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Greenhouse gas emissions reduction options for Western Australian agriculture

Department of Primary Industries and Regional Development, Western Australia

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Greenhouse gas accounting for Western Australian agriculture 2022

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Gordon Stephenson House
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Acknowledgment of Country

The Department of Primary Industries and Regional Development (DPIRD) acknowledges the Traditional Custodians of Country, the Aboriginal peoples of the many lands that we work on and their language groups throughout Western Australia and recognises their continuing connection to the land and waters. DPIRD respects the continuing culture of Aboriginal peoples and the contribution they make to the life of our regions, and we pay our respects to Elders past, present and emerging.

Contents

Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACCU	Australian carbon credit unit
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DPIRD	Department of Primary Industries and Regional Development
GHG	Greenhouse gas
GWP	Global warming potential
ha	Hectares
IPCC	Intergovernmental Panel on Climate Change of the United Nations
LCA	Life cycle analysis
LULUCF	Land use, land-use change and forestry
Mt	Megatonne (one million tonnes)
N_2O	Nitrous oxide
NIR	National greenhouse gas inventory report
R&D	Research and development
t	Tonne
WA	Western Australia

Definitions

Abatement: Reducing or removing greenhouse gas emissions.

Australian Carbon Credit Unit (ACCU): Tradable credits generated by abating emissions or sequestering carbon.

Carbon account: An inventory of all greenhouse gas emissions and carbon sequestration for a product, organisation or business.

Carbon flux: The exchange of carbon between different parts of the Earth's system, such as between the atmosphere and plants or soils.

Climate adaptation: Acting to reduce vulnerability to climate change impacts such as weather extremes, natural disasters, sea-level rise and water scarcity.

Climate change: A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere.

Carbon neutrality: Reducing greenhouse emissions where possible and compensating for the remainder by insetting/offsetting.

Emissions intensity: The amount of emissions (kilograms of carbon dioxide equivalents) generated in the production of 1 unit of product.

Insetting: Generating non-tradable credits by abating emissions or sequestering carbon and using to reduce the net emissions of a business.

Life cycle analysis: A standardised way to model the environmental impact (such as emissions) associated with the life cycle of a product, process or service.

Mitigation: Avoiding, reducing or offsetting greenhouse gas emissions through practice change or implementation of new technology**.**

National Greenhouse Gas Inventory: Provides estimates of Australia's emissions by state, sector and source, using standardised methods.

Net emissions: The balance of total emissions less any carbon sequestration.

Offsetting: Using a tradable credit (ACCU) to lower the net emissions of a business.

Pre-farm (or upstream) emissions: Emissions from the production of inputs such as fertilisers, herbicides and fuels prior to arriving on the farm.

Post-farm (or downstream) emissions: Emissions produced in the life cycle of the product after leaving the farm, such as transport, packaging and processing.

Scope: Term used to categorise business or industry emissions based on where in the value chain they are generated.

Scope 1: Emissions generated on the farm.

Scope 2: Emissions generated in the production of purchased electricity.

Scope 3: Emissions generated in the production of inputs such as fertilisers and herbicides, as well as in packaging and processing.

Sequestration: Removing carbon from the atmosphere and storing it in vegetation or soil. Carbon can be sequestered through natural processes and human activity.

See also Cowie et al. (2023) for further definitions.

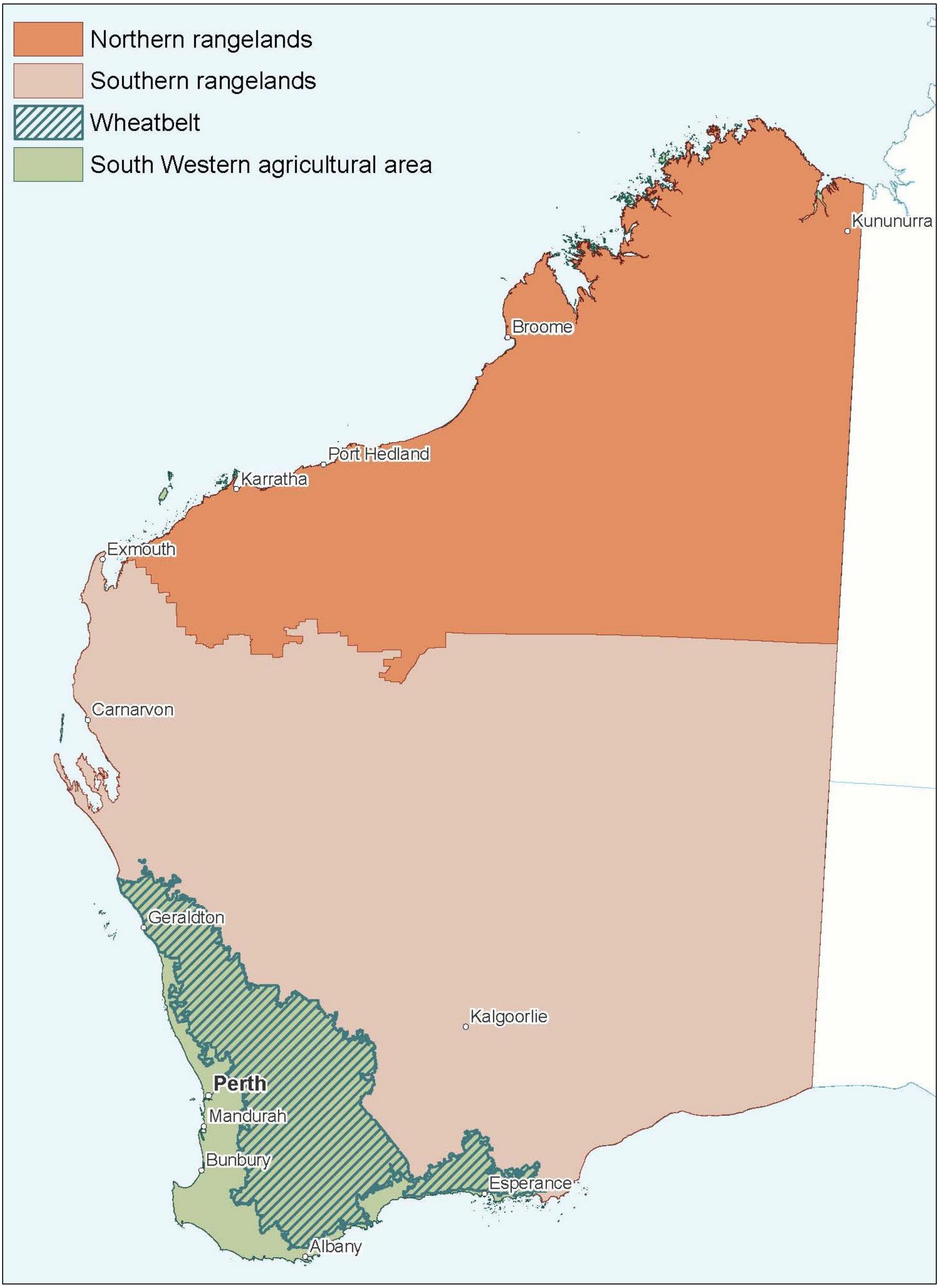

Figure 1. Map of Western Australian agricultural regions

Abstract

This report presents new modelling of the greenhouse gas emissions attributable to Western Australia's agricultural industries and provides an overview of sequestration at the state level. The report improves and expands on the estimates from previous technical reports by the Department of Primary Industries and Regional Development (DPIRD), most notably Curnow et al. (2022). The report presents a new, much broader picture, capturing not only emissions from agricultural activities in Western Australia (WA), but also the emissions associated with the production of agricultural inputs and the sequestration that occurs on agriculturally managed lands. This broader picture of emissions aligns with frameworks for emissions reporting at the business and product level.

Results

Total on-farm and pre-farm emissions are estimated to have been about 14.8–15.5 megatonnes of carbon dioxide equivalents (Mt CO_2e) per annum over the period from 2020 to 2022. Emissions originated largely in the beef (5.3–5.6 Mt CO_2e per annum), grains (4.4–5.1 Mt CO_2e per annum) and sheep (3.8–4.0 Mt CO_2e per annum) industries. The combined emissions of the remaining major industries (dairy, pork, chicken meat, eggs, horticulture) are estimated to have been about 1.4-1.5 Mt CO_2e per annum. Examples of current mitigation efforts and challenges are discussed in the context of the industry-level estimates.

Methane from enteric fermentation accounted for about 40 to 44 per cent of estimated total emissions, with some indication that this share may be decreasing over time through lower livestock numbers and increasing grain production. There is also evidence that, as grain yields have increased over time, pre-farm emissions are becoming increasingly important to WA agriculture's mitigation efforts.

Due to data limitations, it has not been possible to include carbon sequestration and carbon flux in the modelled emissions estimates for the industries. In the future, new methodologies may enable allocation for different industries and could potentially enable the calculation of net emissions for some industries.

Implications

With the global emphasis on climate change, it is increasingly important for producers across all sectors of the economy to understand their carbon footprint and to be able to compare it to industry benchmarks. However, total emissions at the industry level should not be the only indicator for businesses seeking to evaluate strategies for profitability and greenhouse gas mitigation, as their marginal effect on global warming will ultimately depend on the changes in the emissions intensity of the business' products. While state-level emission estimates provide a broad view, individual farm-level carbon accounting is essential to determine the carbon footprint of individual farming systems and products.

Reducing net emissions in agriculture will require a combination of emissions reduction strategies and increased on-farm sequestration. Such strategies may target total emissions or emissions intensities, or both. If more output is generated from fewer inputs, the emissions intensity of the product will improve even if total emissions are unchanged. By continuing to improve their productivity and efficiency, WA agricultural businesses are taking the first steps towards more profitable and sustainable production, as even small actions can lead to significant long-term mitigation.

Introduction

Western Australia's climate has changed over the last century, particularly over the last 50 years. Western Australian agriculture has been on the forefront of this change. The average temperature has so far risen about 1°C. Rainfall has increased over the north and interior, declined along the west coast, and decreased by about 20% over the lower south-west. Estimates suggest that changes in seasonal conditions have reduced annual average farm profits by 23%, or around $29,200 per farm, when considering the period 2001 to 2020 relative to 1950 to 2000 (Hughes et al. 2022).

While producers across Western Australia (WA) have managed to continue to grow their industries in spite of these adverse changes, the challenges of adapting will become increasingly difficult unless action is taken to address the underlying causes of climate change.

The urgency of climate action is widely recognised by industries, markets, consumers and governments. This urgency is felt across industries and across economic sectors, not just by agriculture. However, agriculture is in a unique position to respond to the challenges and opportunities that are emerging in response to climate change. As the global economy decarbonises, opportunities are emerging for agricultural businesses that can demonstrate low-emission or carbon neutral production systems through a verified carbon account.

The purpose of this report is to present an overview of our current understanding of the greenhouse gas emissions attributable to Western Australian agriculture for 2020, 2021 and 2022. The report improves and expands on previous estimates, including the results presented in an earlier DPIRD report by Curnow et al. (2022). As it is not currently possible to estimate sequestration levels for WA agricultural industries, sequestration is covered separately and at the state level. Finally, the report outlines some key implications of the findings.

This report and the estimates presented are not a replacement for verified carbon accounts at the business level. Rather, the report is intended to provide information and context to producers and stakeholders who are interested in this emerging space.

The report reflects our current understanding of emissions and sequestration. Due to the inherent complexity of agricultural systems and the diversity of environments in which they operate, there are considerable uncertainties associated with any modelling of agricultural emissions, especially for a sector as large and diverse as Western Australian agriculture. The estimates contained in this report will need to be revised as new information becomes available and as improvements are made to the way emissions are calculated.

Emissions

To claim low-emissions or carbon neutrality status for their products, producers will need verified carbon accounts that reflect not only on-farm emissions, but also emissions that occur off-farm in the production of inputs such as fertilisers.

Depending on whether emissions are being estimated at the level of an economy (made up of sectors), or whether they are being estimated at the level of an individual business or product, there are different ways to report and categorise emissions. The key differences are summarised below:

- *At the business level*, carbon accounts are used to demonstrate and verify the emissions profile of an individual agricultural business and to understand how different changes to the production systems will impact emissions.
- *At the product level*, the emissions associated with the product are estimated through a carbon footprint. This includes all emissions pre-farm, on-farm and post-farm, including transport, processing and packaging.
- *At the economy level*, emissions are reported for WA and other Australian jurisdictions in the National Greenhouse Gas Inventory Report (NIR). Emissions are grouped into five sectors: agriculture, land use, energy, industrial processes and waste.

Agricultural business or product level emissions will include sources that, at the economy level, are attributed to other sectors. Nevertheless, these emissions are an important part of an agricultural business or product's carbon account. The modelled emissions estimates presented in this section includes all major emissions sources in line with the carbon accounting guidelines for agricultural businesses. The sequestration and land use side of the carbon account is covered later in the report.

Gases

Most of the atmospheric warming effect of emissions from agriculture is due not to carbon dioxide but to the much more powerful greenhouse gases methane and nitrous oxide. The most significant on-farm sources of each gas are outlined below:

- *Methane (CH_4):*
    - enteric fermentation from ruminants
    - decomposition of manure
- *Nitrous oxide (N_2O):*
    - breakdown of nitrogenous fertilisers, legumes and microbes
    - urine from animals
- *Carbon dioxide (CO_2):*
    - breakdown of soil applicants (such as lime)
    - breakdown of urea
    - breakdown of plant residue

Methane, nitrous oxide and carbon dioxide vary in their effect on global warming. To compare these effects, global warming potential (GWP) values are used to express emissions in terms of carbon dioxide equivalents (CO_2e). As each greenhouse gas differs in the length of time it remains in the atmosphere, a time horizon of 100 years is generally used for these values (GWP100). These values are regularly reviewed by the IPCC. The GWP100 conversion factors (CER 2024) developed for the IPCC's Fifth Assessment Report are:

- 1 tonne of carbon dioxide = 1 tonne of CO_2e
- 1 tonne of methane = 28 tonnes of CO_2e
- 1 tonne of nitrous oxide = 265 tonnes of CO_2e

These GWP100 values factors are used in the NIR and in this report. They account for methane's relatively short atmospheric lifetime (after which it breaks down into carbon dioxide), with an average lifetime of about 12 years used in the IPCC's GWP100 calculations. Carbon dioxide and nitrous oxide have much longer atmospheric lifetimes, generally extending beyond 100 years. If we consider a shorter time horizon than 100 years, the relative warming impact of methane increases considerably.

Reporting by scope

In carbon accounting for businesses and products, emissions are often classified into three scopes. Emissions are assigned to a scope depending on where in the value chain they occur. For an agricultural business, the breakdown into scopes goes as follows:

- *Scope 1:* Emissions generated on the farm.
- *Scope 2:* Emissions generated in the production of purchased electricity.
- *Scope 3:* Emissions generated in the production of inputs such as fertilisers, herbicides and fuels, as well as in the post-farm value chain, such as packaging. If feed/livestock is purchased from another business, any emissions that occurred in its production are also included in scope 3.

Scope 1 emissions are sometimes referred to as direct emissions, while scope 2 and scope 3 emissions are referred to as indirect emissions.

Scope 3 emissions can be further broken down depending on where they occur in the value chain. Scope 3 emissions occurring in the production of inputs are referred to as either 'pre-farm' or 'upstream' emissions, while scope 3 emissions occurring post-farm are referred to as either 'post-farm' or 'downstream' emissions. Examples of pre-farm scope 3 emissions include emissions arising via the production of fertilisers, pesticides and other chemicals, or lime extraction. Examples of scope 3 emissions occurring post-farm include off-site waste management.

In this report, we consider all scope 1 and 2 emissions, but only pre-farm scope 3 emissions. Many pre-farm inputs are imported and therefore emissions released in their production occur overseas. Carbon accounts done at a business level for product certification need to account for all these emissions even though these overseas emissions are not captured in the NIR. Post-farm scope 3 emissions are not included in the estimates presented in this report, which is focused on agricultural production systems, but these should be reflected in consumer-oriented life cycle assessments of the carbon footprints of retail products.

Reporting by sector

Australia's greenhouse gas emissions are reported each year in the NIR, which estimates and classifies emissions using a set of rules outlined by the United Nations Framework

Convention on Climate Change. The NIR fulfils Australia's emissions reporting requirement to the United Nations, which enables global comparisons of emissions on a country-by-country basis. The NIR also includes emission estimates at the state and territory level, including for WA.

Indirect (i.e. scopes 2 and 3) emissions of farm businesses are not included as part of the agriculture sector in the NIR. Any indirect emissions that occur overseas in the production of inputs are not included in the inventory for WA, while indirect emissions that occur in WA are accounted for in other sectors. Examples include:

- Emissions from electricity and fossil fuel used on-farm are captured by the energy sector.
- Emissions from the pre-farm production of inputs such as fertilisers and chemicals are captured by the industrial processes sector unless they occur overseas.
- Emissions from the production of feed imported from overseas – as with other imported inputs – are not captured by the NIR.
- Emissions from post-farm handling of waste are captured in the waste sector.

Such emissions are not included in the NIR estimates for the agriculture sector, but they are an important part of the carbon accounts of agricultural businesses.

The emissions attributed to the NIR's agriculture sector have been largely stable between 2014 and 2022, at about 9.6 million tonnes (Mt) CO_2e per annum, as depicted in Figure 2. About 10% of WA's total greenhouse gas emissions in 2022 were attributed to the agriculture sector, not accounting for carbon sequestration. While a central part of an agricultural business' carbon account, sequestration and emissions related to land use-related activities are captured separately under the Land Use, Land Use Change and Forestry (LULUCF) sector.

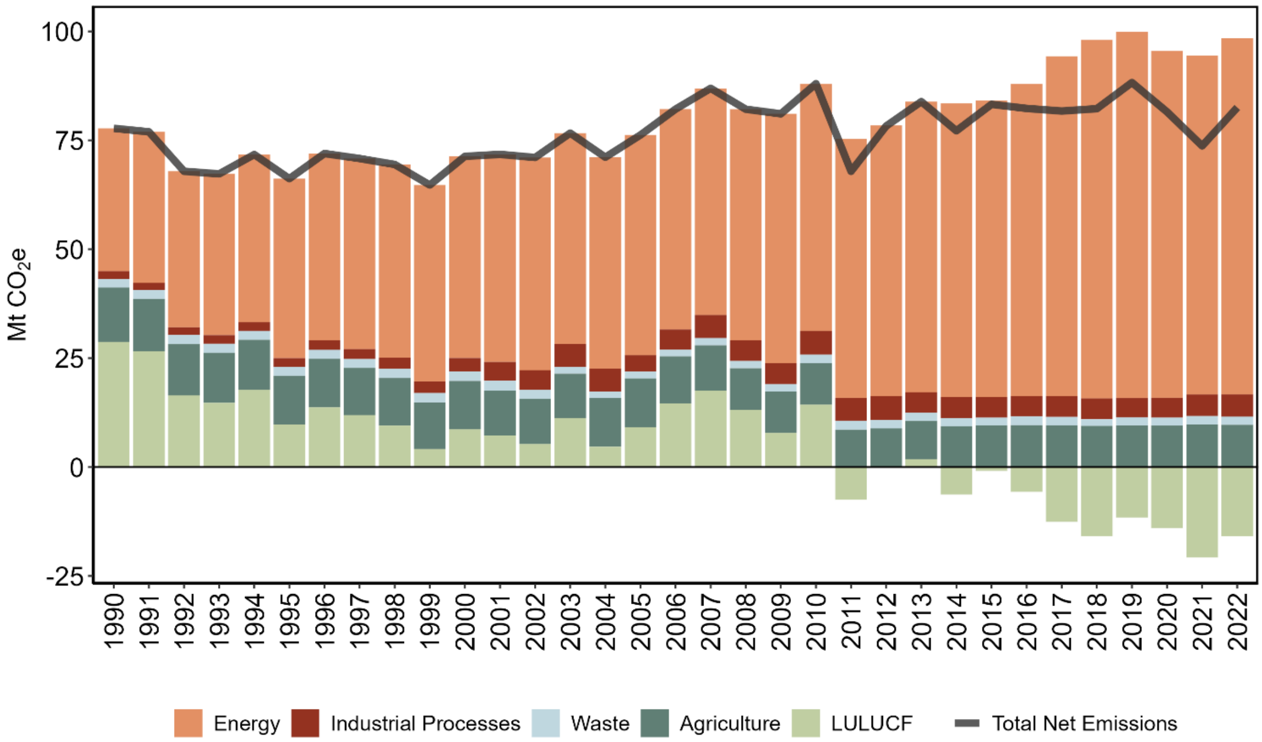

Figure 2: Contribution (Mt CO_2e per year) of the different sectors to WA's total net emissions from 1990 to 2022, as estimated in the NIR

Modelling methodology

DPIRD has undertaken modelling and analysis for each of WA's major agricultural industries. The modelling spans not only the emissions that are included in the NIR, but also WA agriculture's remaining scope 1, 2 and 3 (pre-farm) emissions. This includes emissions attributed to imported inputs, such as feed, fertilisers and chemicals. The modelling provides a more complete picture of each industry's emission profile in a way that is more consistent with carbon accounting for businesses and products.

For each industry, the major emission sources from cradle to farm gate were modelled. For emission sources captured in the agriculture sector of the NIR, each industry's emissions were generally estimated in line with the most recent version of the NIR (DCCEEW 2024), reflecting the latest data and changes to emission factors. Where the NIR does not provide estimates by industry (e.g. use of urea and lime), allocations were informed by Curnow et al. (2022) and d'Abbadie and Machon (2024). Pasture-related emissions were allocated based on herd sizes (dry sheep equivalents) and their geographical distribution. As beef herd numbers in the ABS survey data (which underpins the NI estimates) are likely underreported (Fordyce et al. 2020), estimates for pastoral beef herd instead build on a simple projection of the 2018-19 beef cattle herd inventory from Wiedemann et al. (2023). As it is not feasible to disaggregate NIR data for land use-related changes in carbon stocks, these have not been included.

The modelling approach taken here follows that of Machon & d'Abbadie (2024), and their estimates are presented here for the WA beef, sheep, dairy, pork and grains industries. For the purpose of this report, the WA eggs, chicken meat and horticulture industries were also modelled following a similar approach.

The NI does not estimate WA agriculture's emissions from pre-farm sources, such as the manufacture of fertilisers, chemicals and imported feed, nor from the use of fuel and electricity. Therefore, these emission sources were modelled based on relevant literature. For the grains industry, the modelling follows the methodology of d'Abbadie and Machon (2024), with updated emission factors to align with DCCEEW (2024). For pork, emissions were modelled based on Copley et al. (2024), ratioed to the size of the WA industry. Modelling of energy (electricity and fuel) and purchased feed emissions for dairy was based on Gollnow et al. (2014). For sheep, estimated energy emissions as well as purchased feed volumes were based on Wiedemann et al. (2016), scaled to the WA flock. For feedlot cattle, feed intake was calculated as per the NIR. Emission factors derived from the AusLCI database (ALCAS 2024) were then applied to purchased feed estimates for sheep and feedlot cattle. Feedlot energy use was modelled based Wiedemann et al. (2017). For pastoral beef, energy emissions were estimated from ABARES (2024) survey data. Pre-farm emissions from fertilisers and liming for dairy, sheep and beef were modelled following Lopez et al. (2023) and Lopez et al. (2024), with estimates of each industry's application of urea and other fertilisers derived from the NIR.

There is a high degree of uncertainty for emissions estimates for agriculture. For instance, DCCEEW (2024) indicates uncertainties in the order of 25% for enteric fermentation, 37–55% for manure management and 56% for agricultural soils and liming. As new data and research become available and more accurate emission factors are documented for WA conditions, the estimates provided here will need to be revised.

Due to the current limits in our understanding of industry-level sequestration capacity, sequestration and land use-related emissions were not included in the modelling. Figure 3 summarises the boundary of the emissions modelling (red-dashed line) against the NIR sectors and emissions scopes described above.

Results presented in this report were present based on the best available information as of early 2024, and due to the uncertainties and the limitations, the modelling will need to be revised as information becomes available.

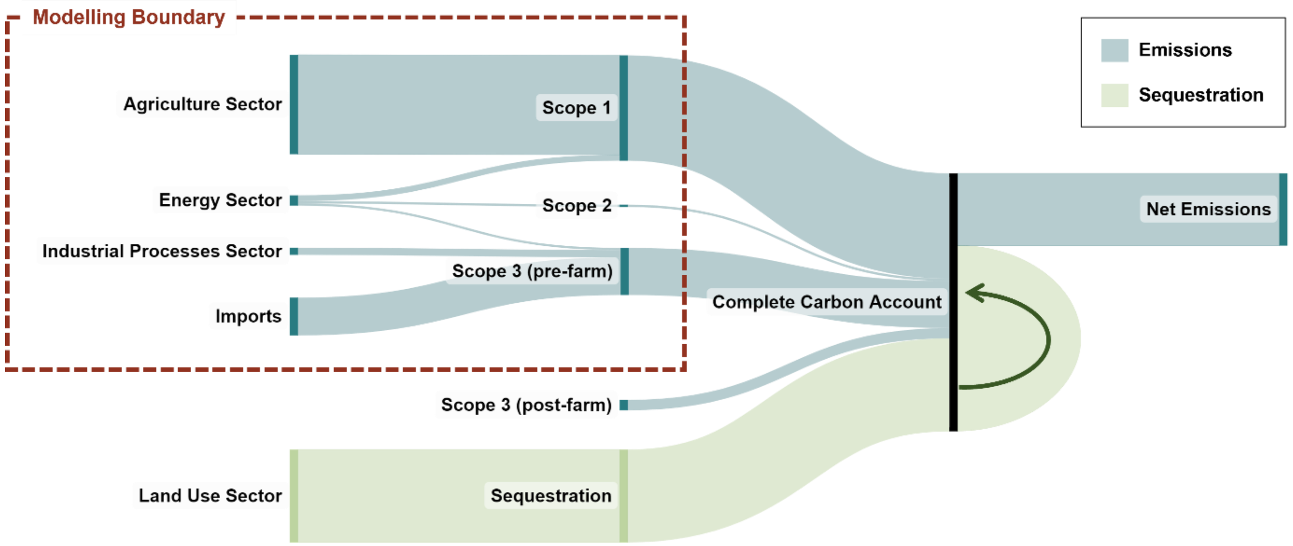

Figure 3: Boundary of the modelling relative to emissions and sequestration sources

Modelling results

Total emissions from WA agriculture industries were estimated to have been about 15.34 Mt CO_2e in 2022. This is slightly lower than the estimated 15.55 Mt CO_2e in 2021, but higher than the estimated 14.82 Mt CO_2e in 2020. These year-to-year fluctuations are typical, reflecting seasonal variability and other factors. As noted previously, this estimate is considerably higher than the estimate of agriculture sector emissions included in the NIR, as it captures agriculture's scope 1 emissions more fully and includes scope 2 and scope 3 (pre-farm) emissions. The estimated total emissions from WA agricultural industries between 2020 and 2022 are summarised by scope in Table 1.

Table 1: Estimated emissions of WA agricultural industries by scope

Scope	2020 [Mt CO_2e]	2021 [Mt CO_2e]	2022 [Mt CO_2e]
Scope 1	11.28	11.68	11.48
Scope 2	0.17	0.17	0.14
Scope 3	3.37	3.76	3.72
Total	**14.81**	**15.55**	**15.34**

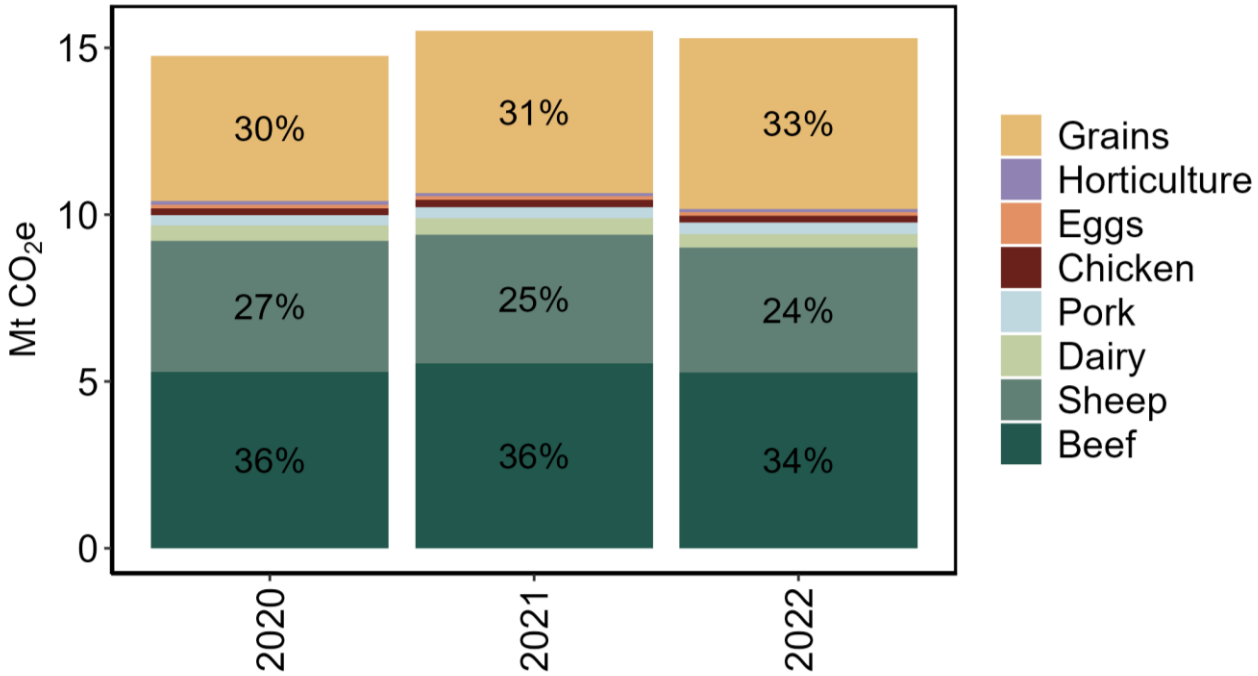

Figure 4: Estimated total emissions of WA agricultural industries

Figure 4 shows the total projected emissions for each year to. Each major agricultural industry was modelled separately and then combined to calculate the total emissions for WA agriculture. Table 2 summarises the results of the emissions modelling for each industry. Scope 1, 2 and 3 emissions by industry in 2022 are provided in Table 3.

Table 2: Estimated total emissions by industry and year

Industry	2020 [Mt CO_2e]	2021 [Mt CO_2e]	2022 [Mt CO_2e]
Beef	5.34	5.58	5.32
Sheep	3.96	3.88	3.77
Dairy	0.50	0.53	0.43
Pork	0.36	0.40	0.42
Eggs	0.14	0.14	0.14
Chicken meat	0.32	0.32	0.32
Horticulture	0.10	0.10	0.10
Grains	4.37	4.87	5.11
Total	**14.82**	**15.55**	**15.34**

Note: Emissions that occur in the production of WA-sourced feed are counted both in the WA grains industry (which produces the feed) and in the livestock industries (which use the feed as an input). This is corrected for when calculating total emissions so that there is no double counting.

Table 3: Breakdown of projected emissions by industry and scope, 2022

Industry	Scope 1 [Mt CO_2e]	Scope 2 [Mt CO_2e]	Scope 3 [Mt CO_2e]	Total [Mt CO_2e]
Beef	4.99	0.01	0.32	**5.32**
Sheep	3.19	0.00	0.58	**3.77**
Dairy	0.35	0.01	0.07	**0.43**
Pork	0.30	0.01	0.10	**0.42**
Eggs	0.02	0.01	0.11	**0.14**
Chicken meat	0.04	0.03	0.25	**0.32**
Horticulture	0.06	0.02	0.02	**0.10**
Grains	2.52	0.05	2.54	**5.11**

Emissions by source

Currently, methane emissions from enteric fermentation contribute the largest proportion (45% in 2020) to WA's total agriculture emissions (Figure 5 and Table 4).

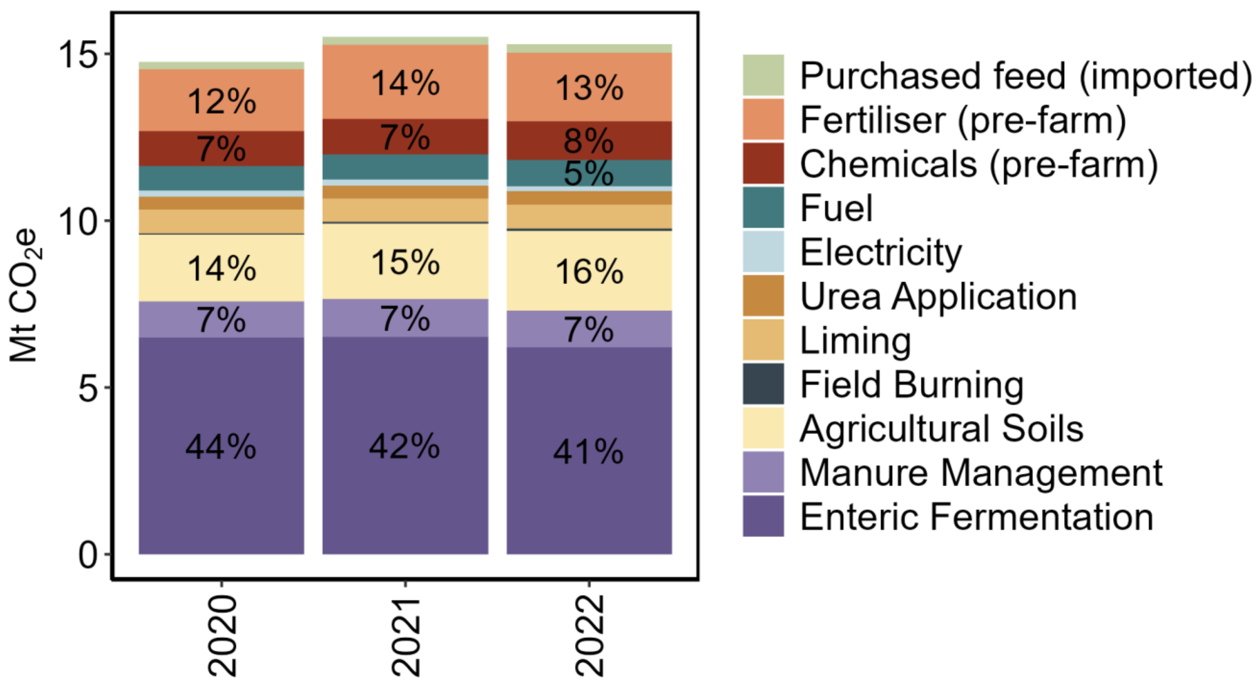

Figure 5: Emission sources for WA agriculture

Emissions sources: Definitions

Enteric fermentation: Methane is emitted as a by-product of rumination, largely by burping cattle and sheep, and to a lesser extent by pigs. It is influenced by feed intake, feed quality and herd size.

Manure management: A combination of methane and nitrous oxide are emitted from manure, especially in intensive industries like piggeries and feedlots. The level of emissions depends on the production system (conventional versus free-range) and how waste is handled.

Agricultural soils: Nitrous oxide is emitted from soils both directly (microbial nitrification and denitrification of fertiliser and manure nitrogen) and indirectly (through nitrogen removed from soils via volatilisation, leaching, runoff or harvest of crop biomass). This source of nitrous oxide is not to be confused with land use-related emissions and sequestration through the accumulation of soil carbon.

Liming: Lime is used to maintain the correct soil pH for optimal plant growth. After lime is applied, carbon dioxide is released during the neutralising process.

Urea application: Urea is an inexpensive source of nitrogen that is widely used in WA agriculture. The application of urea releases the carbon dioxide that was fixed during the industrial manufacturing process.

Field burning of residues: Stubble is usually retained to prevent erosion, increase soil water content and promote soil health. Some paddocks are burnt before seeding, especially when the stubble is heavy and will cause problems with seeding.

Electricity: Emissions from the generation of electricity from the grid.

Fuel: Emissions from the production and consumption of fuels (including diesel and petrol), such as use in vehicles, machinery and irrigation.

Fertiliser (pre-farm): Emissions from the pre-farm manufacture of fertilisers, including urea.

Chemicals (pre-farm): Emissions from the pre-farm manufacture of chemicals such as pesticides and herbicides.

Purchased feed (imported): Emissions from production of imported feed, such as soybean meal. While these emissions occur overseas, they are an important component of carbon accounts for livestock producers who purchase imported feed.

Purchased feed (WA): Emissions from the production of feed within WA, occurring upstream (pre-farm) from the perspective of the livestock industry. To avoid double counting of these emissions, which occur in the WA grains industry, this category is not included when calculating total emissions for the whole of WA agriculture.

Table 4: Total emissions by source

Source	2020 [Mt CO_2e]	2021 [Mt CO_2e]	2022 [Mt CO_2e]
Enteric fermentation	6.50	6.51	6.20
Manure management	1.09	1.14	1.10
Agricultural soils	2.00	2.26	2.39
Field burning	0.04	0.05	0.07
Liming	0.71	0.71	0.71
Urea application	0.39	0.39	0.41
Electricity	0.18	0.18	0.15
Fuel	0.73	0.74	0.77
Fertiliser (pre-farm)	1.84	2.22	2.06
Chemicals (pre-farm)	1.06	1.07	1.17
Purchased feed (imported)	0.29	0.28	0.29
Total	**14.82**	**15.55**	**15.34**

Figure 6 depicts the emissions data Table 4 across each of the industries considered. Industry emissions are divided by source and relative share of the total. The emission profiles of each industry are largely determined by the intensity of the production system.

Enteric methane dominates emissions from the beef (70%), sheep (59%) and dairy (53%) industries. Collectively, WA agricultural industries generated about 6.2 Mt CO_2e from enteric fermentation in 2022 (see Table 3). Manure management contributes about 65% of pork industry emissions and is a significant share of emissions across all livestock industries (about 1.10 Mt CO_2e, Table 3). Emissions from purchased feed make up 75% of the egg industry emissions, 77% of the chicken meat industry emissions and 24% of pork industry emissions. The bulk of the animal feed is from WA grains industry, but most feed-related emissions arise from the small component of imported soybean meal sourced from South America. Just over half of emissions associated with purchased feed is from feed sourced from the WA grains industry, with the rest of feed-related emissions arising from imported feed from outside WA. Feed from overseas is likely to have a higher emissions intensity than WA-sourced feed. A significant share of emissions from the horticulture and grains industries come from lime application and pre-farm production of fertiliser and chemicals.

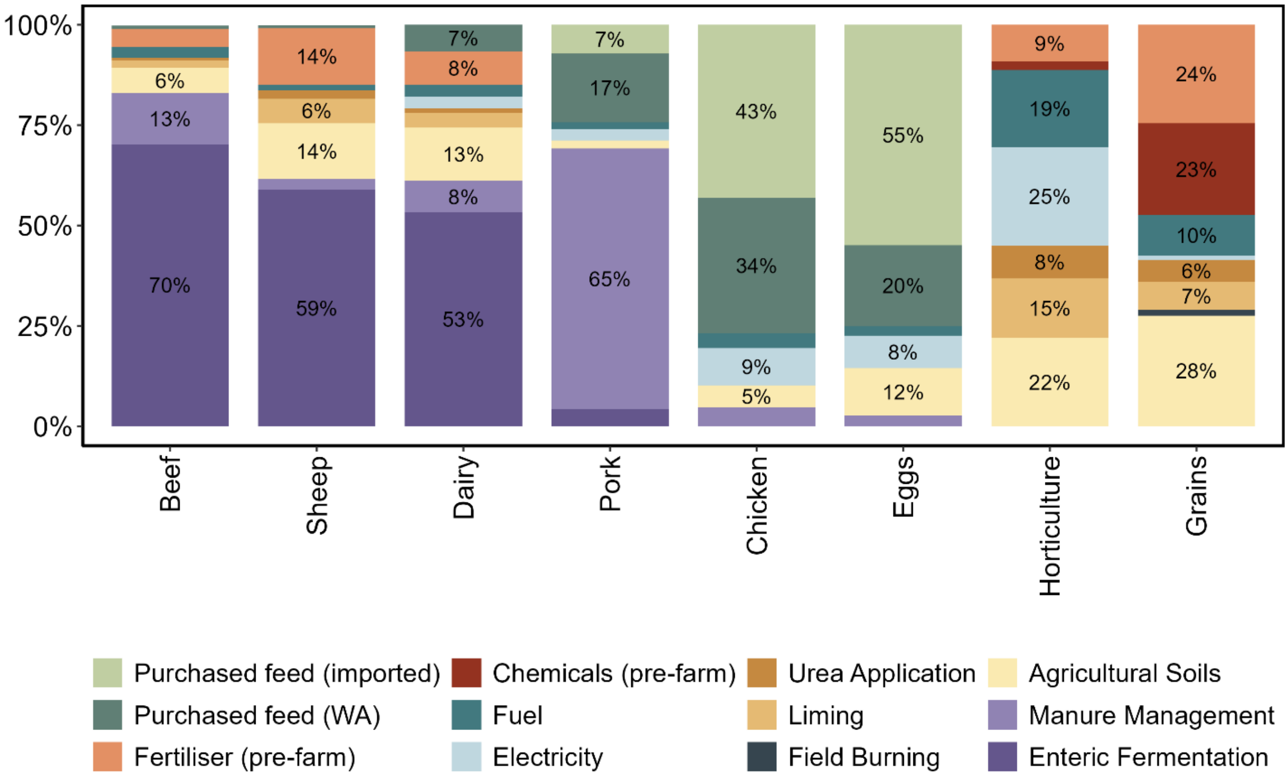

Figure 6: Relative share of estimated industry emissions by source, 2022

Table 5: Breakdown of emissions by greenhouse gas type

Greenhouse gas	2020 [Mt CO_2e]	2021 [Mt CO_2e]	2022 [Mt CO_2e]
Methane (CH_4)	7.53	7.60	7.25
Nitrous oxide (N_2O)	2.06	2.31	2.45
Carbon dioxide (CO_2)	5.49	5.91	5.90
Total	**15.07**	**15.82**	**15.60**

Note: All scope 2 and 3 emissions were modelled as carbon dioxide only.

With changes in the relative prominence of different emission sources (Table 4) there are implications for the relative contributions of methane, nitrous oxide and carbon dioxide toward WA agriculture's total emissions. These changes are summarised in Table 5. Methane emissions have fallen somewhat between 2020 and 2022, both in absolute and in relative terms, while emissions of carbon dioxide and nitrous oxide have both increased.

The following section explores the emissions profile of each industry in greater detail.

Industry profiles

Agriculture plays a fundamental role in Western Australian society and in maintaining the diversity of the state economy. More than 90% of the food eaten by Western Australians is produced on farms and pastoral properties spread across the state. The sector underpins the viability of many regional towns, with agriculture, forestry and fisheries industries employing over 180,000 people along primary industry supply chains and contributing more than $16 billion to the WA economy in 2021-22 (Maharjan et al. 2023). The breakdown by industry of values of production is shown in Figure 7.

Agricultural industries have a strong focus on maintaining their competitive position in world markets. About 70% of WA food and fibre is exported. WA agriculture plays an important role in food security not only for WA's and Australia's growing population, but also for our export partners.

Western Australian agriculture is made up of thousands of small and medium enterprises, most of which are family-run, although corporate ownership of broadacre grains farms is growing. The businesses span broadacre grains (wheat, barley, oats, lupins, canola), extensive livestock (cattle and sheep), intensive livestock (pigs, poultry, dairy) and horticulture (vegetables, fruit, wine).

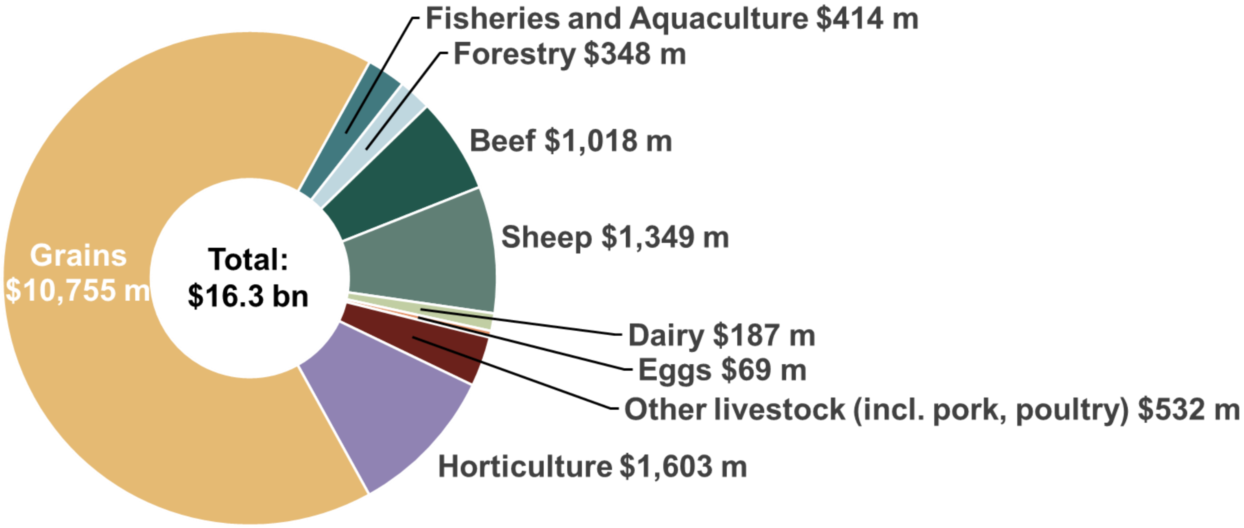

Figure 7: WA agrifood, fibre, fisheries and forestry value of production, 2022
Adapted from Maharjan et al. (2023).

In this chapter, we identify the different sources of emissions for each industry in 2020, 2021 and 2022 and highlight opportunities and potential challenges to mitigating emissions into the future. The estimates do not reflect carbon sequestration, as currently there is insufficient data to produce such estimates at the industry level.

Beef

Total beef industry emissions were estimated to have been about 5.32 Mt CO_2e in 2022 (Figure 8). More than 70% of emissions were methane from enteric fermentation. In 2022, about 13% were attributed to manure management and about 6% to nitrous oxide from agricultural soils. Fuel, feed, lime and fertiliser use contributed about 10% of total emissions.

Emissions attributed to rangeland systems are relatively high on a per-head basis due to lower productivity and longer turn-off time compared to cattle in the South Western agricultural area.

Beef industry facts

WA manages about 10% of Australia's beef cattle herd.

Exports account for about 80% of total production. Half of WA's beef production is slaughtered domestically.

About 65% of WA's herd is managed in the rangelands, mostly *Bos indicus* cattle grazed on native grasses and shrubs. The rest are managed in southern agricultural regions, predominantly *Bos taurus* grazed on improved pastures.

Feedlot herds are estimated to have numbered around 40,000 cattle in 2021.

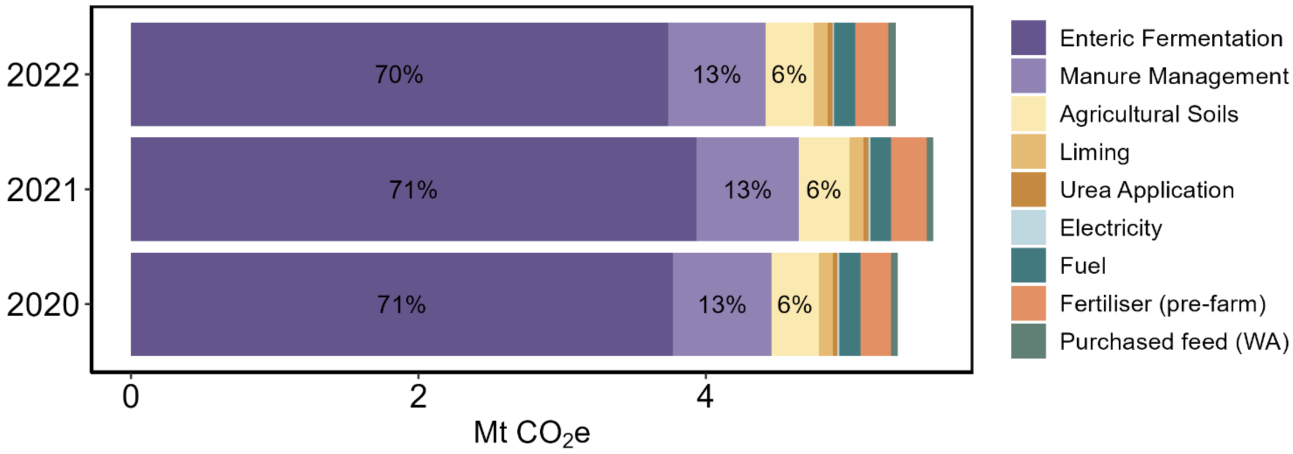

Figure 8: Estimated emission sources for the beef industry

Current mitigation efforts and challenges

The beef industry is developing strategies to reduce methane emissions, including feed and grazing innovations as well as breeding and managing herds for more efficient growth.

Anti-methanogenic feed additives are now being produced for use in intensive livestock systems. While there has been significant global investment into anti-methanogenic feed additives, they may not be available or easily implemented in grazing systems. WA has a relatively small feedlot herd, making widespread uptake of feed additives more difficult in the short term. In the meantime, some mitigation can be achieved through improvements through the development of anti-methanogenic pastures and forages. Improvements in genetics and herd efficiencies, particularly reproduction rates and turn off times, could also contribute to improvements in emissions intensity of beef products.

Sheep

While WA sheep numbers have declined by 65% over the past 30 years, the industry's gross value of production has increased, with farmers generating more value from fewer animals. The reduction in the flock size and gains in production efficiency have resulted in a lowering of the industry's emissions (Figure 9).

Emissions from the WA sheep industry (both wool and sheep meat) were estimated to have been about 3.77 Mt CO_2e in 2022. About 59% was methane generated by enteric fermentation. Agricultural soils and pre-farm fertiliser production each contributed 14%. Smaller volumes of emissions arose from manure management and energy use.

Sheep industry facts

In 2022, the WA flock numbered 13.7 million head, 21% of the national flock.

Most sheep are in the South Western agricultural area on improved pastures. A small number (less than 150,000 head) are in the southern rangelands.

Over the past 30 years, WA's flock has declined by 65%, from 38.4 million head in 1990 to 13.7 million in 2020.

This decline has largely been due to the collapse of the reserve price scheme for wool in 1991, which triggered a gradual shift towards dual-product flocks.

In 1991, wool made up 91% of the value of the industry. By 2022, the proportional value of wool had fallen to 48%.

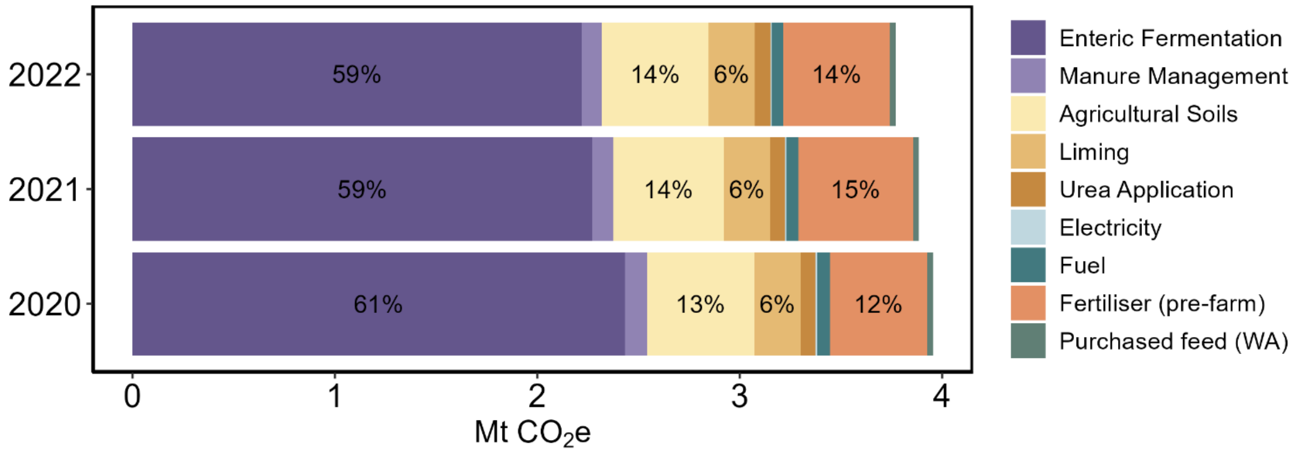

Figure 9: Estimated emission sources for the sheep industry

Current mitigation efforts and challenges

The sheep industry is engaged in a range of mitigation work including breeding and managing flocks for more efficient growth that, along with feed additives and grazing practices, reduce methane emissions. The industry is also working to sequester carbon by planting trees and through best-practice soil management.

While significant global investment has been made into anti-methanogenic feed additives, they may not be available or easily implemented in grazing systems. Smaller decreases in methane emissions can be achieved through improvements in herd efficiencies and genetics and through development of anti-methanogenic forages and pastures such as Biserrula, chicory, plantain and Eremophila, although more research into issues of photosensitivity and palatability is needed.

Dairy

It is estimated that dairy industry emissions totalled 0.43 Mt CO_2e in 2022. More than half of these emissions were due to methane, mostly from enteric fermentation (53%) and, to a lesser extent, collected manure (8%). 13% of emissions were attributed to agricultural soils, including nitrous oxide from manure deposited by grazing animals.

While most dairy cow manure is deposited directly onto pasture, manure collection in dairy provides an opportunity for treatment and storage practices to reduce emissions. Smaller sources of emissions include purchased feed (locally produced hay and grains), energy use, urea application and fertiliser manufacture (Figure 10). Emissions vary between years due to changes in the reported size of the dairy herd.

Dairy industry facts

The WA dairy industry is small compared to other states, with dairy cattle numbers representing under 5% of the national herd.

WA's total herd size has fallen over the past five years. However, genetic improvements have increased milk yield per cow.

With farm consolidation, some farms have increased their herd size.

The industry is dominated by grass-fed systems with most operations found in the higher rainfall southwest.

Most WA milk is supplied as fresh milk and there is little value-adding within the dairy industry.

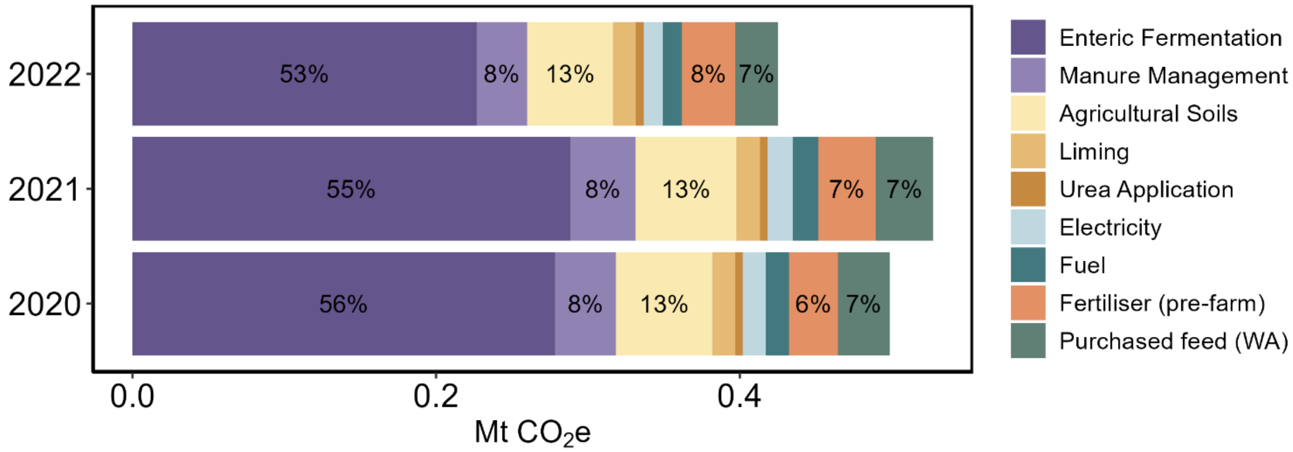

Figure 10: Estimated emission sources for the dairy industry

Current mitigation efforts and challenges

The dairy industry is highly exposed to market drivers from consumers and international milk processors and, as such, is committed to adopting anti-methanogenic feed additives as soon as they are available. WA dairy farmers have been proactive in undertaking carbon accounts of their enterprises and are actively pursuing improvements in nitrogen use efficiency of pastures. There has been a push to capture waste from milking facilities in lined containment evaporation ponds to prevent leaching of nitrogen into the water table.

Most dairy producers are family businesses with limited scope to install covered ponds to capture dairy effluent emissions. Dairy herd manure can only be captured during milking, which accounts for only 11% of the year, and this limits the ability of farmers to reduce emissions from manure.

Pork

Emissions from the pork industry were estimated to have been about 0.42 Mt CO_2e in 2022 (Figure 11). Emissions vary between years due to changes in reported pig numbers. Almost two thirds were methane from manure management and therefore highly dependent on the housing system. Conventional shed operations treat waste in ponds. Deep litter operations generally stockpile straw and manure for use on farm or for sale. In free-range operations, waste is deposited directly onto paddocks with the nutrients used to support pasture and crop production.

Enteric fermentation is a smaller source of methane, at about 4%. About 17% of emissions were from feed purchased within WA, and an additional 7% from imported feed. Agricultural soils, electricity and fuel use are minor sources of emissions.

Pork industry facts

WA's herd numbered an estimated 340,000 pigs in 2019-20, about 15% of the national herd.

The industry is located mainly in the Wheatbelt, Great Southern and South West regions.

The WA pork industry uses three production methods:

- Conventional (raised in sheds)
- Deep litter (raised on straw)
- Rotational outdoor (free-range)

Over the past 20 years, consumer sentiment has driven an increase in the number of free-range operations.

The industry relies mainly on feed grain produced in WA, with some feed in weaner systems sourced from overseas.

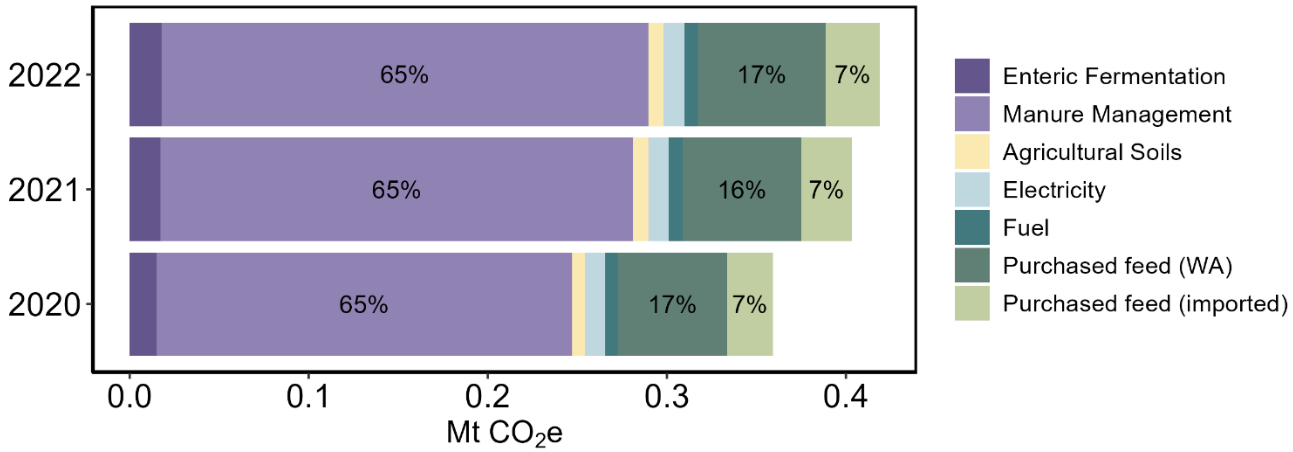

Figure 11: Estimated emission sources for the pork industry

Current mitigation efforts and challenges

The pork industry is proactively developing programs and management tools to improve sustainability and reduce emissions. Most research and development has focused on manure management, by far the largest source of emissions. Methane capture and reuse will require new infrastructure, such as covered ponds, which has high capital costs and not commercially viable at all scales of operation.

While the replacement of imported soybean meal with locally sourced feed has the potential to reduce emissions, it will take time to develop a system based on WA grains, such as lupins. Formulating lower emissions diets for intensive livestock is highly technical as the correct balance of amino acids, energy and fibre is crucial for optimising feed efficiency and growth rate.

Chicken meat

Total emissions from the chicken meat industry were estimated to be about 0.32 Mt CO_2e in 2022 (Figure 12).

About 77% of emissions are from purchased feed, with 34% attributed to WA-sourced feed and 43% to feed imports, mostly soybean meal. About 9% of emissions are from electricity use. Manure management and agricultural soils each contributed about 5%, while fuel use contributed 4%.

Chicken industry facts

The WA chicken meat industry is dominated by two large companies encompassing much of the supply chain. Limited production information is available.

The number of chicken farms in WA has grown significantly since 2018, largely due to changing availability from other Australian states.

Most chicken operations in WA are located on the outskirts of the Perth metropolitan area.

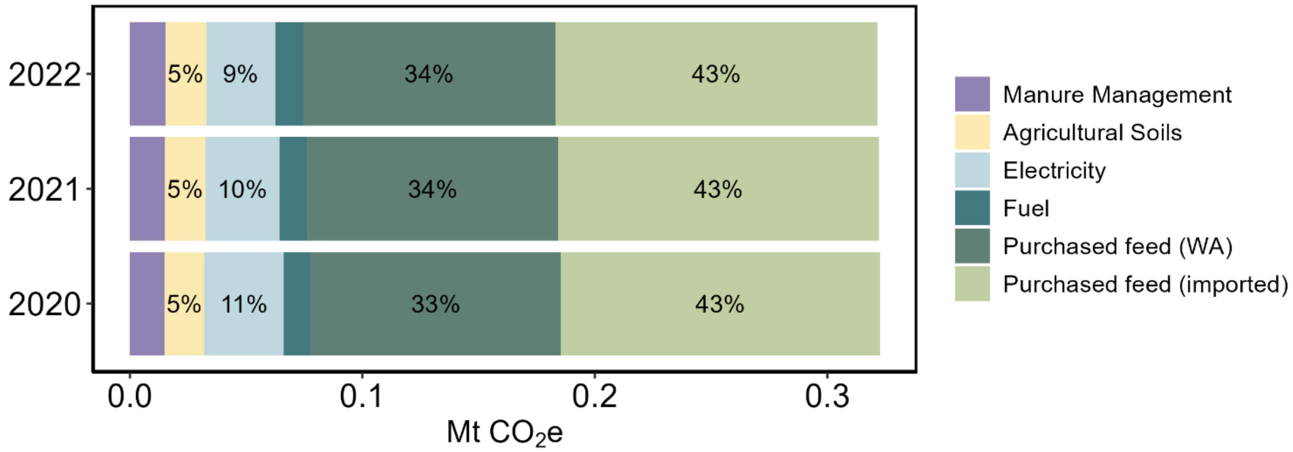

Figure 12: Estimated emission sources for the chicken meat industry

Current mitigation efforts and challenges

The chicken meat industry has identified the major sources of emissions along its supply chain. Mitigation efforts are focused on improving energy-use efficiency and reducing emissions through diets.

Replacing imported soybean meal with WA-produced protein meals or certified low emission soy could play a significant part in mitigating emissions from the industry. However, formulating new diets is highly technical and any new diet will need to optimise feed conversion and early growth. Productivity improvements, including optimised feed conversion, would lower the emissions intensity of WA chicken meat.

The growing trend towards free-range production will likely increase emissions through higher feed conversion ratios and nitrous oxide emissions from deposited manure. Australian research is yet to confirm the scale of this emission source and identify mitigation options for nitrous oxide. Small mitigation opportunities for nitrous oxide may exist by cycling nutrients from deposited manure into crops.

Eggs

In 2022, total emissions from the egg industry were 0.14 Mt CO_2e (Figure 13). Emissions mostly come from feed production, with feed largely consisting of imported soybean and milled WA grain products. About 75% of the industry's total emissions are from feed inputs. A quarter of these emissions originate in the WA grains industry, while the rest occur overseas in the production of imported feed ingredients. Emissions from agricultural soils are the next largest contributor at 12% of total emissions, followed by electricity use at 8%. Smaller volumes of emissions arise from manure management (3%) and fuel use (2%).

Egg industry facts

WA had about 1.4 million layer hens in 2020. The distribution between housing systems is approximately:

- 50% free-range (including mobile egg production operations)
- 30% caged
- 20% barn-laid

In free-range operations, waste is deposited on the outdoor area, with various methods used to manage waste in adjoining sheds. In other operations, waste is captured for direct application onto broadacre crop paddocks (about 60%) or processing by commercial composters (about 40%).

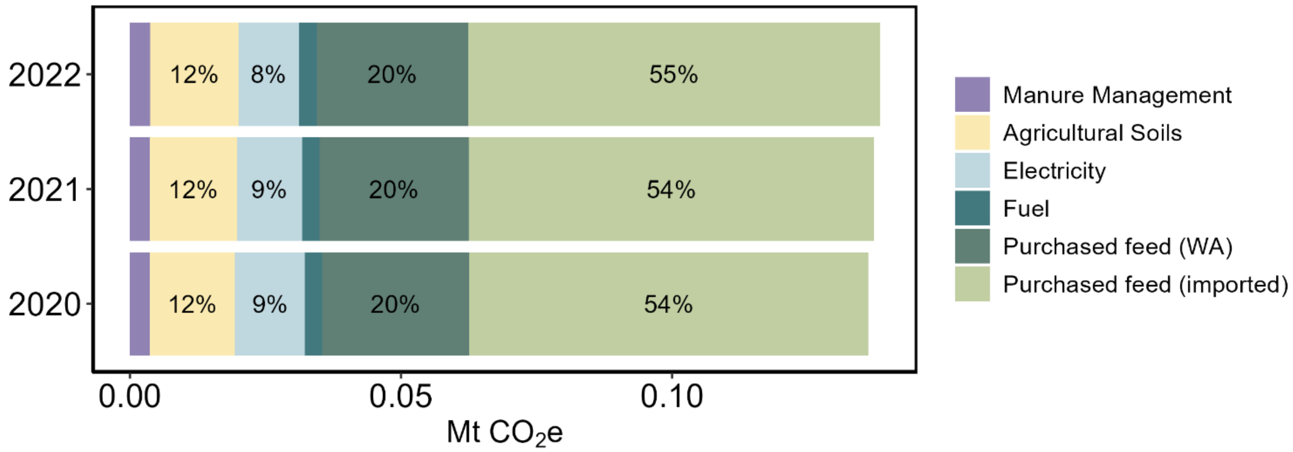

Figure 13: Estimated emission sources for the egg industry

Current mitigation efforts and challenges

Only about a fifth of estimated egg industry emissions occur on-site. Mitigation efforts in the industry are therefore focused on improving energy-use efficiency and moving to lower-emission feed sources with improved feed conversion ratios. Replacing imported soybean meal with WA-produced protein meals could play a critical role in mitigating emissions from the egg industry. However, formulating new diets is highly technical and any new diet will need to maximise feed conversion ratios and early growth.

Companies such as Coles, Woolworths, Aldi, Nestlé and Unilever have either already transitioned or committed to cage-free eggs by 2025. In response, production is shifting towards cage-free systems. The growing trend towards free-range egg production will likely increase emissions through higher feed conversion ratios and nitrous oxide emissions from deposited manure. Small mitigation opportunities for nitrous oxide may exist by cycling nutrients from deposited manure into crops.

Horticulture

In 2022, total emissions from the horticulture industry (annual and perennial crops) were estimated at 0.10 Mt CO_2e (Figure 14). About 44% of emissions were from energy use, reflecting the industry's reliance on electricity and fossil fuels for machinery, irrigation, packing sheds and cool rooms. Other significant emissions sources include agricultural soils (22% of total emissions), liming (15%), and indirect emissions from the production of fertilisers (9%) and chemicals (2%).

Horticulture industry facts

WA horticulture products include fruit, vegetables, grapes, oils and flowers. Vegetables generate 48% of WA's horticultural production value, while fruit and nut varieties generate about 44%.

The industry spans the Ord River irrigation area in the north, Carnarvon in the Gascoyne, the South West and coastal sands near Perth.

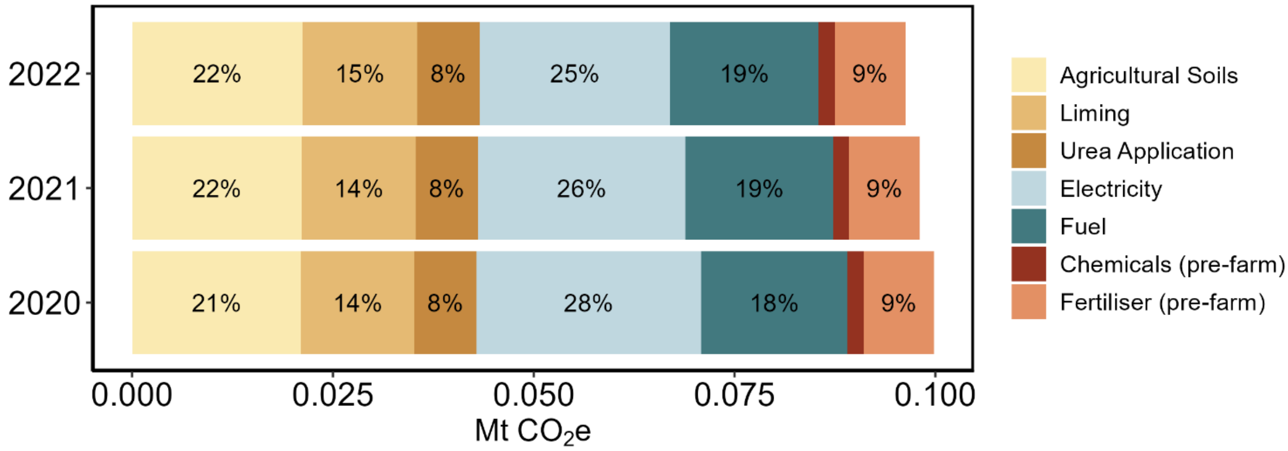

Figure 14: Estimated emissions from the horticulture industry

Current mitigation efforts and challenges

The horticulture industry is highly exposed to markets seeking to reduce carbon footprint of horticultural supply chains. Industry groups such as Vegetables WA are helping producers develop skills in carbon accounting and mitigation plans.

Managing fertiliser use on deep sandy soils will require better monitoring systems to achieve greater fertiliser use efficiencies. The development of low-emissions fertilisers will help reduce indirect emissions.

For many growers, improving irrigation energy and water use efficiencies are an important challenge, which if addressed could yield significant mitigation co-benefits. Electrification of farm equipment and on-farm cooling and processing facilities will provide significant reductions in emissions, however most horticultural enterprises will take some time to replace plant and machinery with emerging electric models.

Grains

2022 emissions from the grains industry are estimated to have been 5.11 Mt CO_2e. About half occurred off-farm in the production of inputs, mostly fertilisers (25% of total emissions) and chemicals (23%). The largest on-farm emission source was nitrous oxide released from the breakdown of crop residues and loss of nitrogen from agricultural soils (28%). Other sources of emissions were fuel (10%), urea (6%) and lime (7%). Smaller sources of emissions include electricity use and field burning of crop residues (Figure 15).

Grains industry facts

The WA grains industry is dominated by wheat, barley, canola and oats, with lupins and other pulses also produced.

About 90% of production is exported. Production varies considerably from year to year depending on seasonal and market conditions.

Cropping is rainfed and often part of a mixed system with animals grazed on pastures in rotation with crops.

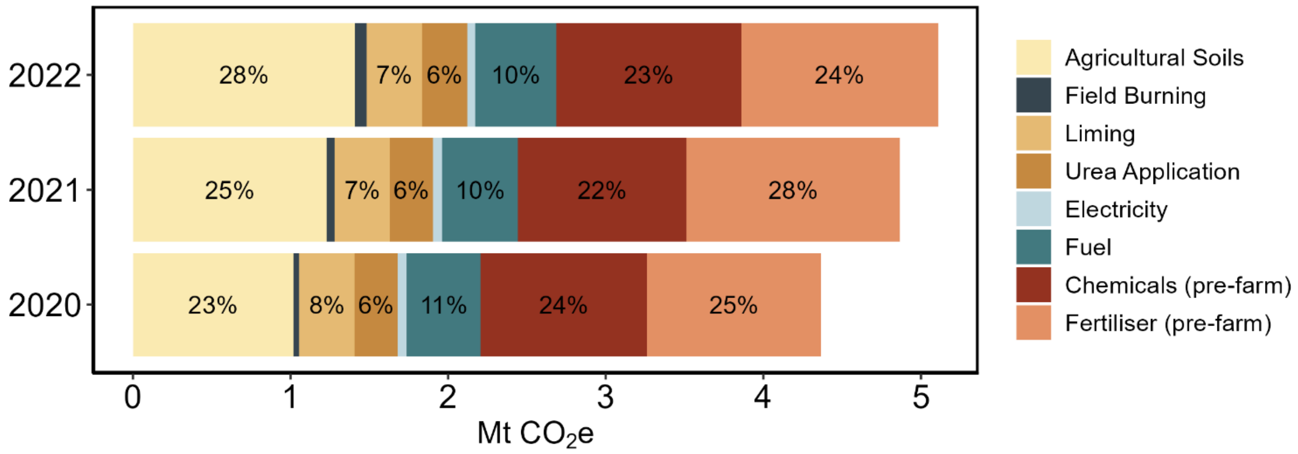

Figure 15: Estimated emission sources for the grains industry

Current mitigation efforts and challenges

Grains industry bodies are undertaking carbon accounting and benchmarking to better understand emissions profiles and mitigation opportunities. A significant amount of WA canola is exported to biofuel markets in the European Union, which requires producers to follow strict environmental guidelines. The CBH group has been working on providing carbon-neutral barley for beer manufacture (CBH 2023). The industry is investigating lower-emissions fertilisers and fertilisers that will support increased nitrogen use efficiency to reduce emissions.

DPIRD produces information and recommendations around nitrogen use efficiency and optimising cropping systems for yields and profit (DPIRD 2024c). DPIRD also models emissions under different production scenarios including liming strategies, fertiliser timing and rotations. An opportunity could exist to better cycle nutrients from intensive livestock onto crops. Limitations include distance to use, volumes available and processing of nutrients suitable for transport and broadscale application.

Most WA cropping systems are minimum or no-till, sowing crops into residues from previous crops. These systems are dependent on herbicides, which makes up a significant proportion of production costs and of emissions.

Carbon sequestration

Carbon sequestration refers to the process of capturing and storing atmospheric carbon in vegetation and soils. Both emissions reductions and carbon sequestration are crucial to carbon neutrality in agricultural value chains. This section outlines how sequestration is accounted for and analyses the potential for sequestration on agricultural land.

Agricultural and pastoral enterprises manage 40% of WA's landmass, or just over 100 million hectares, making agricultural land management a key determinant of sequestration at the state level. More than 38% of land within Western Australia's pastoral land division (rangelands) consists of privately held leasehold areas for grazing. In the South Western agricultural area, 60% of land is privately owned agricultural land.

State-level estimates

In the NIR, carbon sequestration is accounted for under the land use, land use change and forestry (LULUCF) sector. The LULUCF sector also captures emissions resulting from direct human-induced land use, land use change and forestry activities, including activities in agriculture. Carbon sequestration and emissions are estimated for six land use types:

- Forestland
- Cropland
- Grassland
- Wetlands
- Settlements
- Other Land

Figure 16 details the land use categories attributable to WA's LULUCF sector. Every year, the Department of Climate Change, Energy, the Environment and Water (DCCEEW) collates spatial data to model land use across the landmass and estimate carbon sequestration and emissions are then estimated for each land type. A significant component of the LULUCF account is transitions between land types (e.g. forestland to cropland or cropland to forestland), which have implications for emissions and sequestration levels. WA agricultural industries operate across several of these land use categories, and because so much of WA is managed by agriculture, agricultural activities significantly impact carbon sequestration and emissions attributed to LULUCF.

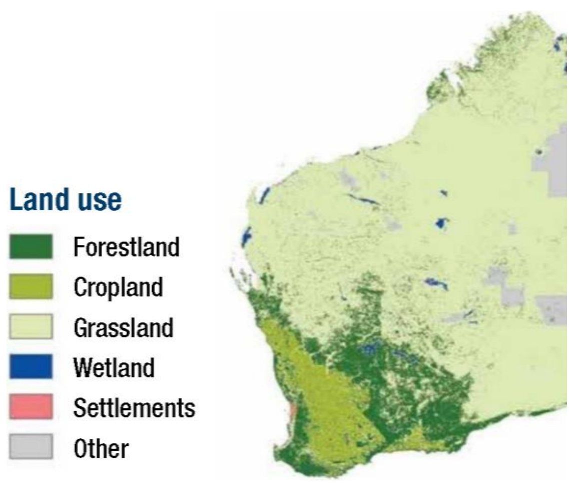

Figure 16: Land use in Western Australia. Source: DCCEEW (2024)

Figure 17 shows that from 1990 to 2010, WA's LULUCF sector was a net emitter of greenhouse gases, meaning that more carbon was emitted from land use related activities (such as land clearing and fires) than was sequestered. Since 2010, this picture has changed, and the LULUCF sector has in most years been sequestering significantly more carbon than it emitted. As a result, the LULUCF sector has helped to lower the overall net emissions of the WA economy (see Figure 2.1). This has largely been driven by WA forestland, with a smaller contribution from cropland soils in some years (2015 to 2022).

In 2022, net sequestration from the LULUCF sector was 15.9 Mt CO_2e, equivalent to about 16% of total emissions from the rest of the WA economy (98.4 Mt CO_2e). This implies that WA's net emissions in 2022 were about 82.5 Mt CO_2e. While on average the LULUCF sector contributes significantly to lowering WA's estimated net emissions, the sequestration levels are highly variable from year to year due to a number of factors such as rainfall, fires and the amount of biomass that is harvested, cleared or planted.

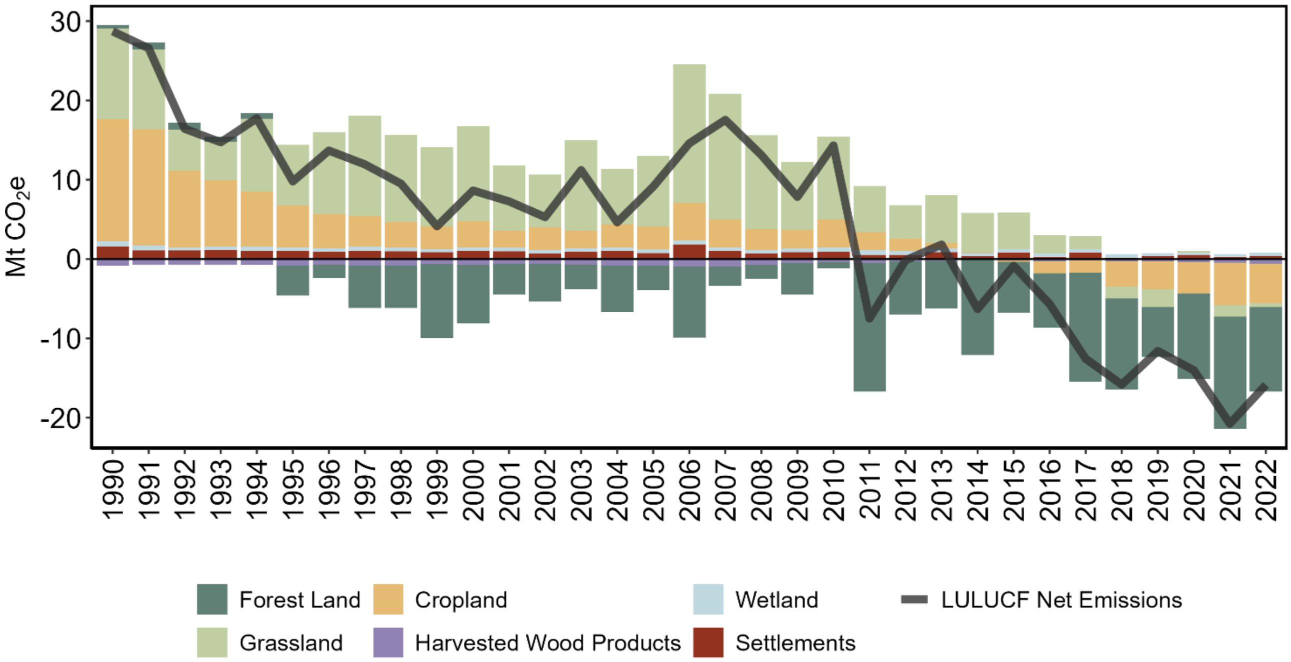

Figure 17: Greenhouse gas emissions (above horizontal axis) and sequestration (below horizontal axis) from the WA LULUCF sector (1990 to 2022), as estimated in the NIR

Forestland

Forestland is the main carbon sink for WA and includes forests, plantations and remnant bushland. Forestland is mainly above-ground carbon and accounted for 10.6 Mt CO_2e of sequestration in 2022 (Figure 17). Forestland includes all lands with a vegetation height of two metres or higher and a crown canopy cover of 20% or more over an area of at least 0.2 hectares (DCCEEW 2024). The NIR distinguishes between permanent forestland (e.g. national parks and reserves) and land that has converted to forestland (e.g. regrowth on deforested land, natural regeneration and plantations).

Cropland

Cropland occurs across the WA broadacre agricultural zone. Carbon flux in this category is influenced primarily by soil carbon content and is driven by season, crop types and rotations, tillage practices, soil improvement techniques (e.g. green manuring) and irrigation. For the last 8 years, WA's croplands have been sequestering more carbon, whereas prior to 2014 they had consistently been net emitters (see Figure 17). For instance, in 2022 cropland sequestrated 5.0 Mt of CO_2e, while over the previous five years (2017 to 2021), cropland sequestered an average of 3.5 Mt of CO_2e each year.

Grasslands

WA grasslands vary from extensively managed savannas in the arid interior and across the rangelands through to intensively managed continuous pasture. Grasslands vegetation is generally dominated by perennial and annual grasses with low tree cover (less than 20%), with grazing as the predominant land use on agricultural land. In 2022, WA's grasslands sequestered 0.4 Mt CO_2e. However, over the five years between 2017 and 2021, the grasslands fluctuated between emitting 1.6 Mt CO_2e in 2017 and sequestering 2.3 Mt CO_2e in 2019 (Figure 17). Carbon flux in this category is influenced primarily by sparse woody vegetation and soil carbon. Carbon fluxes in semiarid and tropical grasslands (Rangelands) are influenced primarily by rainfall, fire and grazing pressure while carbon fluxes in the high rainfall grasslands are influenced primarily by grazing intensity, pasture composition and fertiliser regimes.

Wetlands, settlements and other land

The remaining land use types (wetlands, settlements and other land) have limited impact on agriculture and are small contributors to overall emissions in WA.

Methods for businesses

There are several approved methods for increasing carbon sequestration. These are captured in the Australian Government's ACCU Scheme (previously the Emissions Reduction Fund). Businesses can use these methods to offset their emissions, hold as an asset, or sell into the secondary market.

Vegetation:

- Re-establish native forest cover via promoting regrowth by reducing livestock grazing intensity and controlling and suppressing weeds and pests to enable revegetation or rehabilitation.
- Establish new forests (mallees and other species) via direct seeding or planting of seedlings where there is currently no forest (e.g. cropland, grassland). This can include harvested and non-harvested plantations.

Savanna fire management:

- Increase sequestration in dead organic matter and avoid emissions by reducing the frequency and intensity of late dry season fires in northern Australia.

Management of agricultural soils to increase soil carbon:

- Convert annual pasture to perennial pasture.
- Increase crop or pasture yield through irrigation, applying ameliorants or nutrients.
- Convert cropland to permanent pasture.
- Alter the stocking rate, duration or intensity of grazing.
- Retain stubble after a crop is harvested.
- Convert from intensive tillage practices to reduced or no tillage practices.
- Use a cover crop to promote soil vegetation cover, improve soil health or both.

There is high confidence that savanna fire management (in the Kimberley region), establishing new forests as either plantations, blocks or belts or re-establishing native forests on pastoral lands in WA's rangelands can sequester carbon.

The potential of soil carbon methods in a WA context is uncertain. Managing soils to increase soil organic carbon may have localised success but overall, there is low confidence in achieving widespread sequestration for WA due to:

- Limited (and unreliable) summer rainfall to sustain perennial pasture systems.
- Highly weathered soils resulting in very low sequestration potential.
- Suitable areas in the higher rainfall zones already having converted to perennial pastures (apart from some small pockets of high-value pasture species such as lucerne and perennial ryegrass in very high rainfall zones).
- Dominance of profitable and high-yielding cropping enterprises in broadacre agricultural areas with few and often unimproved pasture phases.
- More than 90% of WA cropping land is already under minimum tillage.
- Average temperatures in the rangelands and parts of the northern and eastern wheatbelt will limit soil carbon sequestration regardless of rainfall.

Limitations

Estimating the proportion of sequestration that occurs on agriculturally managed land compared to Crown land and reserves is difficult because the NIR does not provide a regional breakdown of land tenure. Curnow et al. (2022) estimated that, in 2020, about 7 Mt CO_2e of carbon sequestration could be attributed to agriculturally managed land, equivalent to about three quarters of the state-level estimate. However, this estimate relied on the then-available NIR data (DCCEEW 2022), which is now outdated.

Estimating the area of grassland on agricultural land versus crown land is challenging, as it consists of vast areas of spinifex and sparse woody grasslands in the rangelands along with a smaller area of high-rainfall pastures in the South Western agricultural area. It is assumed that 38% of grassland is held by private/leasehold managers across WA, although this likely underestimates the true area. Estimates of carbon fluxes at a regional level are not yet available from DCCEEW. This lack of regional-level data makes it impossible to determine the extent of grasslands sequestration in the Rangelands and the South Western agricultural area.

Plantations and revegetated areas are likely to occur on agricultural (previously cleared) land, with many land managers actively rehabilitating forests and bushland on farms. About 14% of remnant vegetation is found on farmlands, so it is expected that much of the sequestration in this category occurs on privately held lands. DPIRD is working with DCCEEW to improve the allocation of sequestration to agriculture.

While accurate estimates of sequestration across WA are likely to be central to carbon neutrality, current estimates have a very high degree of uncertainty due to a lack of accurate sequestration data for grassland and forestland. This gap in data limits the state's capacity to accurately determine the likely availability of sequestered carbon for offsetting emissions – both in the agricultural industries but also for hard-to-abate sectors like mining. In addition, at the farm level, better accounting methodologies are required to monitor carbon sequestration dynamics more accurately for insetting purposes.

Implications

The results presented in this report provide a new perspective on emissions from Western Australian agricultural industries. The emissions estimates presented are consistent with the frameworks that an individual producer is likely to encounter as corporations, consumers and finance markets increasingly request verified carbon accounts for agricultural products. The results may be used by producers who seek a guideline or benchmark against which to assess their own initial carbon accounts.

The estimated emissions presented in previous sections, including the emissions profiles presented for each industry, are statewide aggregates, and the picture revealed by the carbon accounts of individual producers may look very different. For instance, some livestock producers may source more or less of their feed from WA than is the case for the whole of their industry. Therefore, undertaking a farm-level carbon account is a valuable first step for producers looking to determine their on-farm emissions and start the journey towards emissions mitigation.

Individual producers who seek to lower net emissions will likely need to utilise on-farm sequestration in addition to emissions reduction efforts. The role for sequestration in reducing net emissions is a reflection of the unique characteristics of agricultural production and land use, as well as an acknowledgement of the fact that agricultural emissions are generally considered hard to abate.

Lowering net emissions across WA’s agricultural industries is a significant task that will take time and require the adoption of a broad suite of mitigation strategies as well as the development of better understanding of on-farm sequestration potentials. Some agricultural industries will be able to reduce emissions more easily in the short term while others will be more constrained by technical limitations and existing infrastructure. Sequestration will likely play an important role in offsetting hard-to-abate emissions.

The diversity of emission sources that contribute to the emissions for each industry means that there is no single pathway for a sector as diverse as WA agriculture to lower its carbon footprint. Rather, businesses within each industry may draw on several complementary mitigation strategies that align with its profitability objectives. It is generally the case that improvements to production efficiencies will benefit both profitability and emissions intensity. Those agricultural businesses who are able to produce more outputs from fewer inputs are likely to be both profitable and also to have a lower emissions intensity than their competitors. This may provide a further competitive advantage as consumers and corporates increasingly demand lower emissions intensity products. Even if the mitigation impacts are small, the impacts of small improvements in efficiency and profitability could lead to a multiplier effect that enables further mitigation over time (Kingwell 2023, Machon & d’Abbadie 2024).

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