GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

MAY 2023

SUSTAINABILITY

INITIATIVE

In the spirit of reconciliation GRDC acknowledges the Traditional Custodians of country throughout Australia and their connections to land, sea and community.

We pay our respects to their Elders past, present and emerging and extend that respect to all Aboriginal and Torres Strait Islander peoples today.

CONTENTS

EXECUTIVE SUMMARY

The Australian grains industry has an excellent reputation for supplying 'clean and green' products and for research that supports the development and adoption of sustainable cropping practices. Changing community and government expectations regarding climate change, greenhouse gas (GHG) emissions, biodiversity, and other environmental factors, along with the need for ethical, social and governance reporting to access finance and markets offer potential opportunities and risks for the grains industry going forward. These factors, along with grower concern and interest in improving the sustainability of their businesses and in having a positive impact, provide impetus for GRDC to develop a specific position and plan for ongoing investment in sustainability.

GRDC's purpose of creating enduring profitability for grain growers includes investing in better outcomes for the environment and Australian communities. The sustainability of grain farms is enhanced when people, profit and planet are improved (Figure 1).

In 2022, the GRDC Board established an internal Sustainability Initiative (SI) with the primary objective of developing an overall analysis of sustainability issues and opportunities for the grains industry, and a pipeline of GRDC investments in research, development and extension (RD&E) that support increased delivery of sustainability outcomes.

In reviewing GRDC's investment portfolio in 2022, 162 projects and around $200 million were identified as supporting growers to adopt improved practices or technologies with direct environmental benefits. This level of investment represents 25% of GRDC's total portfolio of investment (*circa* $803 million). This does not include broader value delivered with regards to social and economic benefits – for example, every single GRDC investment is focused on grower profitability, as well as supporting world-class RD&E capacity and ability with broader community benefits.

While it is not GRDC's role to set sustainability targets for Australian grain growers, GRDC supports proactive RD&E on sustainable practices in the grains industry. In this regard, GRDC is working closely with the National Farmers' Federation (NFF), grain grower representative organisations, Grain Producers Australia and GrainGrowers Limited, and other stakeholders in primary industries, on realistic and credible metrics that can be used to monitor significant change against the sustainability frameworks supported by industry.

‘While it is not GRDC’s role to set sustainability targets for Australian grain growers, GRDC supports proactive RD&E on sustainable practices in the grains industry.’

One of the four pillars of GRDC’s RD&E Plan 2023-28 is ‘Thrive for Future Generations: Australia’s grains industry remains a global leader in sustainability, for people, the planet and our long-term ability to farm’. With an explicit sustainability pillar in the RD&E plan, alongside the environmental benefits delivered through the other pillars, GRDC is clearly signalling the priority placed on RD&E that supports the enduring profitability of Australian grain growers. GRDC is working towards accelerating investment in sustainability beyond existing work.

This position paper (May 2023) states GRDC’s commitment to investing in the sustainability of the Australian grains industry and its alignment with industry frameworks. A situation analysis on current GRDC investment with sustainability outcomes is summarised as input into a proposed investment pipeline to ensure momentum to deliver against GRDC’s RD&E Plan 2023-28.

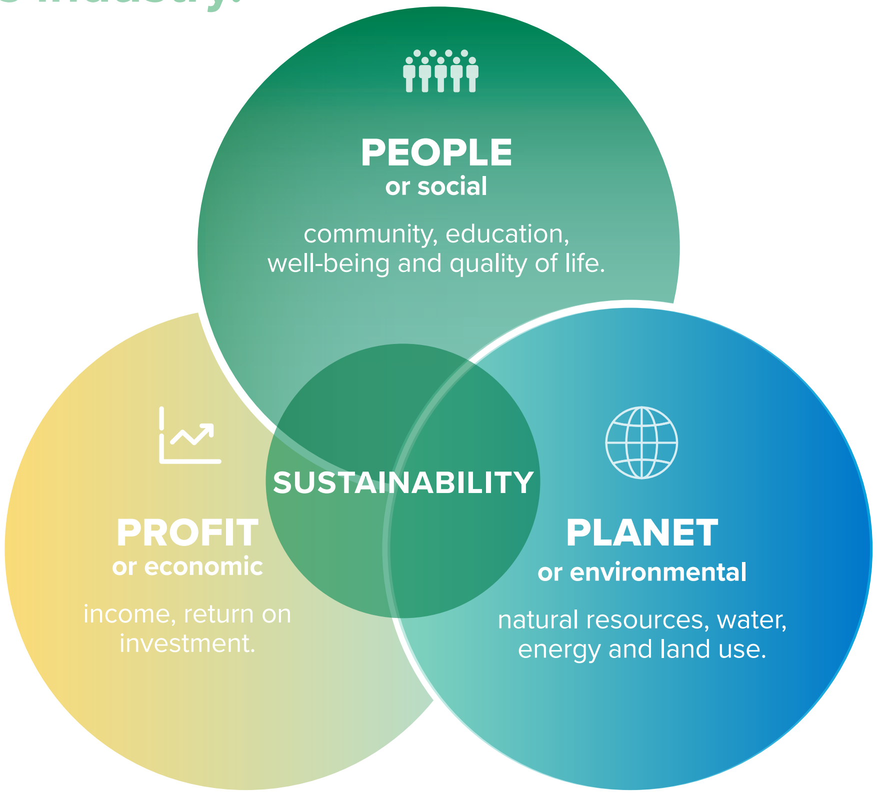


Figure 1: Three aspects of sustainability: people, profit and planet.

SUSTAINABILITY FRAMEWORKS

Australia is a global leader in the development of industry-based frameworks that articulate industry aspirations to meet community and commercial expectations for agricultural production, and enable reporting on progress towards these goals. Evidence is arising that, in lieu of industry frameworks, other international jurisdictions are seeing a proliferation of competing commercial frameworks.

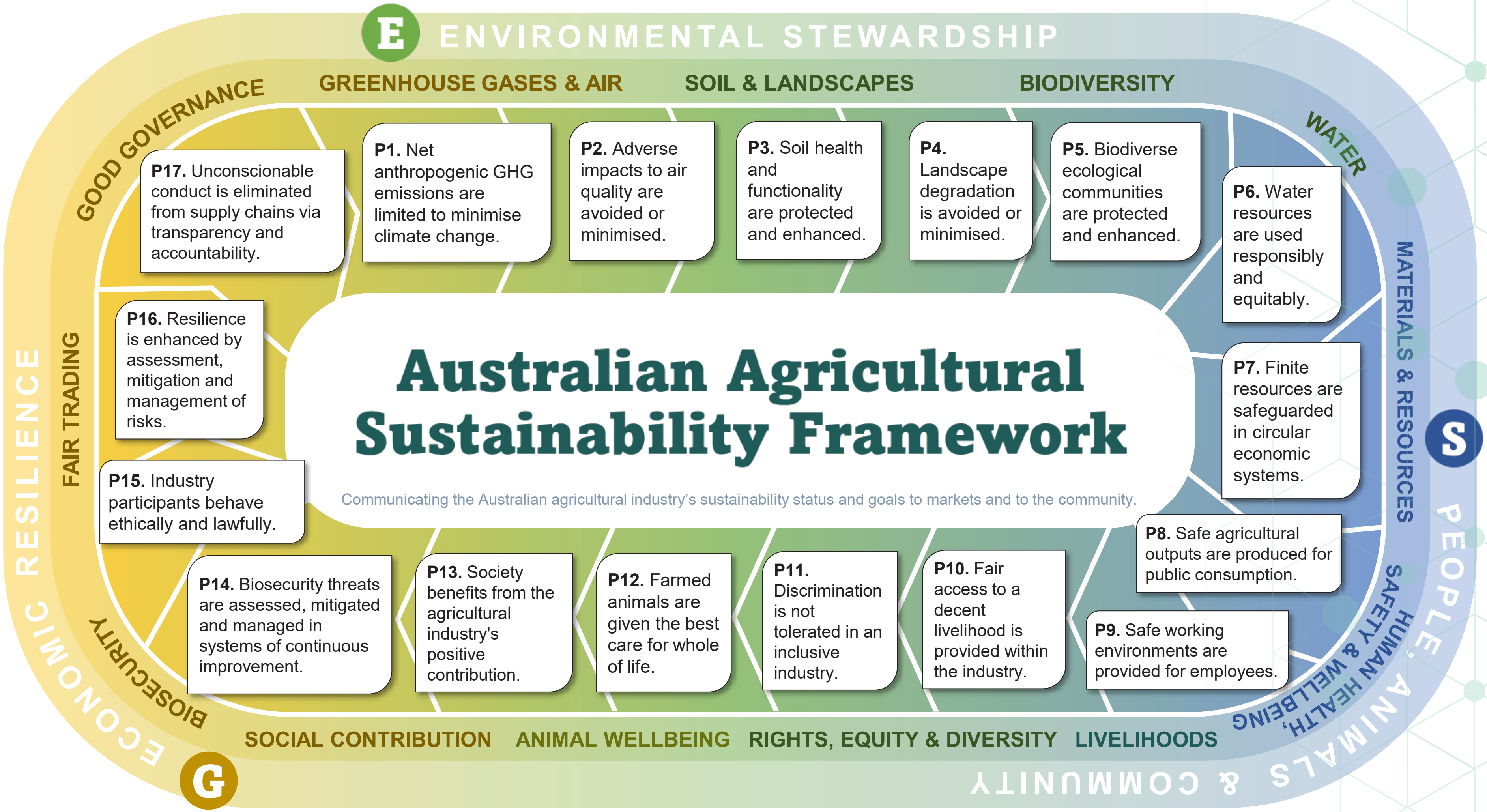
Australian grain has an enviable global reputation as 'clean and green' supported by research that focuses on the development and adoption of sustainable crop management. For many decades most Australian grain growers have had sustainability front of mind. Most growers want to pass on the farm to the next generation in better condition than they inherited it, and grain growers have been at the forefront of the adoption of conservation agriculture, soil testing, and precision agriculture approaches to better target cropping inputs.

Since 2020, the NFF has been developing the Australian Agricultural Sustainability Framework (AASF) with financial support from the Australian Government's Agriculture Biodiversity Stewardship Package. It seeks to develop a consistent approach to how Australian agriculture communicates its sustainability ambitions and progress to markets and communities by establishing a series of high-level sustainability principles and criteria that can be implemented within specific commodity or regional sustainability frameworks. The development of the AASF is up to version four (see Figure 2). GRDC is participating in the AASF community of practice established to facilitate information sharing and collaboration to resolve shared challenges like alignment, consistency and data requirements.

'GRDC is participating in the community of practice established to facilitate information sharing and collaboration to resolve shared challenges like alignment, consistency and data requirements.'

Figure 2. Australian Agricultural Sustainability Framework

- 17 principles (P) of sustainability for the Australian agriculture industry, AASF Version 4



The development of Behind Australian Grain, the Australian grains sustainability framework, has been a whole-of-value-chain effort facilitated by GrainGrowers Limited. GRDC has supported the development of the framework on both the steering committee and working groups convened to develop the pillars, priorities and metrics that will constitute the framework. In 2020, participating stakeholders, including GRDC, agreed to support the launch of the framework. The current framework has the three pillars of 'Responsible Stewardship', 'Building Capacity and Wellbeing' and 'Consumer Confidence', with each pillar supported by specific priorities and goals (see Figure 3).

GRDC's positioning and ongoing investment in sustainability will align with both the Behind Australian Grains and the AASF which support industry's efforts to develop and demonstrate the sustainability of Australian grains and the broader agricultural industries. This alignment includes investments that enhance farming practices to enable industry to meet its sustainability aspirations, develop metrics that can be used by the frameworks, and, in some circumstances, generate the data necessary to demonstrate the progress towards these goals.

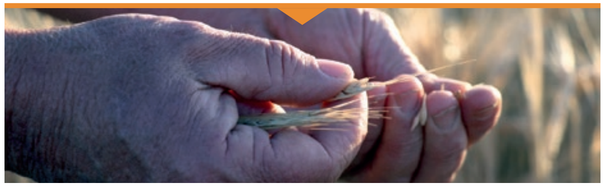
As many of these challenges will be shared across Australia's agricultural commodities, GRDC will seek to support forums like the AASF's Community of Practice, and Agriculture Innovation Australia (AIA) to identify opportunities for cross-commodity co-investment to support the sustainability of Australian grain growers as part of GRDC's purpose of creating enduring profitability.

'GRDC's positioning and ongoing investment in sustainability will align with both the Behind Australian Grains and the AASF which support industry's efforts to develop and demonstrate the sustainability of Australian grains and the broader agricultural industries.'

Figure 3: The three pillars of 'Behind Australian Grain'
- the Australian grains sustainability framework facilitated by Grain Growers Limited

RESPONSIBLE STEWARDSHIP

Responsible stewardship throughout the value chain, caring for our environment and protecting Australia's biosecurity underpin our productivity, profitability and global reputation.



OUR PRIORITIES

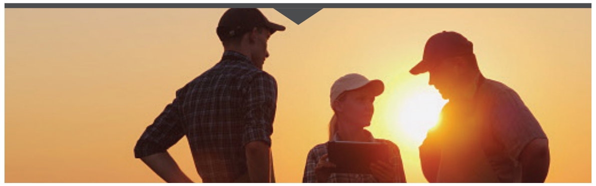
- Caring for and improving our natural capital.
- Thriving in a changing climate
- Responsible use of inputs
- Maintaining and strengthening biosecurity

OUR GOALS

- Proactively improve the health of our soils
- Increase in proactive biodiversity stewardship
- Reduce our industry's net greenhouse gas emissions
- Manage climate-related risks through investment and development of adaption tools to improve water use efficiency in rainfed grain production.
- Demonstrate science-based best practices in pest, weed and disease control while ensuring productivity, safety and environmental outcomes.
- Continue to implement a world-leading whole of industry approach to managing biosecurity risks.

BUILDING CAPACITY & WELLBEING

The safety and wellbeing of our people and the communities in which we operate are crucial to our sustainability. We focus on improving the adaptability and resilience of the people and businesses involved in our value chain.



OUR PRIORITIES

- Supporting the safety and wellbeing of our people
- Growing the capacity of our people and communities to be adaptable and resilient

OUR GOALS

- Zero workplace fatalities throughout the value chain (on farm and post farm gate) and contribute to closing the gap between regional and broader community safety and wellbeing indices
- Increased leadership capacity, diversity and skills development to enhance sustainability, industry capacity, and livelihood.

CONSUMER CONFIDENCE

Our ability to understand and respond to the evolving needs of our consumers is paramount to our sustainability. We focus on world-leading supply chain assurance to deliver safe and healthy products, and also engaging with consumers about how they are produced.

OUR PRIORITIES

- Engaging with our consumers about their evolving needs and expectations
- Continuing to deliver world-leading supply chain assurance systems
- Ensuring consumers have confidence in the safety and environmental benefits of agricultural technologies, innovation and practices

OUR GOALS

- Continue to deliver safe products via robust supply chain assurance mechanisms and strong industry governance systems
- Proactively address our customers' evolving food safety expectations and health needs.
- Increased awareness and trust in how grain products are produced.
- Support innovations which enhance our supply chain's ability to meet tomorrow's demands and safety needs of our consumers and the community.

GRDC'S SUSTAINABILITY INITIATIVE

The sustainability of a business or activity is widely considered to be concerned with its impact on economic returns, the environment (i.e. land, air and water), and local and broader communities (i.e. social or human capital). These impacts are often referred to as the 'triple bottom line', or the three 'Ps' – profit, planet, and people. GRDC's purpose is to create enduring profitability for Australia's grain growers, which recognises that economic returns might not be enduring or sustainable if we ignore the environmental or social impacts of our research and development, and the practices promoted to the industry.

Australian grain growers are known internationally for adopting sustainable farm management practices, and the industry is known internationally and locally for producing 'clean and green' grain products. For example, most growers want to pass on the farm to the next generation in better condition than they inherited it, and grain growers have been at the forefront of the adoption of zero-tillage, soil testing, and precision agriculture approaches to better target cropping inputs.

The GRDC Sustainability Initiative contains six science- based workstreams for which analysis was undertaken to report previous RD&E instigated by GRDC and others, the knowledge gaps remaining, and where GRDC might invest in the future. An important initial step in Sustainability Initiative analyses was a review of the GRDC investment portfolio and identification of GRDC investments that delivered environmental outcomes. A summary of this portfolio analysis is provided in Annex A.

The program logic for the GRDC Sustainability Initiative is presented in Figure 4. These outcomes will be further refined and aligned to the GRDC RD&E Plan 2023-28. Expected immediate, intermediate and long-term outcomes are articulated as a consequence of foundational activities commissioned through the SI workstreams. A brief description of the workstream follows, with further details provided in Annex B.

Figure 4: GRDC Sustainability Initiative program logic
with foundational activities, immediate, intermediate and long-term outcomes

Purpose / outcome

AUSTRALIAN GRAIN GROWERS HAVE ENDURING PROFITABILITY

Longer term outcomes

AUSTRALIAN GRAIN GROWERS...

- have productive land and natural capital assets.
- retain access to markets and market premiums.
- increase access to environment related income streams.
- meet environmental regulations without loss of profitability.
- have adequate access to labour and services in their local community.

Intermediate outcomes

AUSTRALIAN GRAIN GROWERS

- Understand and demonstrate whole of farm GHG emissions and grow crops of low GHG emissions intensity
- Understand long term cycling of carbon in their system, including market implications
- Know how to manage soil health, including soil carbon and other soil constraints
- Are able to purchase farm inputs with a low to zero emissions footprint
- Demonstrate to customers (and regulators) the state of on-farm environmental assets and impacts of farm operations
- Can make farming system practices and business plans that enhance farm natural capital
- Can manage profitable trade-offs between productivity and environmental outcomes
- Maintain and grow community trust.

INVESTORS

- Understand whole of farm impact on environmental and social sustainability to inform financial services.

GOVERNMENTS

- Can develop environmental and social sustainability metrics (e.g. National Greenhouse Gas Inventories) that reflect locally validated science and current practice.

Immediate outcomes

RD&E PORTFOLIO

Directed at delivering environmental and social sustainability outputs and adoption of outputs by grain growers, value chain or government.

Foundational activities – outputs of SI

INVESTMENT STRATEGY THAT INCLUDES

- Identification of environmental and social sustainability indicators to report on GRDC's RD&E portfolio
- Identification of industry needs to deliver intermediate outcomes
- Gap analysis of needs against existing RD&E outputs and extension requirements
- Identification of environmental and social sustainability indicators to inform new research outcomes
- Identification of indicators relevant to the workstream in the AASF.

WORKSTREAM SUMMARIES

WS1

Greenhouse gas accounting and regulation

This workstream considers how GRDC can respond to the implications of the Australian Grains Baseline and Mitigation Assessment report (Sevenster et al., 2022) regarding GHG accounting and regulation, including updating the grain industry assessments for current and future emissions, and research that improves data collection, assumptions, model predictions and the accuracy of these accounts. Australia has been a leader in GHG accounting and life-cycle assessment, but further research is required that creates evidence for improvements and verification of existing emissions factors for Australian grain production. In particular, revised emissions factors for nitrogen losses from fertiliser and organic matter breakdown which were recently accepted by national regulators need to be adopted in the GHG accounting (baselines and subsequent estimates). Likewise, clarification is needed on the accounting methods used by the National Greenhouse Gas Inventory and the development of reliable methodologies for the Emissions Reduction Fund. The development of appropriate farm business tools, carbon calculators and skills will assist grain producers to analyse options for participating in premium markets based on low emissions intensity grain production.

WS2

Greenhouse gas mitigation

This workstream is based on formulating a response to recommendations from the Australian Grains Baseline and Mitigation Assessment report regarding reducing the emissions intensity of the Australian grains industry. There may be opportunities to reduce pre-farm gate emissions associated with crop inputs through research, development and commercialisation investments to reduce upstream emissions, such as existing co-investment in Hydrogen to Ammonia research projects. The potential impacts of legumes, control traffic farming and precision agriculture were identified in the baseline report as emissions mitigation strategies and these need verification on-farm. Development and extension that delivers improved integration of farming practices which are suited to lowering emissions in specific farming environments are needed, especially on mixed farms that produce multiple commodities. Further research is needed that improves nitrogen uptake and utilisation by plants, such as genetic improvements, controlled-release fertilisers that better match the timing of nitrogen release to plant need, decision support for nitrogen applications, and digitally-enabled precision fertiliser management.

WS3

Carbon sequestration

The objective of this workstream is to advise how GRDC's RD&E might enhance carbon (C) sequestration on grain farms, both in soils and vegetation. A priority investment area is exploring the prospect of new ways to build stable soil C (humus). Research is needed to increase soil C in the grain production systems, including interactions with the cycling of nitrogen and other nutrients, the role of organic soil amendments and soil biology, and dual purpose or pasture cropping to retain more C from biomass produced in the paddock and in revegetation areas. "Mosaic farming" may offer increased biodiversity and improved farm sustainability by not cropping poor performing parts of the farm and redeploying that land as vegetation-based C sinks, or long-term pasture.

WS4

Soil health

Aspects of soil health (other than soil C in WS 3) are considered in this workstream. GRDC has significantly invested in overcoming soil constraints and improving soil chemical and physical properties to boost water-use efficiency and crop production over the past two to three decades. Soil testing is widely adopted by growers mainly to inform fertiliser decisions, but there is a need for a Soil Health Index at local, regional and national levels – i.e. an aggregated measure of important soil properties to monitor the impact of agriculture and better identify management practices that improve our soils. In particular, the role of soil biology in soil health needs to be better understood, including research into investigating the impact of soil biological activity on physical and chemical fertility, and the role of soil biota in the accumulation and breakdown of soil C.

WS5

Environmental services - land, water and biodiversity value

GRDC can help the grain industry in the identification of the market drivers for the creation of broader environmental and other social benefits on-farm and beyond. This rapidly developing area includes C markets, emerging markets for eco-systems services/biodiversity, premiums created by sustainable procurement frameworks, and production of co-benefits in terms of increased yield, reduced input costs, and improved risk management. GRDC can play a role in identifying the underlying market drivers and the value of sustainability outcomes in capital markets, especially where financial incentives might be offered. There is a handful of growers already benefitting from these incentives, and case studies can help others develop a clear compelling economic rationale for change, including understanding the potential value pools attached to the market drivers. In collaboration with other primary industries, delivering land, water and biodiversity benefits from farm operations is a priority, either as win-win or trade-off opportunities for production and environmental outcomes.

WS6

Social and human capital

The social and human capital of the grains industry takes into consideration not just the people involved in the grains supply chain, but also the positive contribution the grains industry makes to wider Australian society. The grains industry not only provides clean and green products for national and international markets, it creates employment and underpins rural communities and economies, which contribute to community trust, social licence, and science-based regulation of the industry. Social indicators can provide a measure of change in the social and human capital of the grains industry, its communities and broader society. In collaboration with grains representative bodies and other research and development corporations, GRDC needs to support better monitoring of social trends and impacts of RD&E in rural communities. Training opportunities for students, researchers, growers and rural leaders could also be enhanced. GRDC also wants to strengthen its commitment to understanding and responding to community concerns to ensure its social license to operate remains.

ANNEX A

GRDC

INVESTMENTS WITH ENVIRONMENTAL IMPLICATIONS

Background

The purpose of GRDC RD&E investments is primarily focused on the productivity and profitability of growers. However, the adoption of new on-farm practices and technologies that deliver increased grain profitability can also influence one or more environmental resources. Grain growers use environmental resources (e.g., soil, water, nutrients, energy), and manage biotic and abiotic challenges to crop production by employing practices that can have various environmental effects, as well as delivering high and sustainable grain yields.

In early 2022, a situation analysis[1] was undertaken to help identify and quantify GRDC investments with outcomes or outputs, that when adopted by growers could have favourable environmental effects (Umbers 2022). This annex summarises the approach and results of this analysis.

Approach

Investment outcomes and outputs were evaluated as to whether these could have effects on various environmental areas. The environmental categories of interest were determined by considering:

- scientific evidence of linkages between some on-farm practices and technologies and environmental resources,
- the various environmental assets used by growers and how these may be affected by on-farm activities,
- GRDC's Environmental Plan of 2008 ('A Responsible Lead'),
- alignment with the United National Sustainable Development Goals, where applicable, and
- other environmentally relevant reports and projects by various industry bodies (e.g., NFF, GGL).

Investments were tagged as being relevant to one or more environmental area.

Categories of Environmental Effects

Developing a list of environmental areas of relevance and how GRDC investments can have environmental effects led to considering the resources used or impacted in grain production. Some of these were relatively easy to identify, e.g., soil, water, nutrients. However, describing what could result from the adoption on-farm of the outcome of a GRDC project investment on these resources was more complex.

The preservation, enhancement or avoidance of detrimental impacts to these environmental resources is one way to classify benefits – e.g., reducing soil erosion, or water contamination, or pesticide residues in the environment. There is also the issue of adaptation to, or remediation of, environmental challenges – e.g., adapting to a changing climate, or ameliorating soil constraints to enhance access to soil water and nutrients.

When formulating the various environmental categories and related effects, input and guidance was also taken from a few sources. These included the United Nations Sustainable Development Goals (SDG), and their classification of environmental impacts. The main ones considered were the SDGs concerning soil, water, nutrient management, sustainable use of ecosystems and climate change. These frequently refer to adaptation to, or mitigation of an environmental challenge or threat, as much as taking steps to directly address or have impact on these. As such, investments with outcomes (i.e., new technologies or practices) that are about adaptation or mitigation of environmental challenges were evaluated, along with those having more direct environmental impacts.

Other sources consulted were the 'Environmental Plan for the Grains Industry' a review of some of the scientific literature about on-farm practices and environmental impacts developed by GRDC in 2008, and also the work included in the draft targets in the document provided by 'Behind Australian Grains' (https://www.behindaustraliangrain.com.au/insights-report/) produced by GrainGrowers Ltd.

Direct and indirect outcomes were referenced for various environmental areas. Direct environmental effects were identifiable in the practice or technology adopted having a direct, and often measurable, linkage to environmental assets or resources. In the context of grain production, these resources could include soil, water, air and nutrients associated with issues such as soil erosion, salinity, nutrient losses into waterways, greenhouse gas emissions, changes in soil carbon, pesticide residues, or non-target impacts from pesticide use.

Many GRDC investments also have outcomes that, when adopted, can have indirect consequences for environmental resources, which may be related or linked to resource management, or are about adaptation to environmental circumstances or challenges. Examples could include:

- improving disease resistance in crop varieties leading to reduced fungicide use.
- improving soil moisture relations and removing constraints to plant access to soil water contributing to reduced drainage below the root zone, salinity risk, runoff or leaching.
- improved management of nutrients, for example nitrogen (including improved nitrogen fixation by legumes) and phosphorus, leading to reduced fertiliser use and decreased embedded energy required by fertiliser manufacture.
- the avoidance of spray drift and reduced consequent risks for non-target organisms and contamination of other resources.

There are often linkages or relationships between the various environmentally relevant effects, for example, where improved soil management has secondary effects on water and nutrient dynamics, and soil organic matter levels.

It is relatively common to find more than one environmental effect or consequence when evaluating investment outputs and outcomes. Table 1 below lists direct environmental effects as proposed in this analysis.

Table 1. Direct environmental effects as considered for investments

ENVIRONMENTAL CATEGORY	Beneficial direct effect from adoption of improved practices and technologies
Climate change, carbon, energy	Reduced GHG emissions (e.g., CO_2, CH4, N_2O) Enhanced soil organic matter / carbon
Soil	Improved soil health, water and nutrient provision Reduced soil erosion risk (wind, water) Reduced risk of dryland salinity
Water	Reduced waterlogging, runoff, deep drainage, leaching, sediment movement, eutrophication
Nutrients	Reduced nutrient losses (nitrogen, phosphorus, etc.)
Pesticide use, residues, non-target organisms	Reduced pesticide use Reduced impacts on non-target organisms Reduced pesticide residues in products and soil

Table 2 lists what are considered to be technologies, or practices that result from GRDC investments that are linked to or have indirect consequences on environmental resources or challenges.

Table 2. Environmentally linked, indirect investment outputs, technologies and practices as included in the analysis.

ENVIRONMENTAL CATEGORY	Technologies or practices with indirect environmental consequences or adaptation to environmental circumstances or challenges
Climate change, carbon sequestration, energy	Adaptation to changing climate (e.g., heat, drought, frost) Reduced energy use - actual on-farm activities and embedded (e.g. fertilisers).
Soil	Improved soil physical health - structure, drainage, aeration, sodicity, compaction Improved soil biological health, organic matter and nutrient provision Improved soil water capture, storage and availability Management of soil pH Reduced soil and subsoil constraints on plant growth.
Water	Reduced runoff, waterlogging, leaching, surface water contamination. Improved plant water use efficiency.
Nutrients	Improved nutrient/fertiliser use efficiency Improved nitrogen fixation by legumes/pulses Measuring and matching fertiliser use with crop use / need.
Managing pests, weeds and diseases	Improved biological, cultural control/management Improved crop resistance to disease, virus, pests, nematodes Use of new, effective, or safer pesticides Use of integrated pest/disease/weed management.
Biosecurity & plant health	Surveillance and incursion management Plant adaptation to environmental challenges Improved crop competitiveness, vigour, architecture.

Direct environmental outcomes

As of May 2022, the GRDC investment portfolio included approximately 560 investments, totalling over $803 million over their life. Within this, 162 investments, totalling around $200 million, were identified that can lead to growers adopting improved practices or technologies that can have a direct environmental effect. These have been allocated into environmental categories as in Table 3.

Investments that lead to reduced pesticide usage, reduced losses of nutrients from the system, and improved soil health and water/nutrient provision are dominant. These features are also frequently important for grain productivity gains and enduring grower profit.

Table 3. GRDC investments where direct environmental effects were identified.

DIRECT ENVIRONMENTAL EFFECT	No. of Projects	$M total investment
Reduced GHG emissions (CO_2, N_2O)	3	6.23
Enhanced soil organic matter / carbon	2	4.17
Improved soil health, water and nutrient provision.	24	31.69
Reduced soil erosion risk (water, wind)	5	1.13
Reduced dryland salinity risk	2	2.3
Reduced runoff, drainage, leaching, erosion	8	8.43
Reduced nutrient losses (N&P)	19	23.84
Reduced pesticide use	77	109.1
Reduced impacts on non-target organisms	15	9.3
Reduced pesticide residues	7	5.74

Indirect environmental outcomes

Not all GRDC investments have direct environmental effect on-farm. However, many of the technologies and changed on-farm practices that result from GRDC investments can have both productivity and indirect environmental benefits.

These indirect environmentally linked consequences from the adoption of GRDC investment outcomes contribute to the realisation of overall environmental management. Many investments have multiple indirect environmental outcomes. The most common of these, numbers of related investments and funding involved are shown in Table 4.

Among the 162 investments where direct effects can result, are several that also have indirect environmental benefits, and so, are able to be counted as potentially leading to both direct and indirect environmental effects and outcomes. Similarly, among those with only indirect outcomes, many have more than one, and so, can be allocated to more than one category. Thus, the portfolio does not split into discreet components that add up to the overall total.

Table 4. GRDC investments with indirect environmentally related consequences

INDIRECT ENVIRONMENTALLY LINKED EFFECT	No. of Projects	$M total investment
Adapting to a changing climate (drought, heat)	18	23.7
Reduced energy use – actual and embedded (e.g. fuel, fertiliser)	15	22.3
Improved plant water use efficiency	124	296.7
Use of integrated weed/pest/disease management	112	208.2
Improved resistance to disease, viruses, pests, nematodes	29	57.6
Improved fertiliser use efficiency – macronutrients (N&P)	15	26.4
Improved nitrogen fixation by pulses and legumes	46	97.7
Use of safer, effective pesticides	23	93.2
Crop adaptation to environmental challenges	21	29.8
Improved soil health, organic matter, biology	11	22.9
Reduced soil/subsoil constraints on plant growth	24	41.8

Adoption of outcomes, technologies, and practices

As noted, the environmental effects identified as flowing from R&D investments are realised by the adoption of the outcomes from these investments, either as changed on-farm practices or technology adoption. Table 5 shows some examples of on-farm practices or technologies resulting from R&D outcomes collected into environmentally linked areas of interest. These practices may be useful in assessing and monitoring farm sustainability, rather than measuring the environmental benefits directly.

Table 5. Environmental benefits and related practices or technologies for each environmental category.

SOIL HEALTH	Relevant on-farm practices
Improved soil physical health -structure, drainage, aeration, sodicity, compaction	Addressing soil structure issues, subsoil constraints, use of gypsum, reduced tillage, use of controlled traffic techniques.
Improved soil biology / organic matter and nutrient provision	Reduced cultivation, crop residue retention, soil ameliorants, companion planting, green/brown manuring, crop rotation.
Improved soil water storage and availability	Reduced/no-tillage, removal of soil constraints, modifying soil pH, crop residue retention, maintaining ground cover.
Management of soil pH (acidity), sodicity	Use of lime, dolomite, gypsum.
Reduced risk of dryland salinity	Improved structure, addressing sub-soil constraints, improved water use efficiency.
Reduced soil constraints on plant growth	Practices that address soil constraints, deep ripping, spading, claying.
WATER MANAGEMENT	
Improved water use efficiency	Summer weed control, improved soil structure, organic matter, rooting depth, crop protection, breeding, disease resistance.
Reduced runoff, waterlogging, deep drainage, water contamination (fertiliser, pesticide)	Retaining crop residues, no-tillage, water repellence & sodicity, Reduced runoff, pesticide drift, nitrogen & phosphorus management, improved WUE.

NUTRIENT MANAGEMENT

Improved fertiliser use efficiency – macronutrients and micronutrients	Soil/tissue testing, fertiliser decision tools, increased WUE, nutrient budgeting, variable rate technology.
Improved nitrogen fixation (pulses legumes)	Breeding, disease resistance, management of soilborne pathogens, removal of soil constraints, improved rhizobia inoculants.
Targeting and matching fertiliser use with crop need	Soil, sap and tissue testing, nutrient budgeting, biomass measurement and remote sensing.

ENERGY / GHG / CHANGING CLIMATE

Adaptation to changing climate – drought, heat	Improved water use efficiency, photosynthesis, breeding, soil management genetics for water efficiency and heat tolerance.
Reduced energy use – fertiliser, on-farm activities, pesticides	Improved fertiliser use efficiency, nitrogen fixation, reduced operations on-farm, controlled traffic farming, reduced draft of soil machinery, practices and breeding that reduce pesticide use.

PEST, DISEASE & WEED MANAGEMENT

Improved biological, cultural control of pests/weeds/diseases	Use of biological controls for pests, weeds, use of tillage, rotations, break crops.
Improved resistance to disease, viruses, pests	Breeding and genetics for disease, insect, virus, nematode resistance / tolerance.
Use of Integrated pest/disease/weed management	Many forms of integrated management of pests, weeds, diseases. Integrated programs of genetic, cultural, chemical and biological management.
Use of new, effective, safer pesticides	Investments in pesticide discovery, minor use permits, investments with chemical companies.

PLANT HEALTH

Adaptation to environmental challenges	Breeding and gene discovery for adaptation to drought, heat, nutrient efficiency, hostile soils, acidity, etc.
Surveillance, pest, weed, disease biology	Investments related to biosecurity, surveillance, understanding disease and plant interactions.
Improved crop competitiveness. vigour, plant architecture	Using cultivars with increased plant competitiveness against weeds, vigour, rooting depth, WUE.

ANNEX B

SUSTAINABILITY INITIATIVE

WORK-STREAMS

WORKSTREAM

WS1 GREENHOUSE GAS ACCOUNTING AND REGULATION

Longer Term Outcome

- Australian grain growers retain access to markets and market premiums.
- Australian grain growers meet environmental regulation without loss of profitability.
- The community trusts Australian grain growers and allows them to innovate.

Intermediate Outcome

- Australian grain growers can understand and demonstrate whole of farm GHG emissions and grow crops of low GHG emissions intensity.
- Australian grain growers can demonstrate to customers and regulators the state of on-farm environmental assets and impacts of farm operations.
- Australian grain growers can maintain and grow community trust.
- Investors can understand whole of farm impact on environmental and social sustainability to inform financial services.
- Government can develop environmental and social sustainability metrics that reflect locally validated science and current practice.

Current knowledge

The imperative to limit the impact of climate change in accordance with the United Nations Paris Agreement (COP21) has resulted in a drive for increased transparency on greenhouse gas (GHG) emissions of industries and businesses, and government plans to reduce emissions across every sector of the global economy, including the Australian grains industry.

The Australian government and grains industry needs to understand emissions arising from Australian grain production to report against its national goal of reducing GHG emissions to 43 percent below 2005 targets by 2030, and towards net zero emissions by 2050. The government is also involved in developing policy that guides Australian industry to contribute to these targets. This information is also critical to government as it negotiates trade and market access with trading partners and addresses Australian community expectations.

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Similarly, capital markets are requiring listed companies across the value chain to disclose the GHG emissions profile of their operations and progress against reduction targets. Banks and other financial institutions are seeking to understand the emissions of businesses holding debt. This is driving a growing preference in domestic and international markets to source low emission intensity grain. The use of GHG performance is also a competitive advantage for farming investment funds in attracting capital investment and sustainability-linked loans by banks. Similarly, farm businesses are seeking to understand opportunities to sequester carbon (C), either to offset their own emissions or to sell either through a carbon project purchased by the Australian Government's Emissions Reduction Fund or through a voluntary scheme.

To date, GRDC has invested in the development of a lifecycle analysis (which quantifies all emissions resulting from grain production, including emissions generated in the manufacture of farm inputs) for each of Australia's grain producing agro-ecological zones, and has developed a 2005 baseline for emissions and emissions intensity of Australian grain production (Sevenster et al., 2022). Through Agriculture Innovation Australia (AIA), GRDC is investing in the development of a common GHG accounting methodology to be used by all commodity sectors of Australian agriculture.

Investments will also target the identification of trade and market access, and end use market imperatives for the Australian grains industry to demonstrate its low GHG emissions intensity credentials.

Understanding market drivers for GHG accounting

Despite growing trends towards increased reporting of GHG emissions at the sector level and by individual farming businesses, current trade and market access restrictions are largely limited to the export of canola for the EU biodiesel market. Likewise, market signals for verified low GHG emissions grain are nascent, with some grain marketers offering a premium for International Sustainability and Carbon Certification barley. The retail banking sector has only recently commenced offering sustainability-linked loan instruments. The highest level of interest in verifying low GHG emissions produce has been by corporate agricultural investment funds accessing capital investment through inclusion of low emissions mandates within their objectives.

AgriFutures Australia is due to publish a report on environmental and social lending in rural industries which outlines the current state and trend towards banks seeking more information on grain growers GHG emissions. AgriFutures has also recently issued a request for quotes to understand potential trade impacts around the EU's Carbon Border Adjustment Mechanism on some Australian agricultural commodities.

GRDC is an investor in a coalition of industries seeking to understand the impact of the EU's Product Environmental Footprint (PEF) on Australian agriculture and has a current project with AEGIC that is examining commercial forces on sustainability attributes (Convenience, Healthy, Ethical, Sustainability and Safety) of Australian grain.

Understanding GHG inventories and emissions intensity

Research to understand emissions of Australian grain production has been undertaken at an industry scale and at regional levels. The Grains Baseline and Mitigation Assessment developed a 2005 GHG emissions baseline for Australian grain production that confirmed Australia as a world leader in regard to the GHG emissions intensity of its grain production. The report reinforced the outcomes of previous lifecycle assessments undertaken for every grain producing agro-ecological zone in Australia. It also underpinned CSIRO's jurisdiction report on Australian canola, which has supported the export of on average $1.5 billion of Australian canola into the European Union's biodiesel market annually.

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On-farm GHG calculators

Several on-farm GHG calculators have been made available to Australian farmers, including the Cool Farm Tool and the University of Melbourne's Primary Industry Climate Challenges Centre's Greenhouse Accounting Frameworks for Australian Primary Industries. CSIRO, the Macquarie Bank's agricultural fund Viridis and the Clean Energy Finance Corporation have developed FarmPrint, which is used by Viridis and is presently embedded in a complex spreadsheet.

The Council of Research and Development Corporations Climate Initiative found in 2020 that Australian primary producers viewed GHG accounting as complex and time consuming. Some work is underway to assist farmers become more competent in GHG accounting with extension groups in south-eastern Australia (e.g. Cool Soils Initiative) and in Western Australia (Carbon Neutral Grain Pilot Project). There is also a similar extension program offered by Meat and Livestock Australia and training courses are being delivered by some banks to their farming clients. In Western Australia and other states, a number of farm advisers have integrated GHG accounting into their service offering, while some corporate agricultural clients are utilising environmental consultants.

Present approaches to on-farm GHG calculators in Australia are based on Tier 2 lifecycle assessment approaches. CSIRO's use of the APSIM crop model to undertake modelling of GHG emissions in the Australian grains industry demonstrated the ability to develop Tier 3 dynamic GHG calculators that produce GHG calculations that are specific to the environment and practices of farm enterprises.

Locally valid emissions factors

The CSIRO/GRDC Grains Baseline and Mitigation Assessment report demonstrated the need for GHG accounting to be locally validated. This report compared GHG emissions relating to Australian grain production modelled using country-specific tier 2 emissions factors incorporated into the National Greenhouse Gas Inventory (NGGI) against international databases that utilise the IPCC's tier 1 default factors. Additionally, the report identified the high proportion of nitrous oxide (N2O) emissions attributed to crop residues in NGGI and recommended the accuracy of the emissions factor be further assessed. However, recent changes in emissions factors for nitrogen losses from fertiliser and organic matter breakdown need to be factored into the GHG baselines.

Informing policy

The Grains Baseline and Mitigation Assessment report suggested there was no simple pathway to lowering absolute emissions associated with Australian grain production without creating vegetative offsets within the farming business or buying offsets created elsewhere. Given it is likely that emissions are an inevitable consequence of grain production, the report recommended pathways to lowering the GHG emissions intensity of Australian grain (i.e the emissions per tonne of grain produced).

In addition, the research referred to consequential lifecycle assessment (LCA) research which identified that any reduction in low GHG emissions intensity grain from Australia could result in an increase of grain production in other regions of the world with higher emissions intensity. This in turn will increase the emissions relating to global grain production. This is important with the issuing of an agriculture sector roadmap to 1.5oC focusing on reducing emissions from land use change issued at the 2022 Sharm el-Sheikh Climate Change Conference by the world's largest agri-commodity traders and processors.

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Relevant metrics

- Development of a regular National Grains Industry GHG Inventory that includes:
  - Net GHG emissions calculated across the National Greenhouse Gas Inventory reporting for agriculture and land use, including land use change and forestry.
    - Seasonally weighted net GHG emissions reporting for agriculture and land use, land use change and forestry.
    - GHG emissions intensity.
- 2005 baseline (as per CSIRO Australian Grain Baseline and Mitigation Assessment).
- Data on Australian grain growers undertaking GHG accounting – GRDC Farm Practices Survey and/or data from AIA's 'Know and Show' project and/or other companies providing calculator services.
- Australian carbon credit units (or equivalent) generated for either in-setting or sale on the market.
- Number of emission reductions fund methodologies appropriate for use in a profitable grain growing enterprise.
- Reductions in inventory emissions resulting from evidence-based changes to emissions factors.

Example GRDC investments

- Life cycle assessment for farming systems in NSW (GRDC Project code DAN00160)
- Identifying national opportunities for grains emissions mitigation and other environmental using LCA and AusAgLCI (DAN00186)
- Grains sector GHG baseline and mitigation (CSP2006-011RTX)
- Upgrading APSIM nitrogen cycling and loss routines with data from the National Australian Nitrous Oxide Research Program (NANORP) (QUT2102-001RTX)
- Communication and outreach of the insights from the grains sector GHG baseline and mitigation project (CSP2207-002RTX)
- A Common Approach to Sector-Level GHG Accounting for Australian Agriculture (AGI2108-001OPX)
- Australian Participation in the European Union Product Environmental Footprint Technical Advisory Board (AWI1912-001OPX)
- Pathways to deliver "Clean, Healthy, Ethical, Sustainable and Safe" grain-food (AEG2205-003RTX)
- Predicting nitrogen cycling and losses in Australian cropping systems - augmenting measurements to enhance modelling (UOQ2204-010RTX)

Recommendations

1. Understand GHG inventories and emissions intensity.

These inventories will create benefit for grain growers through reducing the pressure on farm-scale GHG reporting. Maintenance of industry GHG metrics will provide government and value chain operators with credible and independent averages on which to base trade and market access negotiations. Examples of how this industry-scale reporting has assisted grain growers can be seen in the access for Australian canola into the EU biodiesel market based on average production emissions at a state level and the many supply chain participants who have utilised the national grains LCA database as part of their sustainability reporting to the market.

GRDC investment can support:

- Development of a national grains GHG inventory that is published at least every three years. GRDC and partners should engage with the inventory team at the Department of Climate

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Change Energy, Environment and Water, and the Australian Life Cycle Assessment Society to identify data requirements to efficiently develop the grains inventory. Authoritative data that informs government, the community, and markets of the GHG profile of Australian grain production through the regular development of a national grains GHG inventory. It is unlikely that there is value in developing such an inventory annually. With the EU PEF looking to refresh compliant data sets every three years, new inventory data should be developed to inform this process.

- Additional RD&E to investigate streamlining inventory development. In particular, timely data on the following areas would increase the timeliness of inventory development:
  - fertiliser use (type, when applied, what crop).
  - crop management practices
  - decarbonisation of crop inputs.
- On-farm GHG calculators
  - The Council of Research and Development Corporations Climate Initiative identified that the majority of Australian primary producers found GHG accounting complex and time consuming, particularly where the farm business runs multiple commodities or operates across different landscapes. RD&E is required to develop and deploy farm scale GHG calculators that are easy-to-use and wherever possible utilise farm data stored in existing repositories, such as farm management software or benchmarking data, via the cloud. GRDC is presently engaging with AIA's Know and Show project to develop a whole of farm GHG calculator engine that is easy-to-use.

2. Know & Show - a whole farm GHG calculator.

The Know and Show effort will cover multiple commodities that are operated within a single farm enterprise and undertake cloud-based geospatial emissions calculations using, wherever possible, permissioned information streams from farm management software from participating farm businesses. The calculator will have an open architecture that allows new technologies to be integrated into its operation as required by the market. It will be updated regularly and will be delivered as a pre-competitive good through farmer facing management software packages. Ideally, the majority of on-farm calculation services will use the same Know & Show 'engine' to avoid divergent approaches and assumptions.

GRDC may also evaluate opportunities to develop Tier 3 emissions calculators for Australian grain production systems for consideration of AIA.

3. Progress locally valid emissions factors.

RD&E that validates the emissions factors used in NGGI reflect actual emissions may result in reporting lower emissions through improved alignment of emissions factors to the Australian environment. These factors will then flow through to on-farm calculators and market reporting. The CSIRO Australian Grains Baseline and Mitigation Assessment recommended that emissions factors for N2O in crop residues be further assessed. Similarly, its identification of controlled traffic farming as a farming practice that lowers soil based and operations emissions research could validate changes that could be implemented by the team at the Department of Climate Change Energy, Environment and Water responsible for developing NGGI.

GRDC investment can support:

- Experimentation at existing 'Farming Systems' research sites within GRDC projects used to validate emissions from different farming systems. Analysis across the breadth of these projects could be undertaken to identify other opportunities to validate Australian specific emissions factors.

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- Research to update the nitrogen emissions associated with Australian grain production, particularly emissions associated with crop residues.
- Validate the hypothesis on emissions intensity reductions resulting from the implementation of controlled traffic farming, legumes and precision agriculture.

4. Inform policy.

RD&E that informs government and industry over the effects of policy options to support a move to a decarbonised economy, in-line with the Paris Agreement goals, reduces the risk that those policy options will have perverse outcomes, such as reducing production, when other policy options may allow the retention of productivity outcomes.

WORKSTREAM

WS2 MITIGATING GREENHOUSE GAS EMISSIONS

Longer Term Outcome

- Australian grain growers retain access to markets and market premiums.

Intermediate Outcome

- Australia grain growers understand and demonstrate whole of farm GHG emissions and grow crops of low GHG emissions intensity.
- Investors understand whole of farm impact on environmental and social sustainability to inform financial services.
- Governments and regulators develop environmental and social sustainability metrics (national GHG inventories) that reflect locally validated science and current practice.

Current knowledge

Green House gases (GHG) are emitted from agricultural soils because of several natural and human-induced processes. The principal GHGs directly emitted on-farm are nitrous oxide (N_2O) and carbon dioxide (CO_2) produced from nitrogen denitrification, the decomposition of residues, use of tractors and other machinery, and the use of lime. Dryland agricultural soils also emit insignificant amounts of methane (CH_4) when anaerobic. In addition to on-farm emissions, GHGs are also associated with the manufacture and transport of inputs (e.g., fertiliser and pesticides) and with the transport and processing of products post-farm gate (Scope 3).

Evidence of N_2O emissions in the Australian grains industry mainly comes from experiments conducted under the National Agricultural Nitrous Oxide Research Program (NANORP), a national research network of 23 projects that developed and delivered effective and practical strategies for reducing nitrous oxide emissions while maintaining crop and pasture productivity. Other information comes from lifecycle and modelling tools - e.g. APSIM

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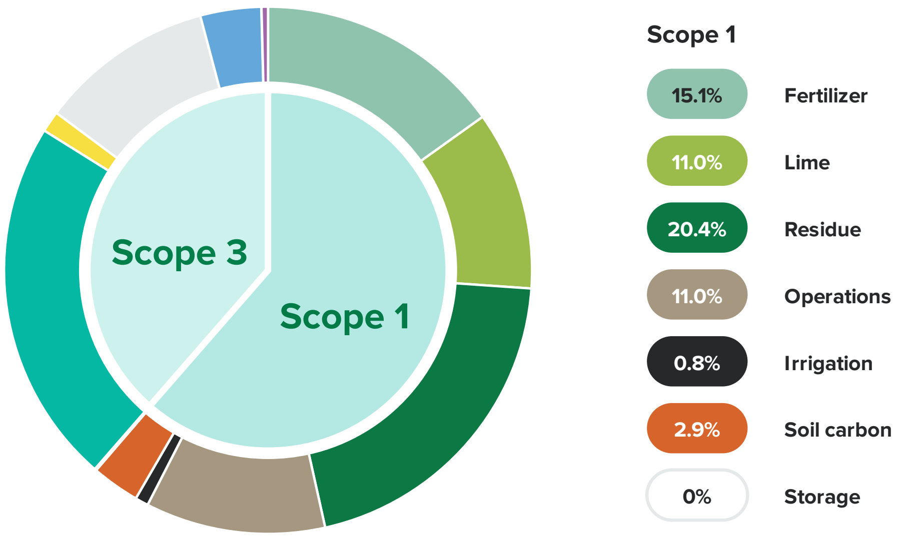
(Holzworth et al., 2014). Modelling has been used extensively to quantify the evaluation of paddock-level management practices to mitigate GHG emissions (Meier et al., 2017; Meier et al., 2020). To this end GRDC has made significant investments in the development and testing of models with the capacity to simulate soil derived GHG emissions, but further improvements are required. NANORP was principally funded by the Australian Government Department of Agriculture, Fisheries and Forestry (now Agriculture and Water Resources) (2012-2016) and was preceded by the Nitrous Oxide Research Program (2009-2012).

GRDC recently engaged CSIRO to establish a 2005 baseline GHG emissions from typical grain systems in various regions (Sevenster et al. 2022). Figure 5 shows a summary of the contribution of different sources to the total emissions from the Australian grains industry.

Figure 5. Predicted breakdown of GHG emissions (for the average Australian grains production - 2005 baseline.

(Source: https://grdc.com.au/about/our-industry/greenhouse-gas-emissions)



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Predicted on-farm emissions (Scope 1) comprise 61 per cent of emissions, dominated by emissions associated with application of fertiliser and lime (26%), denitrification of residue nitrogen (N, ~20%) and fuel use (11%). Overall, the use of fertilisers contributes ~38 per cent of the total GHG baseline emissions, and therefore, is a key factor in mitigating GHG emissions. The report concluded that with uptake of available mitigation practices and technologies, an overall reduction in GHG intensity of ~15% may be feasible, while at the same time increasing production by 30-40% by 2030.

Fertilisers

Through the NANORP program and other more recent work, a small investment was made in evaluating the capability for enhanced efficiency fertilisers (EEF) to reduce N losses and GHG. The work focussed on urease and nitrification inhibitors available at the time, and the initial conclusion indicated that EFFs may significantly reduce N losses and GHG, while raising concerns around expense and reliability of yield benefits.

One solution to moving forward is to reduce the cost of EFFs, potentially through government incentives. More robust data quantifying the impacts of currently available EFFs on N loss reductions and agronomic implications are needed, and new biochemical approaches to EFFs may result in more cost-effective products. The ARC Research Hub for Smart Fertilisers based at the University of Melbourne (https://smartfertiliserhub.org.au) is focused on intensive agriculture, primarily vegetables and other high value crops, where N rates are significantly greater than in grains. While not directly involved, GRDC has a representative on the industry Advisory Committee and is monitoring progress in enhanced efficiency fertilisers.

There may be opportunities to reduce scope 3 emissions (indirect emissions associated with crop inputs) through R&D and commercialisation investments to lower upstream emissions. For example, GRDC is partnering in the 'Hydrogen to Ammonia' project alongside CSIRO, Orica, and the Australian Renewable Energy Agency. Importantly, there is significant international industry investment in this space and GRDC's ongoing investment is likely to be relatively small.

Nutrient and soil management

Supplying needed nutrients for crop production involves attention to the best practice management – i.e. the 4Rs: right rate, right source, right placement and right timing. Improvements in soil and N management, incorporating strategies and budgeting, has been a mainstay of the GRDC investment portfolio over the past 20 years and this is embodied in the 2018-2023 RD&E plan and the proposed plan for 2023-2028. Many investments under KIT 1 (Improve Yield and Yield Stability) provided potential to reduce GHG intensity through improved soil nutrient management.

There has been a shift to topdressing N fertiliser within the season rather than application near sowing which enhances crop uptake, but consequently, more N is applied to the soil surface where it is vulnerable to loss via volatilisation and runoff. A shift to the use of liquid N fertilisers (urea ammonium nitrate) and foliar applications (especially in WA) has implications on N losses that are likely minimal compared to topdressed urea.

Lime

Lime is an important soil amendment applied to address soil acidity. Applying lime increases the profitability of grain production, but at the same time increases total GHG emissions on both a per hectare and per tonne of wheat basis (Barton et al., 2014). It is applied in large quantities compared to other input (1-4 t/ha) and CO_2 emissions occur from its production and transport (Scope 3) and

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dissolution in the soil (Scope 1). In addition, the ratio of N_2O to N_2 emissions increases with decreasing pH due to changes in the total denitrification activity. Accumulating empirical evidence over the past 60 years has shown that the reduction of N_2O to N_2 is impaired by low soil pH, suggesting that liming of acid soils may reduce N_2O emissions. More research is needed to quantify trade-offs to lime use.

Crop rotations

There are a few indications that changing the crop sequence can influence GHG emissions depending on the season and soil type. The inclusion of legumes efficient in symbiotic N fixation, reduce reliance on synthetic N fertiliser as well as providing agronomic benefits for following crops (e.g. reduce disease pressure). Phases of pasture legumes may also result in accumulation of soil C. GRDC has invested in breeding and management to improve the suitability of a number of pulses to Australian farming systems and their inoculants (i.e. symbiotic rhizobia). However, these legumes need to be assessed over the duration of the crop sequence and in terms of profitability (Meier et al., 2017). Legumes have higher respiration rates than non-legumes because of their symbiotic relationships with rhizobia and the N fixation process which is energy intensive.

Waterlogging

Waterlogging is a common problem in high rainfall zones, and also occurs sporadically in wet seasons in other areas. The degree of waterlogging and supply of oxygen for respiration has a profound influence on the rate of denitrification leading to the emissions of N_2O and CH4. Apart from rainfall intensity, the incidence of waterlogging is linked to the soil structure and drainage of different layers. As such, management strategies that modify the soil structure through amelioration and application of amendments, have a role improve the oxygen status of the soil and reducing emissions. Protecting soil structure through the management of compaction also reduces conditions for denitrification. The role of soil biology in denitrification needs to be better understood.

Farm operations

Farm machinery and operations emit GHG primarily from burning fossil fuel and reducing fuel use represents a win-win for growers and the grains industry. Therefore, investments intended or resulting in a reduction in the number of passes by machinery, reduced travel distance, and enhanced trafficability can have positive effects on GHG emissions. For example, the widespread adoption of zero-tillage by grain growers has resulted in a significant reduction in farm fuel use. Advancements in positioning technologies, machine telematics, machine autonomy, farm management information systems and digital agronomy provide new opportunities with operations research in broadacre farming.

Considerable R&D investment is currently being made by private industry in the transition to electric or hydrogen/ammonia tractors or, and although these are still some way off being a cost-effective mainstream option, this area is rapidly developing. Renewable electricity for the farm, home, workshop and irrigation equipment is an option that pays for itself and is increasingly popular. Controlled traffic farming (CTF) has been proposed to reduce fuel costs and mitigate GHG emissions (Sevenster et al., 2022), alongside benefits in reducing soil compaction and N losses mentioned above. Emissions associated with fuel use contribute just under 15% to the GHG baseline and improvements in fuel efficiency of equipment and operations can be translated into emission reduction directly. The adoption of CTF in some areas of Australia is high but could be improved elsewhere.

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Livestock

GRDC consideration of GHG emissions does not deal with losses of GHG that occur directly from livestock, which are principally methane emissions. However, for mixed grain and livestock producers, emissions from feeding livestock and efficiencies in enterprise operations need to be addressed. There may be worthwhile reductions in emissions through better integration of cropping, livestock and other enterprises on-farm, in addition to biodiversity increases.

Example GRDC investments

- Predicting nitrogen cycling and losses in Australian cropping systems - augmenting measurements to enhance modelling (UOQ2204-010RTX)
- Hydrogen to Ammonia Research and Development Project (CSP1904-006OPX)
- Increasing the effectiveness of nitrogen fixation in pulse crops through development of improved rhizobial strains, inoculation and crop management practices (UOA1805-017RTX)
- Nitrogen banking strategies to manage variable and unpredictable nitrogen demand in the MRZ of the Southern Region (BWD2204-002RTX).
- Using soil and plant testing data to better inform nutrient management and optimise fertiliser investments for grain growers in the southern region (ASO1806-001RTX).
- Future Farm Phase 2: Improving grower confidence in targeted N management through automated sensing and decision support (CSP1803-020RMX).
- Fertiliser form and soil interactions when applied in high concentration bands (UOQ1706-006RTX).
- Updating acidification rates, lime recommendations and extension aids to overcome soil acidity constraints to crop production in the southern region (UOA2206-009RTX).
- Northern Farming Systems – Integrating research solutions for improving profitability in summer dominated rainfall systems (DAQ2007-004RMX) A substantive variation (PCR-0007801) to quantify the GHG implications of a range of alternative farming systems across a broad range of environments spanning the eastern grains production regions of NSW and Qld using data from the Northern farming systems field experiment.
- Boosting profit and reducing risk on mixed farms in low and medium rainfall areas with newly discovered legume pastures enabled by innovative management methods – southern region. (DAS1805-003RMX).
- Warm and cool season mixed cover cropping for sustainable farming systems in south-eastern Australia (AEA1812-001OPX).
- Demonstrating the benefits of soil amelioration and controlled traffic practices across a broad range of soil types in Western Australia (WMG1803-002SAX).

Recommendations

GRDC has actively invested in projects which will directly reduce GHG emissions, among other environmental benefits. As indicated in Annex A, many investments improving production efficiency may also indirectly reduce emissions intensity. However, the conclusion of Sevenster et al. (2022) that there "*are no easy wins in term of absolute GHG mitigation in grain cropping*" clearly challenges research to better quantify GHG emission processes, develop improved mitigation practices and technologies, and scale their adoption to benefit the grains industry and global efforts to tackle climate change. A critical agenda of this

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workstream is to continue to seek innovation that can lower GHG emissions while not significantly impacting production or profitability. Areas for increased investment might include:

1. **More robust models.**
   Increasing reliability, certainty and robustness of emissions models based on more comprehensive and diverse datasets is required. Measurement of gaseous emissions is expensive, and error prone at meaningful temporal and spatial scales. Hence, models such as APSIM are increasingly used to quantify emissions of N. With a reliance on models the development and validation of denitrification and other routines needs to be as rigorous as possible, to ensure a robust model for use under diverse conditions.

2. **Management of acid soils.**
   The management of acid soils requires a careful analysis that addresses the trade-offs between N cycling in low pH soils where the transfer of N_2O to N_2 is impaired and plant growth is limited, compared to lime ameliorated soils where CO_2 is emitted from the dissolution of lime. Methods to reduce CO_2 emissions may be possible e.g. incorporation of lime.

3. **Fertiliser formulations.**
   Further RD&E is warranted on enhanced efficiency fertlisers that reduce N losses and GHG emissions, lower their costs, and improve their reliability. Work needs to better quantify the impacts of EFFs on N loss reductions and agronomic implications in grain production systems. New biochemical approaches to EFFs may make them more reliable and cost-effective.

4. **Role of pulses in farming systems.**
   Understanding the impact of different intensification pathways of cropping systems on GHG emission warrants further RD&E, particularly the contribution of pulses and N fixation to farm GHG emissions.

5. **Biological nitrification inhibition.**
   Biological nitrification inhibition refers to direct effects of root exudates from some plants in inhibiting nitrifying microorganisms, so that N in the rhizosphere remains in the ammonium form and is less prone to produce N_2O losses. Nardi et al., (2022) identified key research questions. Until these are answered the value proposition remains unclear and potential for biological nitrification inhibition remains highly speculative for broadacre crops.

6. **Adoption of controlled traffic.**
   Current adoption of CTF in broad-acre farming is ~38% nationally having risen from 3% in 200,3 but plateauing from 36% in 2008 (GRDC Farm Practice Surveys). Overcoming barriers to the adoption of controlled traffic, particularly in southern states where adoption is low, is an area that could be addressed with further extension.

WORKSTREAM

WS3 CARBON SEQUESTRATION ON FARM

Longer Term Outcome

- Australian grain growers have productive land and natural capital assets.
- Australian grain growers retain access to markets and market premiums.
- Australian grain growers have increased access to environment related streams.

Intermediate Outcome

- Australian grain growers understand long-term cycling of carbon in their system, including market implications.
- Australian grain growers know how to manage soil health, including soil carbon deposition and other soil constraints.

Current knowledge

The potential for primary producers to sequester C in soils and on-farm and sell C credits was seen as an opportunity to mitigate GHG emissions globally and provide an income stream for farmers. However, initial opportunities to increase soil C appeared optimistic, especially for grain growers in dry areas, and risks of C decline (e.g. due to drought or fire) were overlooked. In addition, various C trading schemes lock in growers for long time frames (e.g. 50-100 years), and given changes in agricultural practice and policy, this is seen as a risk. The adoption of C Farming in the grains industry has been limited for a number of reasons, but partly because many growers consider that C credits are better off being retained on-farm to offset emissions (i.e. in-setting against their products' GHG footprint, rather than off-setting someone else's emissions). Costs of C measurement and compliance is another consideration.

On-farm carbon (C) sequestration in grain production areas potentially includes soil and long-term vegetation. There has been significant research investment on soil C in grain production systems,

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including interactions with the N cycle, the role of organic soil amendments and impacts of pastures in the farming system – see Annex A. The ability to improve soil C within cropping systems appears limited, and medium to long-term phases of pasture may be required. Stable soil C (humus) requires N and other nutrients, so increased nutrient inputs are necessary. Less investment is apparent in approaches to offset emissions on farms with vegetation, including concepts such as 'Mosaic Farming', whereby poor performing parts of the farm are redeployed as vegetation-based C sinks, or long-term pasture.

The ability to quickly and cost efficiently measure the level of soil organic C will give growers a benchmark to help manage their nutritional program, and this has been the focus of federal government programs. If growers want to build organic matter reserves as a short to medium term opportunity cost rather than depending on annual inorganic fertiliser application for the crop, this will supply the means, the time frame and the cost calculations for doing this. This will allow growers to understand the C cycle limitations and opportunities to support rational market demand and license to operate.

Investment in this space also needs to outline any risk associated with selling any soil organic C sequestered. In terms of on farm vegetation sequestration, only certain farms will have that opportunity. The same risks in regard to any sequestration project (mentioned above) still apply.

Soil C

While C sequestration in soils can be used to reduce net GHG emissions from farms, the ability of growers to build soil C is limited, and the long-term benefits may not be significant. This is because any increase in organic C banked as a credit (formally or informally), will be negated by in-field emissions e.g. CO_2 from fuel, N_2O from N fertilisers or CH_4 from grazing livestock in the pasture phase. Furthermore, the soil C sequestered is in the form of particulates or humus that can be mineralised by plants or potentially lost to the atmosphere in severe drought conditions. Essentially sequestered C is labile and changes in soil C while small and slow, are reversible.

For grain growers to keep access to ecosystem markets and market premiums they may have to show an increased level of functioning soil C. The increased humus fraction builds slowly, providing a range of agronomic benefits – Table 6. Despite these benefits, there is a significant short-term cost to increasing soil organic matter (SOM) levels, not only requiring a source of C (stubble) but also balanced nutrients (N:P:S) to increase resilient humus fractions. Carbon cycling under Australian conditions is not the same as other grain producing export countries such as the US and Europe. The level of mid-term humus fraction is subject to available moisture and soil constraint limitations, and the ability of sandy soils in dry areas to accumulate C is limited. Severe long-term droughts or fire can also deplete soil C reserves. Australian growers and advisers need to have a good understanding of C cycling in our cropping systems to mitigate these risks.

Soil C has other soil health and production benefits, especially as a nutrient bank to provide resilience to the system. Carbon as an indicator is only one elemental part of organic matter. It was previously used as a measure of SOM and an indicator to the resilience of the soil in supporting the farm's productivity over the long term. Growers value SOM as part of a nutrient bank but are uncertain about the risk associated with the C market (Rochecouste et al. 2017, Lawrence et al. 2022). This is a whole of community issue for farmers as the cost of maintaining land ecosystem services is not priced by traders (Daly & Farley 2003).

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Table 6: Biological, physical and chemical co-benefits that high soil organic matter confers to an agricultural production system.

Biological roles	Physical roles	Chemical roles
Reservoir of nutrients	Water retention	Cation exchange
Biochemical energy	Structural stability	pH buffering
Increased resilience	Thermal properties	Complex cations
Biodiversity	Erosion	

Vegetative C

Annual cropping systems do not store C in vegetation for the long term. The opportunity for C sequestration in a cropping system via vegetation is as part of the farming landscape, principally as native bush reserves or plantations on farm. There are a number of specific methodologies around vegetative C sequestration approved by the Clean Energy Regulator.

The main gap in knowledge for vegetative sequestration in cropping systems is based on tree plantings along fence lines and driveways and maintaining nature reserves and vegetation corridors on farm. How can this fit into a cropping landscape, especially those dominated by large paddocks? For cropping enterprises this can be seen as a potential opportunity, not necessarily a risk. Some parts of paddocks have infertile soils that cannot be easily ameliorated, and these rarely return a net profit from cropping – there may be merit in removing these poor areas from production and planting adapted native or other tree/shrub species.

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Relevant metrics

- Tonnes of C sequestered/hectare measured as levels of soil and vegetative organic matter (tC/ha) and recorded changes over time.
- Translate this to tonnes of CO_2 equivalent (tCO_2-e/hectare) using the formula 1 ton of soil C = 3.67 tons of CO_2e.
- Life cycle analysis to determine net emissions as tCO_2-e as a result of the change includes fugitive emissions and scope 3. Note this will change over time.

Example GRDC investments

There have been limited GRDC investment directly focussing on C sequestration, but there are a number of soil C related investments:

- Options to increase soil organic carbon in grain production systems (CSP2302-011RTX).
- Effective characterisation of soil organic carbon in farms for profitable, sustainable cropping and C accounting (CSO00043).
- Carbon storage: Identifying microbial drivers and key modulators in grain cropping (UWS00008).
- Extension (North) for 'Improved management of soil organic matter for profitable farming systems (DAQ00182).
- Participatory adaptation and mitigation strategies for climate change on the mixed farms of North-eastern Australia (DAQ00163).
- Economics of ameliorating soil constraints in the northern region: Soil constraint management and amelioration (USQ1803-002RTX).
- Economics of ameliorating soil constraints in the northern region: Spatial soil constraint diagnoses (UOQ1803-003RTX).
- Investigating the value of companion cropping systems of chickpea and cereals for improved crop and fallow water use efficiency (DAQ2104-006RTX).

Recommendations

1. **Cost-effective practices to increase soil C.** Integral to sustainable grain production is SOM and discovering new approaches to sustain and lift SOM on-farm is paramount. The effect and cost of novel nutrient and stubble management strategies to increase the level of SOM needs to be evaluated. Straightforward, practical and cost-effective strategies designed to accumulate C on-farm need evaluation in a program that facilitates economic comparative assessment across soils and environments. Research done collaboratively with industry practitioners will inform practical, affordable, on-farm nutrient strategies that can be scaled up to broadly lift the soil C storage of Australian farms.
2. **Cheaper soil C measurement.** A significant cost of doing a C audit for reporting is the cost of sampling and measurement. Soil sampling to 30cm across large areas of broadacre farms to a degree that is considered representative is costly. Usually, this involves a minimum of two depth measurements per core, costing $60 for analysis (not including sampling labour). The number of cores required will vary by land type and cropping history. The opportunity for rapid testing using emerging technologies such

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as spectroscopy is seen as being significant to reducing the lab cost and labour. Federal government has recently invested in this area, and progress needs to be monitored.

3. **On-farm plantations and bush reserves.** If grain growers want to increase access to environmental or C credit related income streams, there may be less risk in considering vegetative sequestration integrated with productive cropping systems. For instance, there is the choice for modifying existing capabilities developed from grazing to suit those with natural vegetation or available land for plantations. New research could look at changing existing capabilities in natural vegetation monitoring to suit cropping systems landscape. An important area of potential research is to determine what are the best species by location and in what format would they best suit different farm situations in different agro-ecological zones.

WORKSTREAM

WS4 SOIL HEALTH

Longer Term Outcome

- Australian grain growers have productive land and natural capital assets.

Intermediate Outcome

- Australian grain growers know how to manage soil health, including soil carbon and other soil constraints.
- Australian grain growers demonstrate to customers (and regulators) the state of on-farm environmental assets and impacts of farm operations.
- Australian grain growers can make farming system practices and business plans that enhance farm natural capital.

Current knowledge

Interest in 'soil health' continues to grow with a range of definitions in the literature:

- Food and Agriculture Organisation (FAO) - Global Soil Partnership (GSP): "capacity of the soil to sustain the productivity, diversity, and environmental services of the terrestrial ecosystems".
- Natural Resources Conservation Service (NRCS), US Dept of Agriculture (USDA): "continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans".
- National Soil Strategy: "the capacity of soil to function as a living system. Soil health is the product of physical, chemical and biological soil processes working together to sustain productivity, diversity, and ecosystem services".

There is growing awareness of soil functionality and the critical role for soils in addressing multiple existential challenges (e.g. food and energy security, climate change, biodiversity; Kopittke et al. 2022). Agriculture accounts for 55% of Australian land use, thus sustainable land use practices are critical for industry and society more broadly (ABARES

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2022). The value of soil is recognised nationally and internationally – for example, the EU Soil Strategy for 2030 sets out a framework to make protection, sustainable use and restoration of soils the norm. This strategy proposes a combination of voluntary and legislative actions and is currently developing a Soil Health Law by 2023 to provide a legal framework for soil protection in line with protections for water and air. With 72% total value of Australian agricultural output exported and market expectations for demonstration of sustainability credentials growing, alignment with the global context is critical.

Australia's National Soil Strategy sets out how Australia will value, manage and improve its soil over the next 20 years, and prioritises soil health (Goal 1). There are a number of relevant activities:

- Australian National Soil Information System (developed by CSIRO). Soil Data Use Case Studies to demonstrate value and future potential – includes (1) determining soil organic carbon (SOC) sequestration potential across Australia; (2) soil state and trend for natural capital accounting; and (3) benchmarking for farm management insights.
- Soil Monitoring Incentives Program. Minimum soil testing requirements and measurements.

Best management practices for maintaining soil health are recognised and practised by most grain growers. Many sustainable land practices have become standard for Australian growers. For example, many broadacre cropping farms retain stubble (85% of farms), minimise tillage (68% of farms), ameliorate soil to overcome constraints, and optimise the use of pesticides and fertilisers (65% of farms) (Coelli, 2021). A number of sustainability frameworks for the Australian agricultural industry (AASF), grains (Behind Australian Grain), and other agricultural sectors refer to soil health, but a key gap at present is the lack of indicators for quantifying, monitoring and assessing soil health, which are critical for monitoring and assessment of soil health, establishment of baseline and relevant benchmarks.

Most grain growers and advisors understand the key components that make a healthy soil. For many, crop performance is the ultimate measure of soil health, however, key indicators can identify specific soil issues. It is critically important to establish accurate and relevant (regionally and/or locally) baselines to quantify changes both short-term (measurable) and long-term (possibly modelled) soil indicators. Questions to address include how and when to establish these measurements. Ultimately, the aim is to develop a 'Soil Health Index' for the Australian grains and other industries. To maintain and/or enhance soil health, growers need to be able to measure and monitor changes through time (short- and long-term) in response to change drivers (e.g., shifts in land use management, climate change, etc.) and interpret or assess overall health.

Establishing whether direct or indirect relationships exist between soil management practices and soil health properties is important for growers to understand what practice changes they should implement to improve their soil health and the impact they may have. 'Regenerative agriculture' has gained notoriety in recent years, as did 'organic' and 'biodynamic' in previous decades. Regenerative and sustainable could be used interchangeably, and many leading growers see themselves as regenerative. The role and impact of regenerative and other agricultural practices in maintaining and/or enhancing soil health in the Australian grains industry deserves research attention, as do the attitudes and values of their proponents. There is a need to provide science-based evidence of their impact on soil health and functioning. The potential role of biochar to improve soil health (and soil C sequestration) in the Australian grains industry should also be reconsidered.

Much of soil science in Australia has focussed on chemical and physical characteristics, but what is the role of soil biological function for resilient

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and productive farming systems? The impacts of modern cropping practices and farming systems (i.e., crop productivity, diversification, intensification) on soil biological functions need to be quantified for improved soil health assessment, and recently developed genetic approaches targeting critical functional genes linked to soil processes may be more useful rather than traditional coarse measures (e.g. soil C, microbial activity). Biological indicators need to be developed that are responsive to new land management practices and improve crop performance.

What indicators are best suited for the grains industry to monitor and manage soil health? There is a clear opportunity to work within the framework of the National Soil Strategy and implementation of the National Soil Action Plan 2023-28, and other related activities (e.g. 'Farming for the Future', 'Natural Capital Measurement Catalogue', Food Agility CRC). A combination of soil physical, chemical and biological properties should be included, with biological measures requiring further development given higher spatial and temporal variability (Crookston et al. 2021), and links to productivity and system resilience currently lacking. Measurements must account for the diversity of soil types, seasonality, and different farm management systems, considering the complexity of measuring soil health, practicality, and cost-effectiveness.

Relevant metrics

- Soil pH – considered a 'master variable' influencing nutrient availability and microbial activity. This is measured routinely by growers, along with salinity (electrical conductivity).
- SOC – key component of SOM, important for nutrient cycling, soil structure, water holding capacity. This is also measured routinely by growers.
- Aggregate stability – closely linked with water infiltration, erosion, SOM/nutrient cycling. There are a number of methods for measuring aggregate stability, from soil dispersion test (cheap, easy) to wet sieving (more expensive, need for specialist equipment/expertise).

Example GRDC investments

- Soil Biology Initiatives I and II (UWA00138, DAV00102, DAS00111, UWA00142, DAV00120, UWA00139, CSP00138, DAV00106, UA00119, UA00128, UWA00150, UWS00008, DAW00201, DAQ00164, CSP00135, DAV00105) The initiatives included multiple project investments covering inoculants, root diseases and OM and nutrition. Aim: develop suite of practical methods and cost-effective products, based on scientific understanding of crop root-soil interactions, that will overcome limits to crop performance and significantly improve profit margins in grain cropping systems.
- Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements (UOA1703-016BLX).
- Economics of ameliorating soil constraints in the northern region: Spatial soil constraint diagnoses (UOQ1803-003RTX).
- Incorporating lime to depth in duplex wheatbelt soils (FGI1801-001SAX).
- New knowledge and practices to address topsoil and subsurface acidity under minimum tillage cropping systems of South Australia (DAS1905-011RTX).
- Maintaining Profitable Farming Systems with Retained Stubble (WAN2004-001SAX).
- Quantifying the effectiveness of cover crops as a means of increased water infiltration and reduced evaporation in the northern region (DAQ1705-005RTX).
- Understanding the amelioration processes of the subsoil application of amendments in the

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Southern Region (DAV1606-001RMX).

- Demonstrating the benefits of soil amelioration and controlled traffic practices across a broad range of soil types in WA (WMG1803-002SAX).
- Incorporation of organic soil ameliorants to boost productivity of sandy soils in the M to HRZ of the Wheatbelt of Western Australia (CFG2003-001SAX).
- The WA Stubble Story: Investigating alternative stubble systems for cropping systems in the Western Region (LIE2110-001SAX).

Recommendations

1. Soil health index.
A suitable soil health index needs development to enable growers to demonstrate stewardship and how land management practices are linked to enhanced soil health outcomes. The opportunity to develop a data-driven, evidence base for sustainable land management practices, including conservation and regenerative agricultural practices, should be explored. Opportunities to co-invest with other research and development corporations, industry stakeholders and the natural resource management sector, where the development of soil health indicators and measurement tools, establishment of baselines and development of benchmarking platforms are a key priority (i.e., National Soil Action Plan 2023-28, 'Farming for the Future' program and CRC Food Agility). Metrics must be accessible, feasible, and economical (cost-effective) for growers to adopt. An integrated soil health index will need to cover a range of agro-ecological zones, soil types, and farming systems across the grains industry and have clear linkages with sustainable land use/soil management practices.

2. Soil health return-on-investment.
There is a need for stronger linkages between sustainable soil management practices, soil productivity, farm profitability and soil health measures to be demonstrated. The importance of long-term experimental data and field sites to understand changes through time/space is critical. There is a clear opportunity to build upon and value add to existing GRDC farming systems sites as well as feed into new opportunities such as the Future Drought Fund which is establishing a national network of long-term trials of drought resilience farming practices.

3. Soil biological function.
Stronger relationships between soil biology, soil health and crop performance could lead improved soil management practices. Soil health metrics are dominated by soil physical and chemical properties despite growing awareness of the importance of soil biological functioning and soil biodiversity. Limited functional knowledge and a lack of effective methods to manipulate soil biology are thought to be responsible (Lehmann et al. 2020). Previous GRDC investments (Soil Biology I and Soil Biology II) provided advancements in technical capacity. Continued advancements in the scientific discipline since Soil Biology II concluded (2014) provide an opportunity to revisit the role of soil biological functioning with clear linkages to practice change impacts and associated economic outcomes for the grains industry. This knowledge will lead to the development of soil biological indicators that are responsive to land management practices to compliment chemical and physical soil indicators, and subsequently enhance soil health assessments.

WORKSTREAM

WS5 ENVIRONMENTAL SERVICES BASED ON LAND, WATER AND BIODIVERSITY VALUE

Longer Term Outcome

- Australian grain growers have access to environment-related income streams
- Australian grain growers have productive land and natural capital assets
- Australian grain growers meet environmental regulation without loss of profitability.

Intermediate Outcome

- Australian grain growers demonstrate to customers (and regulators) the state of on-farm environmental assets and impacts of farm operations
- Australian grain growers can make farming system practices and business plans that enhance farm natural capital
- Australian grain growers can manage profitable trade-offs between productivity and environmental outcomes
- Investors understand whole of farm impact on environmental and social sustainability to inform financial services
- Governments develop environmental and social sustainability metrics (e.g., National Greenhouse Gas Inventories) that reflect locally validated science and current practice.

Current knowledge

Analysis of GRDC's investment portfolio (Annex A) found almost 30 per cent of investments, representing 25 per cent of funds invested by GRDC, could be said to deliver outcomes that would have a direct potential environmental effect. GRDC has not invested explicitly in the area environmental markets. However, it is highly likely that underlying data have been collected that could be used to support either (or both) a 'credit', or some natural capital accounting metric that could flow into environmental markets. Growers could already be generating cashflows (or reasonably expect to do so in the future) due to current environmental market activities, and hence, should pay some heed to the emerging environmental markets. However, the extent to which this is already happening, or the extend of developments that are occurring is not well known.

Valuing the environment is a rapidly developing area and many vaguely defined terms are used:

- **Natural Capital Accounting** – the emerging process of including environmental values into 'the balance sheet' in some manner. Accounting for something does not automatically mean a cashflow, or profit/loss will result. Sometimes this includes creating defined 'environmental

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instruments' or 'environmental credits' (such as Australian Carbon Credit Units, or Biodiversity Offset Credits), which may then be monetisable in an environmental market.

- **Biodiversity** – broadly, a measure of the diversity of the biological material in an environment. The level of biodiversity is one metric that flows into Natural Capital Accounting. Sometimes it can be quantified within a government certified 'credit' (or some kind of voluntary instrument) and be then monetised in a government backed or voluntary environmental market.
- **Environmental Markets** – are created when a dollar value can be placed on an ecosystem service that provides benefits for everyone and there are people willing to buy and sell these services in the form of environmental credits. This most obviously includes C trading (in many forms), but also includes biodiversity, clean air, water, fertile soil, renewable energy, and specific schemes like 'Reef Credits'.

Environmental markets

Like C, where global and domestic action has been increasing over the past three decades under the overarching auspices of the 1992 United Nations Framework Convention on Climate Change (UNFCCC)[i], action around 'biodiversity' and 'ecosystem services' has been increasing under the overarching 1993 United Nations Convention on Biological Diversity[ii]. It is generally acknowledged that arrangements around biodiversity are running about 5-10 years behind those in respect of C, reflected in the fact that the 27th Conference of Parties under the UNFCCC was conducted in November 2022[iii], whilst only the 15th conference on biodiversity occurred in December 2022[iv]. Hence, whilst C markets and other economic instruments are now reasonably well developed in many jurisdictions (total turnover in Australia's carbon markets in 2021/22 was around $1.5B), development of markets and economic arrangements around biodiversity and associated issues of natural capital are nascent (probably $200M).

Whilst it is now relatively easy to include 'carbon' into business cases and models, this is not yet the case with 'biodiversity', 'natural capital', or 'ecosystem services' more generally. Often there is no established unit of measure with a defined market ($) value, and the data required to generate such units is often not being collected or is not available for the purpose.

Government programs

Australian State and Federal governments have made a series of policy announcements that are consistent with Australia's expressed commitments to UN goals, including:

- The proposed development of a national biodiversity trading scheme the design of which is currently in early development[ix].
- The development of a voluntary Australian Farm Biodiversity Certification Scheme[x].
- A Carbon + Biodiversity (C+B) Pilot[xi].
- An announced target for 30% landmass to be under conservation by 2030[xii].
- The NSW Government Statement of Intent on Natural Capital Accounting[xiii].

In NSW, a compliance market for biodiversity trading has been in operation since 2016 which had a market turnover of approximately $94M in 2021/22.

Voluntary schemes

There has also been a range of voluntary activities in the corporate and not-for-profit sectors around 'voluntary biodiversity offsetting', and 'carbon+'

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deals involving a carbon offsetting credit with an associated biodiversity or social-impact quantification. Two recent examples include the Australian Wildlife Conservancy announcing the development of a 'biodiversity credit' structure in respect of their investments in properties in Australia[xiv], and Telstra announcing a 'partnership' with the NSW Biodiversity Conservation Trust[xv].

Markets and other financial arrangements around the high-level goals set in the UN Global Biodiversity Framework can be assumed to continue developing in Australia and internationally over the years to 2030. Currently, the only international trading of ecosystem services appears to be in voluntary markets, where a range of standards are applied particularly in the context of 'Carbon+' transactions. There has been explosive growth in the issuance of 'green bonds', and to a lesser extent biodiversity focused 'sustainability-linked bonds'. To this point, no bonds could be identified that relate to the grains sector at present.

Natural capital accounting

There are a range of natural capital accounting initiatives that are progressing, include the United Nation's System for Environmental-Economic Accounting[xvi], and work announced in the USA and Australia. According to the National Farmers' Federation Policy Summary on Natural Capital (2019)[xvii], the international experience has provided a robust foundation with which to build a policy that is unique to the Australian landscape.

Relevant metrics

Having robust and transparent quantifiable metrics is essential for a credible monitoring scheme and attracting investment into new markets. At present there is considerable work being undertaken in improving the measurement of natural capital worldwide[xx].

There are various efforts underway, including by state and federal governments[xxi], to develop credible metrics and standards around financial benefits of natural capital for landholders, by collating and analysing data that links on-farm natural capital investments and financial performance. For instance, the NSW Government Primary Industries Productivity and Abatement program is targeting the development of voluntary on-farm metrics and certification that can be used as the basis for concessional finance into the agricultural sector, and have already commenced discussions with financial institutions regarding the nature of the metrics that might apply[xxii]. While methodologies and metrics do exist (for example, those applicable in C markets), there is a lack of information about how these feed into natural capital accounting methodologies, particularly those relevant to the grains industry.

Recommendations

GRDC should consider cross-industry co-investment opportunities in all cases.

1. **Markets and certification schemes.**
   Current and future markets need to be identified and quantified to monetise 'ecosystem services' in Australia and the extent to which grain growers are already participating in these schemes. While there are several activities and schemes in existence and available for participation (federal, state and voluntary markets), the extent and nature of transactions in environmental markets in the agricultural industry, or in grains specifically, are unclear. It is also necessary to understand how smaller farms are engaging with these markets. Understanding the drivers and barriers for participation of grain growers in these markets is key to identifying data and/or knowledge gaps for further research.
2. **Case studies.**
   Sustainability actions that a grain grower could

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undertake should be identified, specifically the resulting 'biodiversity credit' generated and the current monetary value of the credit(s), to demonstrate the business case as it currently stands. Given the small current market volume, it would appear unlikely that a major grain grower would significantly alter operations purely for a commercial return from selling 'biodiversity' or ecosystem services. However, this is likely quite variable depending on the exact circumstances and business practices of the grower. It may be that obtaining relevant certification for current farming practices is sufficient to take part in existing schemes. Work in this area could also compile data linking the costs and benefits of maintaining or enhancing natural capital and the profitability of grain production systems. This analysis would deliver clearly defined financial values that will support landholders, property valuers, banks, and other financial institutions to incorporate 'natural capital' into their valuation and decision-making processes.

3. **Federal and state legislation.**
   Federal and state legislation and the taskforce on Nature-related Financial Disclosures (TNFD) Framework are under active development, and the Australian financial sector is heavily involved in considering how to re-price lending to the agricultural sector on the basis of metrics being developed. Effort is needed to gain additional insight into how this will be affecting the grains industry, and how RD&E can support the development of data services to make participation easy. Associated with the above, and TNFD arrangements, the potential for an industry-wide best management practice, or similar program/tool can be explored to consolidate sustainability credentials to set a minimum level of performance required to maintain market access. This has potential for leverage of opportunities in new markets and for use in articulating growers' commitments to environmental stewardship to external stakeholders such as the broader community.

4. **Enabling data.**
   Growers need assistance in potentially generating income from ecosystem services through data generated from previous or current investments, or data available from other sources. Such data are assets that may enable grain growers to generate credits and participate in these emerging markets. Research should be focused on: (a) identifying appropriate data and ensuring it is being collected and made available, and (b) identifying how to apply those datasets to creating and then selling quantified on-farm ecosystem services under existing and developing market arrangements.

5. **Natural capital accounting.**
   There are various efforts underway, including by state and federal governments, to develop credible metrics and standards around financial benefits of natural capital for landholders (for example, those applicable in C markets), by collating and analysing data that links on-farm natural capital investments and financial performance. However, there is a need to understand how these will be applied in the grains sector. RD&E is warranted in developing natural capital accounting frameworks to identify examples where a given dataset can be used to generate a defined 'credit'. For instance, can a specific case be identified where the 'accounting for nature' framework can be applied to a grains enterprise, using data that can be easily obtained and verified, resulting in a 'certificate' that can be sold as part of a 'Carbon +' transaction?

6. **Risks and opportunities.**
   Increased regulation is anticipated around environmental sustainability. Feed and industrial markets for grains are exhibiting an increased requirement for sustainability credentials confirming the environmental footprint of production, and the nature of labour and practices within the supply chain. In addition, food and beverage manufacturers with corporate sustainability goals are increasingly requiring

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their raw material suppliers to provide evidence of sustainable production practices. The grains industry needs to understand the risks and opportunities, especially how constraints might affect trade and market access, and how the industry can demonstrate sustainability.

7. **Grower training.**
   Together with government and other industries, opportunities are required to upskill farmers on ecosystem services through specific training or farmer exchange events.

Footnotes

[i] https://unfccc.int/resource/docs/convkp/conveng.pdf

[ii] https://www.cbd.int/doc/legal/cbd-en.pdf

[iii] https://unfccc.int/process-and-meetings/conferences/sharm-el-sheikh-climate-change-conference-november-2022/information-for-cop-27-participants-a-z#:~:text=In%20November%202022%2C%20the%20Government,global%20challenge%20of%20climate%20change.

[iv] https://www.cbd.int/meetings/COP-15

[v] https://www.cbh.com.au/media-releases/2021/06/mou-with-australias-largest-grain-exporter-to-develop-carbon-neutral-grain-products

[vi] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Biodiversity/removing-biodiversity-offset-payment-calculato-from-public-view-consultant-report.pdf

[vii] https://www.cbd.int/doc/c/abb5/591f/2e46096d3f0330b08ce87a45/wg2020-03-03-en.pdf

[viii] https://www.unep.org/un-biodiversity-conference-cop-15

[ix] https://www.allens.com.au/insights-news/insights/2022/09/Federal-Government-invites-views-on-proposed-biodiversity-market/

[x] https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/landcare/sustaining-future-australian-farming/aus-farm-cert-scheme

[xi] https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/landcare/sustaining-future-australian-farming/carbon-biodiversity-pilot

[xii] https://www.reuters.com/world/asia-pacific/australia-set-aside-least-30-its-land-mass-protect-endangered-species-2022-10-04/

[xiii] https://www.environment.nsw.gov.au/research-and-publications/publications-search/nsw-natural-capital-statement-of-intent

[xiv] https://www.australianwildlife.org/ and presentation made by Nick Butcher, Chair AWC, at the 2022 AARES Symposium.

[xv] https://www.bct.nsw.gov.au/bct-telstra-partnership

[xvi] https://seea.un.org/ecosystem-accounting

[xvii] https://nff.org.au/wp-content/uploads/2020/01/2019.05.15_Policy-Summary_NRM_Natural-Capital.pdf

[xviii] Blumenthal, M., Umbers, A. and Day, P. 'A Responsible Lead – An Environmental Plan for the Australian Grains Industry'. GRDC. Published July 2008.

[xix] https://cdn.sanity.io/files/1nr0ob5f/production/459fbfea07cfed646b5c78a37f730b2368250560.pdf

[xx] https://pointadvisory.com/wp-content/uploads/2022/05/Time-To-Take-Stock.pdf

[xxi] https://www.dcceew.gov.au/climate-change/policy/nature-based-solutions-for-climate/financing-solutions#supporting

[xxii] https://www.energy.nsw.gov.au/business-and-industry/programs-grants-and-schemes/primary-industries-productivity-and-abatement

WORKSTREAM

WS6 SOCIAL AND HUMAN CAPITAL

Longer Term Outcome

- Australian grain growers have adequate access to labour and services in their local community.
- The community trusts Australian grain growers and allows them to innovate.

Intermediate Outcome

- Australian grain growers maintain and grow community trust.
- Investors understand whole of farm impact on social sustainability to inform financial services.
- Governments can develop social sustainability metrics that reflect locally validated science and current practice.

Current knowledge

Social indicators provide a measure of change in the social and human capital of the grains industry, its communities and broader society. While contribution to regional economies is often used as an indicator of an impact of farming on society, the impacts of GRDC's investment can be much broader. GRDC's existing Capacity and Ability Framework supports the grains industry in accessing highly capable people and appropriate infrastructure in an environment that supports innovation and research for impact. It could be argued that most GRDC investments in RD&E create employment and support rural communities in either direct or indirect ways.

The initial effort for this focus area will be to map out a plan for GRDC to better target social impacts in its RD&E planning, investments and reporting. Initial priorities will be to:

- Explore previous work to identify and articulate any social and human capital impacts of selected investments.

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- Create opportunities to enhance GRDC's reporting of impact on and investment in social and human capital.

Investing in the people that make up the grains industry has been an investment priority ever since GRDC was established in the 1990s – for example, GRDC's "Partners in Grain" project, which commenced in 2001, looked at how women and young people could be empowered to play a bigger role in the grains industry going forward.

A clear gap in GRDC's investment strategy over the years is the explicit inclusion of Australia's first nations people, including a focus on how to increase their economic participation in the grains industry and leveraging indigenous knowledge to boost agricultural output of the grains industry. Another strategic gap is around the changing business environment for growers, for example requirements for them to respond quickly to new technology, or natural disasters (e.g. fire or flood). GRDC's investment in this area has been largely ad-hoc and needs-driven, albeit some overlap with the previous KIT 5.3 that focused on "supporting grain growers to acquire business management skills".

Relevant metrics

Benchmarking needs to occur within the context of Australian agriculture as a whole. For example, an all of industry approach is needed to move the dial on work health and safety outcomes for the grains industry, given that culture change on farm cannot be driven just by one commodity, requiring a strategic approach across a range of industries. Likewise, exploring specific barriers for women to participate in the grains industry and these be addressed would benefit from a cross commodity approach. To demonstrate the positive contribution of the grains industry to society, the Community Trust in Rural Industries program established that Australian agriculture is perceived by the community as one industry, and is not broken up into individual commodities.

Likely indicators include:

- People (or social), including all variables dealing with community, education, employment, well-being, and quality of life.
- Social indicators provide a measure of change in the social and human capital of the grains industry, its communities and broader society.

Example GRDC investments

- Examining the Grain Industry's Importance in Regional Economies (RAI1904-001CAX).
- Science and Innovation Awards for Young People in Agriculture (DAF1407-001AWX).
- Boosting the capability and capacity of graduate agronomists - GRDC Northern Region (SBM1909-001SAX).
- Community Trust in Rural Industries (RDC1906-004OPXV).
- Rural Safety and Health Alliance (RDC2107-001OPX).
- Exploring a cotton and grains agricultural traineeship model (CRD2207-001FAX).
- GRDC Membership of the Primary Industries Education Foundation of Australia (PIE2108-001SAX).
- Australian Universities Crops Competition (AUCC) 2018, 2019 & 2022 (GGL1804-002AWX).
- GRDC sponsorship of the Horizon Scholarship Program (RDC2003-003SAX).
- WeedSmart Week study tour: East Loddon year 12 ag students (ELP2206-001AWX).

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Recommendations

While GRDC has invested in the human capacity of the grains industry and activities that make a positive contribution the grains industry and the broader community, this has occurred in an ad-hoc manner, often through collaborations across Research and Development Corporations, such as contributions to the Community Trust in Rural Industries project or through broader cross-industry activities such as the Australian Rural Leadership Foundation.

This workstream also overlaps with GRDC's existing capacity and ability framework which focuses on attracting and fostering the talent required to conduct and drive world class grains RD&E, and supporting thought leadership and pathways to innovation, translation and adoption. It also incorporates GRDC's existing activities to support an ever more inclusive and diverse workforce across the grains industry, such as GRDC's participation in the Diversity in Agriculture Leadership Program and GRDC's future Reconciliation Action Plan (currently under development).

The RD&E recommendations for this workstream are thus, not so much to identify investment gaps (other than where outlined below) but rather to add focus and direction to future investments GRDC in this space, noting that in many instances GRDC will need to collaborate with other agricultural industries to achieve effective outcomes and change.

Table 7 below presents metrics were informed by the Australian Agricultural Sustainability Framework, the UN Sustainable Development Goals, Behind Australian Grain and other relevant international frameworks such as the UK-based Global Farm Metric.

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Table 7. Potential human capital metrics and indicators, and RD&E gaps.

Area	Metric	Key GRDC investments to date	Indicator	GRDC investment gap
WORKFORCE	***Safe working environment*** *Physical (accidents and near misses) and emotional health of workers in the grains industry.*	- Rural Safety and Health Alliance - Mental Health investments (e.g., Dealing with the dry)	- Deaths and injuries on farm - Regional wellbeing score - Modern slavery	Consider funding grains component in Regional Wellbeing survey
	Diversity *Supporting an inclusive and diverse grains industry workforce.*	- Diversity in Ag Leadership	- % Women in the grains industry - % Indigenous participation in the grains industry	Breakdown grains workforce (data) No direct investment in indigenous engagement
	Training *Ensure the grains industry has enduring access to the talent required to conduct world class grains RD&E.* • Overlap GRDC Capacity & Ability Framework	- PIEFA membership - Various scholarships (tertiary) - Ag Traineeship - Leadership and study tour investments	- Enrolment in grains traineeships	Knowledge transfer and adoption Need for strategy-driven young grower engagement (so far ad hoc)
	Changing business environment *Enabling growers to respond quickly to a changing business environment (e.g. natural disaster, emergence of new technology, continuing education).*	- Dealing with the dry workshops - Frost workshops - Continuous education (new technologies, farm finance)	- Complexity of operations	Work-life balance for growers Impact of new technologies on regional communities

WS6

Area	Metric	Key GRDC investments to date	Indicator	GRDC investment gap
COMMUNITY	***Community Engagement*** *Community trust relates to the nature of the relationship between industries and the social context in which they operate.*	- Community trust in rural industries	- Community trust and acceptance scores for the grains industry	Reinvest in the community trust in rural industries project
	Regional Impact *The contribution the grains industry makes to local communities. This includes direct contributions through GRDC RD&E.* • Overlap GRDC Impact Plan	- Regional Australia Institute Grains industry's economic importance to rural communities	- Vibrant grain communities (e.g., primary school or sport club enrolment numbers)	No direct investment to measure the impact of GRDC research on socio-economic wellbeing of rural communities.
	Nutrition and Health *Achieve food security and improved nutrition.*	- Previous Grains and Legumes Nutrition Council	- Increased opportunities to differentiate grain and grain crop by-products for higher grain prices	Opportunity with the Grains and Legumes Nutrition Council to fund research into gaps in the Australian Dietary Guidelines.

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ACRONYMS

AASF - Australian Agricultural Sustainability Framework

AIA - Agriculture Innovation Australia

C - carbon

CH_4 - methane

CO_2 - carbon dioxide

COP21 - United Nations Paris Agreement

CTF - Controlled traffic farming

EEF - enhanced efficiency fertilisers

FAO - Food and Agriculture Organisation

GHG - greenhouse gas

GRDC - Grains Research and Development Corporation

GSP - Global Soil Partnership

LCA - lifecycle assessment

N_2 - nitrogen gas

NANORP - National Agricultural Nitrous Oxide Research Program

NGGI - National Greenhouse Gas Inventory

N_2O - nitrous oxide

NRCS - Natural Resources Conservation Service

PEF - Product Environmental Footprint

RD&E - research, development and extension

SDG - Sustainable Development Goals

SI - GRDC Sustainability Initiative

SOM - soil organic matter

TNFD - Nature-related Financial Disclosures

USDA - US Dept of Agriculture

UNFCCC - United Nations Framework Convention on Climate Change

WS - work stream.

ABOUT GRAINS AND GRDC

The grains sector is a major contribution to the national economy with the Australian Bureau of Agriculture Resource Economics and Sciences (ABARES) estimating the total value of the grains industry at more than $23 billion in 2023-24, with wheat alone accounting for more than $15 billion.

Australia's grain production is intricately linked to seasonal conditions, with water use efficiency and agronomic practices and crop varieties critical considerations in an increasingly challenging environment.

The purpose of the Grains Research and Development Corporation (GRDC) is to invest in research, development and extension (RD&E) to create enduring profitability for Australian grain growers.

GRDC invests in RD&E projects to deliver new and improved varieties, farming practices, technologies and capability to the Australian grains industry. These investments drive the discovery, development and delivery of world-class innovation.

GRDC is primarily funded by the Australian Government and levies paid by grain growers on 25 grain crops.

GRDC's strategic investment in world-class, innovative RD&E – on behalf of Australian grain growers - continues to be a critical factor underpinning production growth, leveraging market opportunities and supporting the industry's ongoing success.

Responsible Minister

Senator the Hon Murray Watt
Minister for Agriculture, Fisheries and Forestry

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General Counsel and Company Secretary: Merryn Cossey
Head of Human Resources : Shelley Kowalski
Head of Communications: Toni Somes

GRDC REGIONAL OFFICES

NORTH
Toowoomba - (07) 4571 4800
214 Herries Street, Toowoomba QLD 4350

SOUTH
Adelaide - (08) 8198 8400
Level 1, 187 Fullarton Road, Dulwich SA 5065

WEST
Perth - (08) 9230 4600
Suite 5, 2a Brodie Hall Drive, Bentley WA 6102

CORPORATE OFFICE
Canberra - (02) 6166 4500
4 National Circuit Barton, Canberra ACT 2600
Email: grdc@grdc.com.au

grdc.com.au

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