG)	Spring	1.10	1.42			0.66	1.21	0.99					kg/hd/day
	Summer	-0.22	0.44			-0.22	0.44	0.33					kg/hd/day
	Autumn	0.00	0.60			-0.55	0.60	0.22					kg/hd/day
	Winter	0.22	0.77			0.11	0.77	0.11					kg/hd/day
	Average	0.28	0.81			0.00	0.76	0.41					kg/hd/day
Crude Protein (CP)	Spring	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	25.00	25.00	25.00	%
	Summer	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	7.00	7.00	7.00	%
	Autumn	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	10.00	10.00	10.00	%
	Winter	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	21.00	21.00	21.00	%
	Average	13.8	0.0	13.8	0.0	0.0	13.8	13.8	13.8	15.8	15.8	15.8	%
Dry matter digestibility (DMI	Spring	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	%
	Summer	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	58.00	%
	Autumn	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	%
	Winter	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	%
	Average	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	%

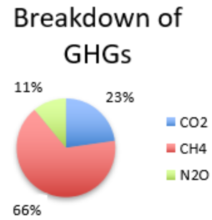
Purchase inventory	Bulls >1	Steers <1	Steers 1-2	Steers >2	Cows >2	Heifers< 1	Heifers 1-2	Heifers >2 (not calving)	Steers >2	Steers 1-2	Steers <1	Purchases - Breeder operation
No. head purchased	1											
Purchase weight (LW/hd)	800											
Live weight / category	800	0	0	0	0	0	0	0	0.0	0.0	0.0	800
Source of livestock (region	sw WA	NSW/VIC	SA pastor	SA pastor	Dairy origi	Dairy origi	Dairy origi	Dairy origi	Dairy origin	Dairy origin	Dairy origin	

Figure 7. SB-GAF output for an example beef enterprise in the SW region of WA. Emissions intensity of 14.2 kg CO2-e/kg LW, excluding sequestration

Beef & Sheep Greenhouse Accounting Tool

Outputs	beef t CO_2e/farm	sheep t CO2e/farm	total t CO2e/farm
Scope 1 Emissions			
CO_2 - Fuel	7.97	0.00	7.97
CO_2 - Lime	48.51	0.00	48.51
CO_2 - Urea	12.83	0.00	12.83
CH_4 - Fuel	0.00	0.00	0.00
CH_4 - Enteric	372.50	0.00	372.50
CH_4 - Manure Management	17.55	0.00	17.55
CH_4 - Savannah Burning	0.00		0.00
N_2O - Fertiliser	6.70	0.00	6.70
N_2O - Urine and Dung	23.11	0.00	23.11
N_2O - Atmospheric Deposition	3.16	0.00	3.16
N_2O - Leaching and Runoff	24.10	0.00	24.10
N_2O - Savannah Burning	0.00		0.00
N_2O - Fuel	0.05	0.00	0.05
Scope 1 Total	**516**	**0**	**516**
Scope 2 Emissions			
Electricity	1.38	0.00	1
Scope 2 Total	**1**	**0**	**1**
Scope 3 Emissions			
Fertiliser	38.65	0.00	38.65
Purchased feed	29.24	0.00	29.24
Herbicides/pesticides	4.24	0.00	4.24
Electricity	0.08	0.00	0.08
Fuel	0.41	0.00	0.41
Lime	3.06	0.00	3.06
Purchased livestock	9.36	0.00	9.36
Livestock on agistment			
Scope 3 Total	**85**	**0**	**85**
Carbon Sequestration			
Carbon sequestration in trees	-117.44	0.00	-117.44
Net Farm Emissions	**485**	**0**	**485**
Emissions intensity			
Sheep meat (breeding herd) excl. sequestration			kg CO2-e / kg LW
Sheep meat (breeding herd) inc. sequestration			kg CO2-e / kg LW
Wool excl. sequestration			kg CO2-e / kg greasy
Wool inc. sequestration			kg CO2-e / kg greasy
Beef excl. sequestration	**14.2**		kg CO2-e / kg LW
Beef inc. sequestration	**11.4**		kg CO2-e / kg LW

Summary	t CO2e/farm
CO_2	135
CH_4	392
N_2O	65



FLINTpro (FullCAM)

FLINTpro is a software system used to report and forecast environmental information and variables including carbon sequestration. The software is capable of integration of geospatial and remote sensing data with advanced scientific models. FLINTpro uses preloaded data sets, as well as capacity to import custom data, or access land sector remote sensing data sets from external providers.

FLINTpro has been developed based on the FullCAM model (Richards and Evans 2004). FullCAM (Full Carbon Accounting Model) has been widely applied by researchers for modelling carbon stock in soils and above-ground vegetation biomass. FullCAM has been applied for tracking greenhouse gas emissions and changes in carbon stocks associated with land use and management in Australian agricultural and forest systems. It has been applied at the national scale for land sector greenhouse gas emissions accounting and at the local scale for monitoring and reporting carbon sequestration projects, such as revegetation and the management of regrowth. FullCAM can be accessed as freely available software system.

Biodiversity Questionnaire

A questionnaire approach provides an ideal entry point for biodiversity credentialling, because it is relatively easy and inexpensive to implement. However, verification of outcomes related to the survey information will be needed to ensure that responses to questions can be linked to the desired outcomes and intentions of beef producers. Verification of outcomes might be achieved using other biodiversity tools (e.g., LOOC-B) over time.

International credentialling schemes provide a good basis for designing an ECIT questionnaire, but some development of Australian-relevant questions will be needed because of differing terminology, environmental conditions and farming systems. Development of the questionnaire would be best undertaken in close consultation with stakeholders. The six core areas covered in the international schemes reviewed should be covered in developing the questionnaire so that its international relevance can be established, and producers become familiar with these areas should they eventually progress to participating in an international scheme.

The six areas are:

1. Maintenance and protection of remnant native habitats and species.
2. Avoiding practices that degrade or endanger remnant native habitats and species.
3. Creating plans to protect and foster native species, including the achievement of greater ecosystem connectivity.
4. Control of input application and storage to minimise impact, including training of personnel.
5. Conduct of a diversified enterprise (multiple species and/or more diverse genetics).
6. Care of soils and beneficial species.

Some example practices that could be the subject of questions for each area might be:

1. Weed and vertebrate pest management; exclusion fencing for remnant bushland.
2. Waste management; tree clearing
3. Plans for rehabilitation of degraded land, plans for preserving environments or species
4. Use of precision methodology for weed spraying, chemical safety training which includes environmental safety
5. Diversified feedbase including grasses, legumes and other species, maintaining sheep/cattle mix where applicable
6. Zero till sowing, soil testing and lime application, timing of insect pest sprays

Key steps to improve confidence in management are;

1. Species selection relevant to local area and ecosystem
2. Ongoing monitoring and management to make sure the area of interest is protected and no issues are emerging
3. Management of invasive species

For ease of use, any questionnaire developed should be incorporated seamlessly with other questions necessary for fulfilling other requirements embedded in the credential, for example questions needed to enable the SB-GAF and LOOC-B analyses. Repetition of basic questions that underlie multiple components of the credential (e.g., land size, proportion of land used for different purposes) can and should be avoided.

LOOC-B

LOOC-B (Landscape Options and Opportunities Calculator for Biodiversity) was developed by CSIRO as a rapid assessment solution, offering a consistent and standardised approach for monitoring how biodiversity has changed over time and anticipating how different management strategies influence the availability and quality of surrounding habitat. The intention for this produce is to continue to allow small scale users to use it for free going forward, which makes this a suitable tool for training and demonstration purposes and at a farm enterprise level. An API is available if there is interest to embed this in the ECIT platform.

LOOC-B provides two modes of analysis, i) monitoring of previous land management interventions and ii) planning environmental interventions. LOOC-B provides four biodiversity indicators: habitat condition, habitat connectivity, biodiversity persistence and threatened species habitat. Habitat Condition is the primary indicator from which the others are derived through modelling with additional spatial environmental data and species observation/ survey data. Habitat condition is scaled between 0.0 and 1.0 in which a score of 1.0 indicates that the habitat is in an intact reference state (i.e., it has high levels of ecological integrity) and a score of 0.0 means there is no capacity for naturally occurring species to persist. Examples of LOOC-B biodiversity assessments are provided in Appendix 8.2.

5. Conclusion

The Grass-fed Beef Credentials project was developed as a 'sprint' activity to provide support for MLA's strategic objectives around verification of industry credentials and to encourage entry-level engagement with climate and biodiversity credentialling.

5.1 Key findings

An extensive review of SCA schemes revealed that while they are proliferating rapidly, the underpinning metrics and data being used to verify credentials is somewhat limited, due to both the high level of systems complexity and diversity, and likely protection of IP by credentialling businesses. Some existing SCA schemes are not at all prescriptive regarding the types of activities and assessment metrics that are required. For example, the Canadian Roundtable for Sustainable Beef's Sustainable Beef Production Standard simply states that the highest level of credential is achieved when the "Operation assesses the success of practices that are supporting carbon sequestration or minimizing emissions". A more transparent, science-based, system for entry-level credentialling would be of value to the Australian beef industry.

The project review identified a wide range of methods and metrics that were being used in SCA schemes, in the areas of GHG emissions, sequestration and biodiversity. Several key metrics need to be carefully selected for verification of credentials and benchmarking. Ideally, these credentials would follow a defined protocol based on information specific to the credential domain. For biodiversity credentials, the use of habitat condition assessment is a generally accepted proxy for biodiversity. According to the Habitat Condition Assessment Scheme for Australia (HCAS), the definition of 'Habitat Condition' is: "the capacity of an area to provide the structures and functions necessary for the persistence of all species naturally expected to occur in that area if it were in a reference state." For climate, GHG accounting methods are required including metrics such as emissions intensity, net/total emissions, and carbon stores in the soil and vegetation. We suggest the use of emissions accounting (SB-GAF) and process models (FullCAM – e.g. via FLINTpro) for climate credentials, and a business practice questionnaire and remote sensing (e.g. LOOC-B) approach for biodiversity credentials. These approaches all offer a strong potential for scientific verification, although further work may be needed to achieve this. For example, there will be a need to ensure that questionnaire responses can be linked with biodiversity outcomes.

Producers and processors will have varying production recording and account keeping procedures that are needed to inform climate and biodiversity standards, and so we recommend using a tiered approach to provide flexibility for entry level credentialling across the Australian beef industry. The 3-tiered approach and achievement criteria were developed with consistency for climate and biodiversity, i.e. Tier 1 – Aware (Learn and Plan), Tier 2- Actioned (Measure and Manage) and Tier 3- Committed (Monitor and Improve). There will be a need to ensure flexibility and updatability in measurement methods and analytical approaches from the initial starting position. For example, applying a framework where several data sources can be linked with a parent metric when calculating a benchmarking value for credentialling.

5.2 Benefits to industry

This project has developed a scientifically grounded foundation for entry-level credentialling for producers and processors. Combined with governance and oversight from an industry representative body such as Meat and Livestock Australia, this should enable consistency and confidence for businesses or entities seeking to credential their products. Supporting the ECIT platform build by establishing a scientifically rigorous set of recommendations that can be applied and adapted to meet the practical requirements for credentialling in the beef industry.

6. Future research and recommendations

The project team has worked hard to deliver value in this project, despite complexity around the scope of the work and challenging deadlines due to the sprint design that was applied. The MLA project managers have been supportive in developing plans for the effective delivery of the work, and helping to develop realistic expectations with other project partners, such as the ECIT build team.

A series of project recommendations were developed in consultation with Technical Committee, Steering Committee and Project Coordinator collaborators. Three tiers of credentialling are proposed, based on training (Tier 1), implementation (Tier 2) and benchmarking (Tier 3), which captures the intent for carbon and biodiversity assessments between comparable enterprises with similar land types within agro-ecological regions. Appropriate training material (Tier 1), on-farm assessment metrics and opportunities for improvement based on a defined SMART (Specific, Measurable, Achievable, Relevant and Time-Bound) management plan (Tier 2) and benchmarking metrics (Tier 3) have been identified and described for each of the climate and biodiversity credentialling tiers.

We suggest the use of emissions accounting (SB-GAF) and process models (FullCAM – e.g. via FLINTpro) for climate credentials, and a business practice questionnaire and remote sensing (e.g. LOOC-B) approach for biodiversity credentials. These approaches all offer a strong potential for scientific verification, although further work may be needed to achieve this. For example, there will be a need to ensure that questionnaire responses can be linked with biodiversity outcomes.

A balanced approach will be needed for transitioning as better methods or indicators emerge. Generally, it will be important to be as consistent as possible with indicators being used and if over time different models are used, then the risk of getting systematically higher or lower results will need to be considered. If there are relevant differences between tools then maybe there is a need to require a producer to use one tool consistently over time, and there would also be a need to flag that credentials derived with one tool are not comparable with others.
Duplication of input requirements needs to be avoided whenever possible when populating components of the ECIT platform, as this will save users a substantial amount time and effort. For example, information from survey responses may provide useful data for other methods. Sourcing data directly from other farm and commercial databases via an API is also suggested. Additionally, inconsistent geospatial data has the potential to reduce the accuracy of value estimates markedly. Standardisation of methods for sourcing and processing geospatial data was identified as an important consideration in a digital platform.

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8. Appendix

Project timeline

8.1 Reference table for Standards, Certification and Assurance schemes reviewed

Scheme	Ref #	Coverage	Sector	Industry	Scope	Parent Framework
Aboriginal Carbon Foundation	2	Australia	Climate	Multiple	Farm gate	
Accounting for Nature (AfN)	3	Worldwide	Biodiversity	Multiple	Farm gate	
AfN-METHOD-NV-07	4	Australia	Biodiversity	Multiple	Farm Gate (Project/Property)	AfN
AfN-METHOD-NV-08	5	Australia	Biodiversity	Pastures (permanent-perennial)	Farm Gate (Project/Property)	AfN
AfN-METHOD-S-02+Landcare+Soil+Method+v1.2	6	Australia	Biodiversity	Multiple		AfN
AgCarE (AgForce)	7	Australia	Natural Capital+ Carbon	Multiple, incl. grazing	Farm gate	
Agricultural Stewardship Scheme Package	8	Australia (Pilot regions)	Biodiversity/Climate/Carbon	Multiple, incl. grazing	Farm gate	ASSP

Australian Farm Biodiversity Certification Scheme Standard	9	Australia	Biodiversity	Multiple, Native Veg focus	Whole Farm vs Regional	ASSP
Animal health index, CSIRO/MLA	10	Australia	Welfare	Multiple	Farm Gate/ Supply Chain	CSIRO/MLA
Australian Agricultural Sustainability Framework	11	Australia	Industry	Beef, Sheep and Wool	Farm gate, Feedlots, Transport, Saleyards, and Processing	
Australian Government Emissions Reduction Fund	12	Australia	Climate	Multiple	Farm gate	ERF
Australian Sheep Sustainability Framework	13	Australia	Industry	Sheep and Wool	on-farm, transport, saleyards, and Australian processors	
Australian Sustainable Products	14	Australia	Climate/biodiversity	Multiple, incl. grazing	Farm gate	
Australian Beef Sustainability Framework	15	Australia	Climate/biodiversity	Beef	Supply chain, framework	
Brigalow Nandewar Biolinks	16	Australia	Biodiversity	Multiple	Farm gate	
Carbon friendly	17	Australia	Climate	Multiple	Farm gate	
Climate active	18	Australia	Climate	Multiple		
Cool Farm Tool	19	Worldwide	Climate/biodiversity	Multiple	Farm gate/ Supply Chain	self
CRSB Certified Sustainable Beef Framework	20	Canada	Climate	Beef	Supply chain	
Dairy Sustainability Framework	21	Australia	Climate/biodiversity	Dairy	Farm gate	
Fairtrade	23	Worldwide		Multiple	Farm gate	
FAO low carbon livestock	24	Worldwide	Climate	Multiple		FAO
FAO Sustainability Assessment of Food and Agriculture Systems (SAFA)	25	Worldwide	Climate/biodiversity	Multiple	Farm gate/ Supply Chain	FAO/UN
Farm Sustainability Services	26	New Zealand		Multiple	Farm gate	
Global Good Agricultural Practices (GAP)	27	Worldwide	Industry/biodiversity/welfare	Multiple	Farm gate/Supply Chain	FAO/UN
Global Reporting Initiative (GRI) – agricultural standards	28	Worldwide	Biodiversity	Multiple	Organisational	
Global Roundtable for Sustainable Beef	29	Worldwide	Sustainability/Climate	Beef	Farm gate/Supply Chain	GRSB
International Financial Reporting Standards (IFRS)	30	Worldwide		Multiple (77 industries)	Farm gate/Supply Chain	

International Organisation of Standardisation (ISO)	31	Worldwide	Sustainability/Climate	Multiple	Farm gate/Supply Chain	
International Sustainability & Carbon Certification (ISCC)	32	Worldwide	Sustainability/Climate	Multiple	Farm gate	UN
ISEAL Alliance	33	Worldwide		Multiple	Supply chain	
ISO/TC 331	34	Worldwide	Biodiversity	Multiple	Farm gate	ISO
ISO/WD 14068	35	Worldwide	Climate	Multiple	Farm gate	ISO
Joint Accreditation Scheme Australia & NZ (JASANZ)	36	Australia/New Zealand	Climate	Multiple	Enterprise	
LOOC-B	37	Australia	Biodiversity	Multiple	Defined project area	
Making More from Sheep	38	Australia		Sheep and Wool	Farm gate	
Midlands Conservation Fund	39	Australia	Biodiversity	Multiple	Farm gate	
MLA CN30 Project	40	Australia	Climate/biodiversity	Red meat	Supply chain	
NAB AgForce Natural Capital Project	41	Australia			Farm gate	
National Feedlot Accreditation Scheme (NFAS)	42	Australia		Livestock lotfeeding	*** Farm + processor	
NSW Biodiversity Offset Scheme	43	Australia, NSW	Biodiversity	Multiple	Farm gate	
QLD Land Restoration Fund	44	Australia, Qld	Climate	Multiple	Farm gate	
Roundtable for Sustainable Biomaterials (RSB) – Biomaterial feedstock production	45	Worldwide	Sustainability/Climate	Multiple	Enterprise	
SB-GAF (Sheep Beef GHG Accounting Framework)	46	Australia	Climate	Multiple	Farm gate	
Smart Farms project - MLA	47	Australia	Climate/Biodiversity	Multiple	Enterprise	
State of the Environment, Land Cond. Assessment Tool	48	Queensland	Natural Capital	Multiple incl. grazing	Farm gate (property/project)	Qld. Govt.
Sustainability Accounting Standards Board (SASB) Index	49	Worldwide	Sustainability/Climate	Multiple (77 industries covered)	Property/Enterprise	UN, GHG Protocol
Sustainable Agriculture Institute (SAI) Farm Sustainability Assessment program (FSA)	50	Worldwide	Sustainability/Climate	Multiple	Enterprise	ERBS
Sustainable Agriculture Network (SAN)	51	Worldwide	Sustainability	Multiple, incl. grazing	Enterprise	UN

Sustainable Agriculture Framework						
System of Environmental Economic Accounting (SEEA)	52	Worldwide	Natural Capital	Multiple	Enterprise	UN
UN Sustainable Development Goals (SDGs)	53	Worldwide	Sustainability/Climate	Multiple	Enterprise	UN
Verra	54	Worldwide	Climate/biodiversity	Multiple	Enterprise	Verra is the Parent Framework to #'s 67-71
Woolworths's sustainability beef - CSIRO	55	Australia	Climate/Biodiversity	Beef	Supply Chain	Australian Beef Sustainability Framework
FLINTpro	56	Worldwide	Climate	Multiple	Enterprise	
Farm-scale Natural Capital Accounting	57	Australia	Natural Capital	Multiple	Enterprise	Research Project funded by Method # 47 (Australian Government Smart Farming Partnership Program)
Sustainable Agriculture Initiative	58	Worldwide	Sustainability	Multiple	Enterprise	SAI Platform
Habitat Condition Assessment System for Australia.	59	Australia	Biodiversity	Multiple	Enterprise	
Commonwealth of Australia (2021) 'National Greenhouse Accounts 2019', in Volume 1, p. 432.	60	Australia	Climate	Multiple	Economic Sectors	United Nations Framework Convention on Climate Change (UNFCCC)
Greenhalh, S., Broekhoff, D., Daviet, F., Ranganathan, J., Acharya, M., Corbier, L., Oren, K., & Sundin, H. (2005). Chapter 10: Monitoring and Quantifying GHG Reductions. In The GHG Protocol for Project Accounting (pp. 1–148).	61	Worldwide	Climate	Multiple	Project	World Resource Institute (WRI) and World Business Council for Sustainable Developm

						ent (WBCSD)
GRDC (2013) Managing soil organic matter a practical guide. Edited by Grains Research & Development Corporation. Online: GRDC	62	Australia	Climate	Multiple	Farm gate	GRDC
Priority Investment Co-benefits Standard (CF-LRP)	63	WA	Biodiversity/Carbon/Culture	Multiple	Farm gate	
Protecting Victoria's Environment - Biodiversity 2037	64	Victoria	Biodiversity	Multiple	Enterprise	Victorian government
Measuring biodiversity and ecological integrity in NSW	65	NSW	Biodiversity	Multiple	Enterprise	NSW government
LOOC-C	66	Australia	Carbon/Climate	Multiple		
Verified Carbon Standard (VCS)	67	Worldwide	Climate/ Sustainability/Biodiversity/ Carbon	Multiple	Property/Enterprise	Verra
VCS VM0026 Methodology for Sustainable Grassland Management (SGM), v1.1	68	Worldwide	Sustainability	Grazing	Property/Enterprise	Verra
VCS VM0032 Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing, v1.0	69	Worldwide	Sustainability	Grazing/Fire	Property/Enterprise	Verra
VCS VM0041 Methodology for the Reduction of Enteric Methane Emissions from Ruminants through the use of Feed Ingredients, v2.0	70	Worldwide	Climate	Enteric Fermentation	Property/Enterprise	Verra
VCS VM0021-Soil-Carbon-Quantification-Methodology-v1.0	71	Worldwide	Climate	Multiple	Property/Enterprise	Verra
World Benchmarking Alliance	72					
Gold Standard	73	Worldwide	Climate	Multiple	Enterprise	UN
ERF Feeding Nitrates to cattle Method	74	Australia	Climate	Cattle	Farm gate	ERF
USDA Low Carbon Beef	75	USA	Climate	Beef	Farm gate	USDA
Natural Carbon	76	Australia	Biodiversity/Climate/Carbon	Multiple	Farm gate, Corporations	
GHG Protocol Agricultural Guidance (April 26)	77	Worldwide	Climate/Carbon	Multiple	Multiple	
Climate Disclosure Standards Board	78	Worldwide	Climate	Multiple		

ERF-Opportunities for the land sector	79	Australia	Climate			ERF
Carbon Credits (Carbon Farming Initiative) Act 2011	80	Australia	Climate			ERF
Carbon Credits (Carbon Farming Initiative) Regulations 2011	81	Australia	Climate			ERF
Carbon Credits (Carbon Farming Initiative) Rule 2015	82	Australia	Climate			ERF
Agricultural	83	Australia	Climate			ERF
Beef cattle herd management	84	Australia	Climate	Cattle		ERF
Reducing greenhouse gas emissions by feeding nitrates to beef cattle	85	Australia	Climate	Cattle		ERF
Estimating sequestration of carbon in soil using default values (model-based soil carbon)	86	Australia	Climate	Multiple		ERF
Estimation of soil organic carbon sequestration using measurement and models method	87	Australia	Climate	Multiple		ERF
Animal effluent management method	88	Australia	Climate	Cattle		ERF
Reducing greenhouse gas emissions by feeding dietary additives to milking cows	89	Australia	Climate			ERF
Reducing greenhouse gas emissions from fertiliser in irrigated cotton	90	Australia	Climate			ERF
Savanna fire management	91	Australia	Climate			ERF
Savanna fire management 2018—sequestration and emissions avoidance	92	Australia	Climate	Cattle		ERF
Savanna fire management 2018—emissions avoidance	93	Australia	Climate	Cattle		ERF
Vegetation	94	Australia	Climate			ERF
Avoided clearing of native regrowth	95	Australia	Climate	Multiple		ERF
Avoided deforestation V1.1	96	Australia	Climate	Multiple		ERF
Human-Induced regeneration of a permanent even-aged native forest V1.1	97	Australia	Climate	Multiple		ERF

Measurement based methods for new farm forestry plantations	98	Australia	Climate	Multiple		ERF
Native forest from managed regrowth	99	Australia	Climate	Multiple		ERF
Plantation forestry	100	Australia	Climate	Multiple		ERF
Reforestation and afforestation V2.0	101	Australia	Climate	Multiple		ERF
Reforestation by Environmental or Mallee Plantings – FullCAM	102	Australia	Climate	Multiple		ERF
Tidal restoration of blue carbon ecosystems method	103	Australia	Climate	Multiple		ERF
Designated-verified-carbon-standard-projects	104	Australia	Climate	Multiple		ERF
Full Carbon Accounting Model (FullCAM)	105	Australia	Climate	Multiple		ERF
Overseer	106	New Zealand	Climate			
European Roundtable for Beef Sustainability (ERBS)	107	EU	Sustainability			
National Stewardship Trading Platform	108	Australia	Carbon/Biodiversity	Multiple		
SustainCERT certification platform	109	Worldwide				
Downforce TechnologiesSabbio- Iceni Earth-Nature's Super App	110	UK based	Biodiversity	Multiple		
FarmLab	111	NSW/National?	Carbon/Biodiversity	Multiple		
Perennial Technology-remote measurement technology for soil carbon sequestration and emissions	112	US based/ global coverage/ Australian branch?	Carbon	Multiple		
Farm Print	113	Australia	Climate			
Australian Farm Institute - Farm Biodiversity scheme	114	Australia	Biodiversity			
Land Condition Assessment Tool (LCAT)	115	Queensland				
NIR2022_20	116					
national-greenhouse-accounts-factors-2021	117					

8.2 LOOC B examples

Figure 8 shows examples of outputs for habitat condition and biodiversity persistence for an 80-ha environmental planting identified in the land use map using the monitoring mode and reported through the LOOC-B web interface.

Figure 9 shows a) forecasts for habitat condition and biodiversity persistence (2021-2045) for a planned environmental planting in a long-term cereal paddock (directly south of the environmental planting shown in Figure 8) and b) the impact on forecast habitat condition, of choosing one of three alternative vegetation type options available through the ERF.

The analysis is most robust for those environments with higher natural tree cover, so may be better suited to higher rainfall or pastoral grazing regions, compared with mixed farming areas. An API interface offers potential for much more in-depth analysis of indicators. An advanced machine learning approach generates the biodiversity indicators, so as more data becomes available the reliability of estimates will improve. Validation of measures and associated uncertainty at continental scale have recently been completed (K Mokany pers comm).

Figure 8. Illustration of change in habitat condition (HC) and biodiversity persistence using LOOC-B associated with an environmental planting ~2006, for an agricultural location in south-west WA.

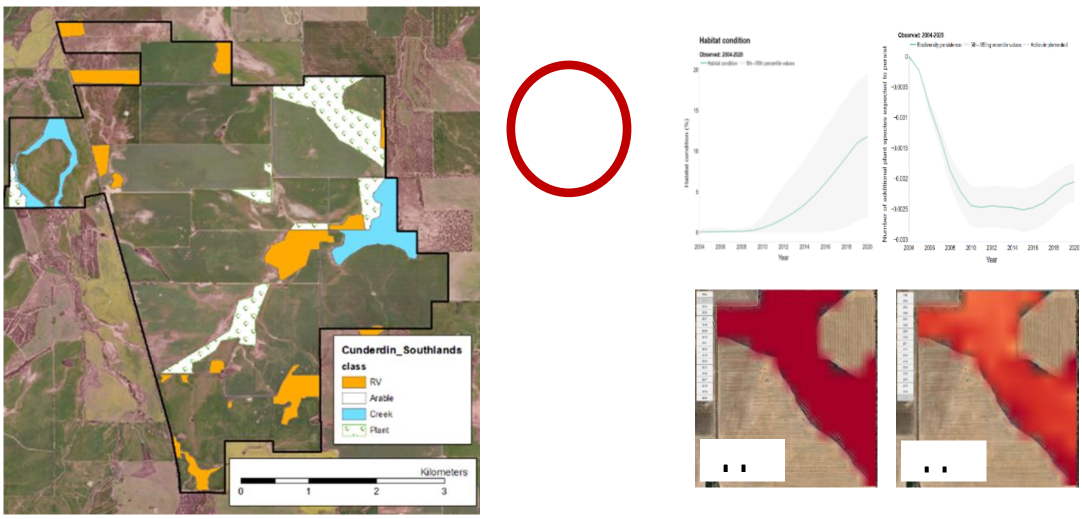
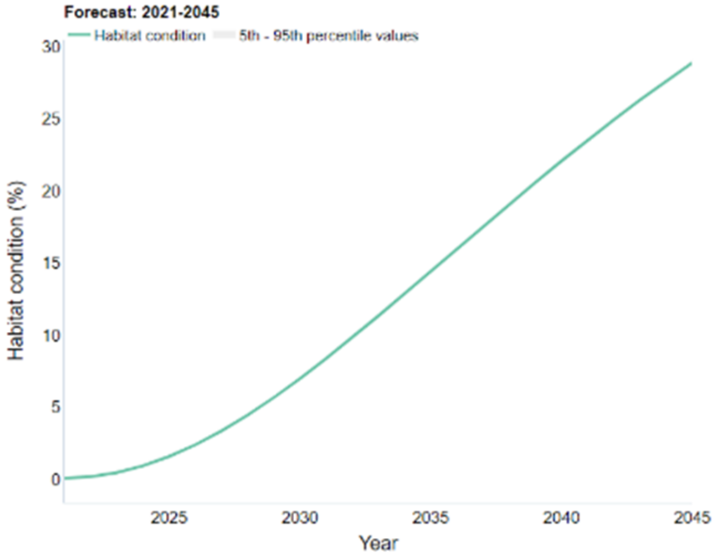
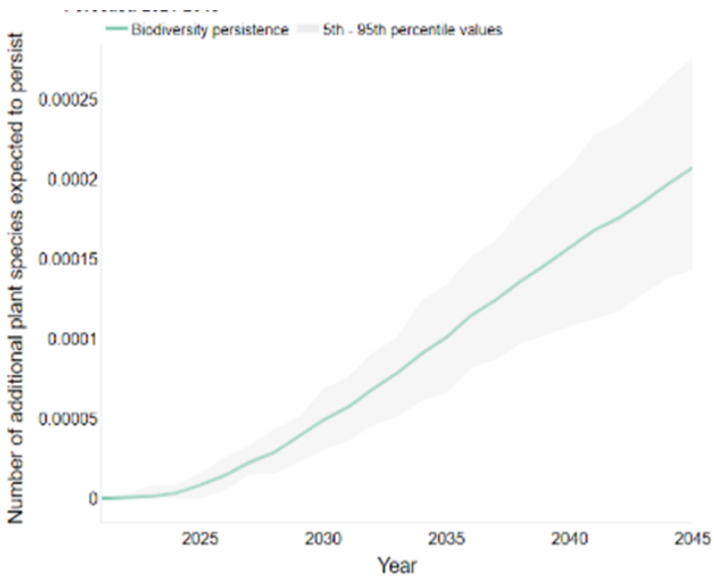


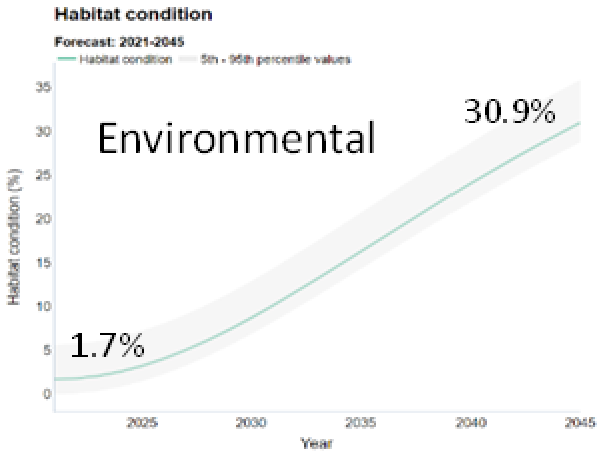
Figure 9. Forecast profiles of habitat condition and biodiversity persistence for an environmental planting (a) and the effect of tree species selection on habitat condition potential gains (b) using LOOC-B in planning mode, for an area of low initial habitat condition in south-west WA.

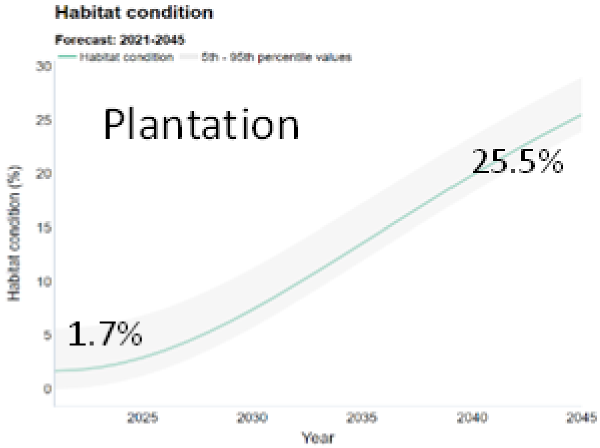
a)

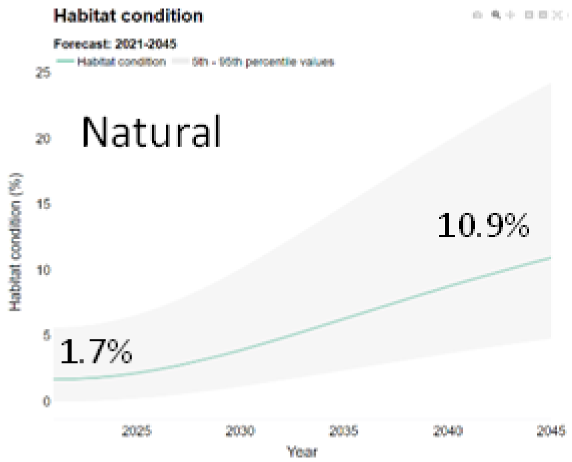




b)

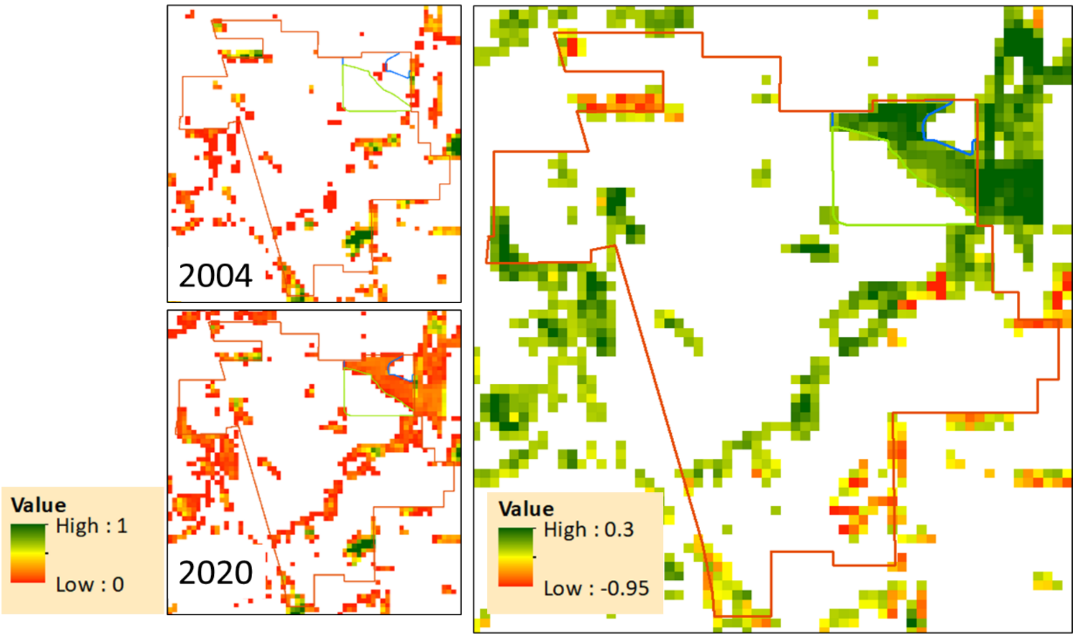






Scale of analysis is defined by the boundary polygon used, from paddock to farm or region (up to 100,000 ha) in LOOC-B. At farm scale, impact of small planting areas are diluted, compared with a paddock scale assessment – so smaller improvements at the farm scale are more significant (Figure 10). Values at a regional scale may have a role in developing benchmarking. Additional data years back to 2004 are now available (HC, BdP, TS) and annual updates to the range of available data years, beyond 2020 are planned.

Figure 10. Habitat condition maps for 2004 and 2020 (left) and the calculated pixel level change in habitat condition (right) where relative to 2004, green pixels indicate improvements and red pixels indicates degradation of habitat condition, at a whole of farm scale using LOOC-B, for a location in south-west WA. Maps are available for download through the API, pixels are approximately 100 m.



At the scale of the paddock or CEA, LOOC-B outputs are reporting known or potential (Planning changes) metrics for HC, Hcon & BdP well and producers could extract progress graphs (e.g., Figure 8 and Figure 9) for use in reporting the impact of biodiversity management implementations by using the web interface alone.

At farm scale, impact of small planting areas are diluted, so smaller improvements at the farm scale are more significant. Additional data could be made available by integration of the LOOC-B API into the ECIT platform for more in-depth analysis through the coding of generic outputs to visually identify major change areas that would help target future areas of intervention. At the regional scale, an assessment of HC stability can be made, which can be used to evaluate benchmarking. Further, interest groups (NRM) can use the tool to target community restoration efforts. The science-based analysis from these indicators could be used to attract gov funding for ongoing conservation efforts.

The principles and methods behind the development of LOOC-B indicators by CSIRO have been extensively published and peer-reviewed. Validation of uncertainty at continental scale reported to AWI/MLA project (K Mokany pers comm).