ACHIEVING NET NEGATIVE EMISSIONS IN A PRODUCTIVE AGRICULTURAL SECTOR: A REVIEW OF EMISSION SOURCES AND MITIGATION OPTIONS

OUTLINE

Aim: Provide an up-to-date review of Australian agricultural emissions and the potential of mitigation options

Context and Background

- Australian agriculture and agricultural emissions
- Emissions intensity across sectors

Mitigation Options

- Production efficiency
- Methane
- Nitrous Oxide
- Land-based CO2
- Renewables

Discussion: application to mitigation scenarios

AUSTRALIAN AGRICULTURE

Background and context

2015–16, the gross value of Australia's agricultural production was $56 billion

- 15% of Australian exports by value, $44.7 billion

National Farmer's Federation has a goal of reaching $100 billion by 2030.

Major industries include red meat, wheat, dairy, wool, sugar, and wine.

In 2015, agriculture occupied 3.8 million km ^{2} (50% of Australia's land area)

- 3.2 million km^2 (about 82%) used for grazing
- 3.14 million km^2 (4%) used for growing crops

ABARES, National Farmer Federation, 2018

AGRICULTURAL LAND USE OF AUSTRALIA 2010-2011

Land Use	Area (km^2)	Percent (%)
Grazing natural vegetation	3,448,896	44.87%
Grazing modified pastures	710,265	9.24%
Dryland cropping	275,928	3.59%
Dryland horticulture	743	0.01%
Irrigated pastures	6,048	0.08%
Irrigated cropping	9,765	0.13%
Irrigated horticulture	4,552	0.06%
Intensive animal and plant production	1,414	0.02%

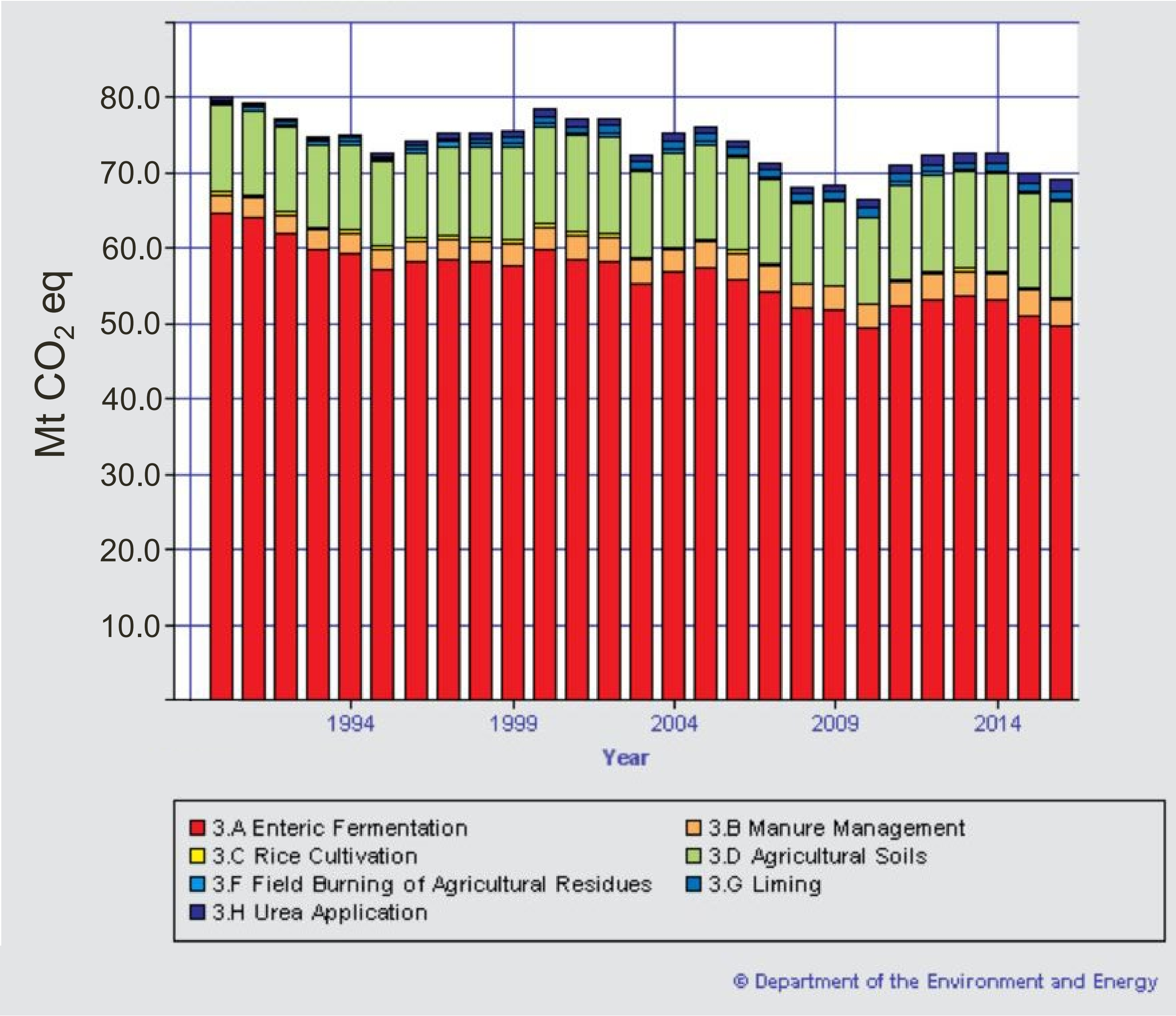
ABARES 2016

AUSTRALIAN AGRICULTURAL EMISSIONS

National Inventory 1990 to 2016

Agricultural emissions account for about 15% of national emissions excluding land use change

69.1 Mt CO_2eq in 2016

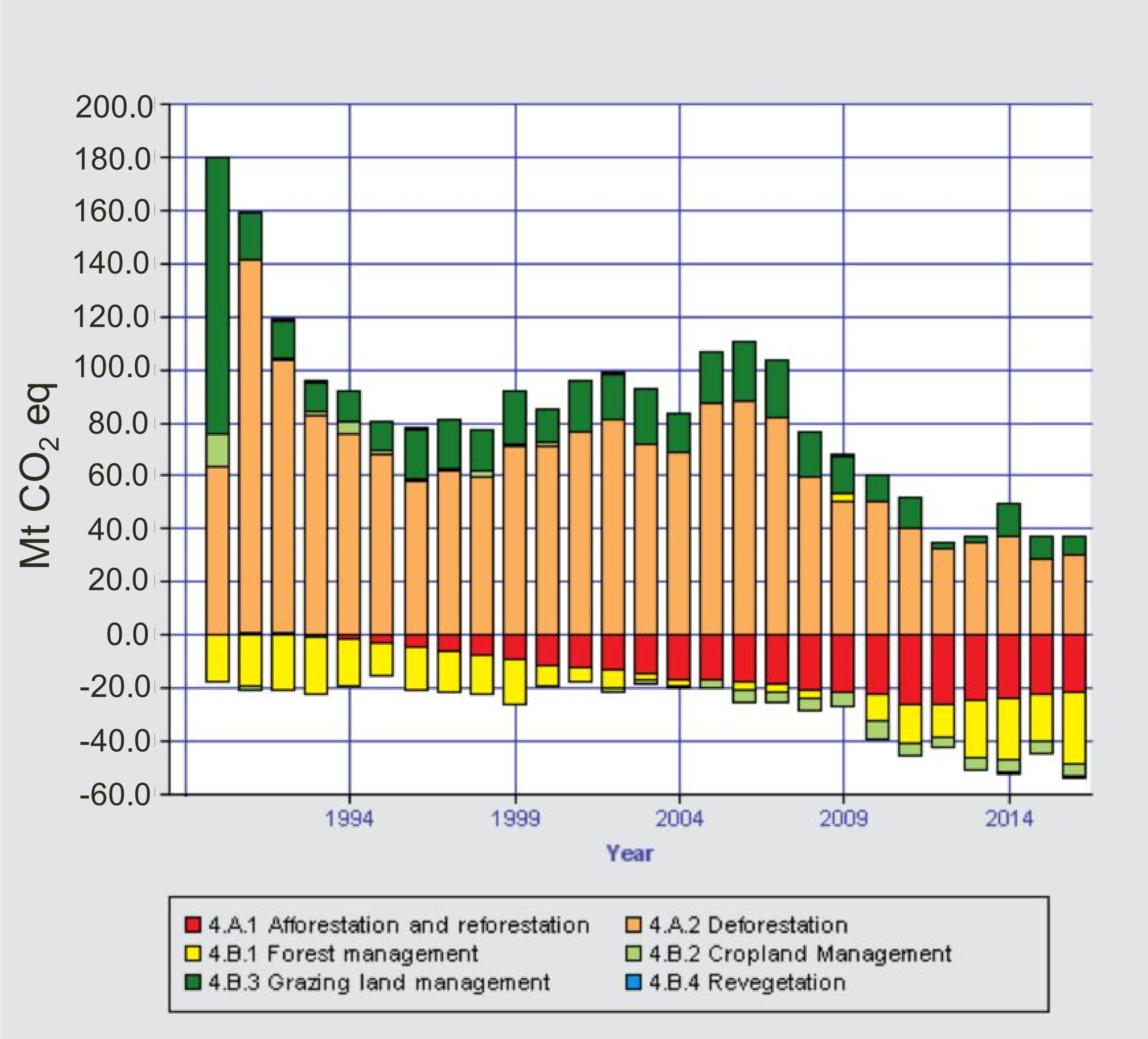


AGEIS

AUSTRALIAN LAND USE & LAND USE CHANGE EMISSIONS:

National Inventory 1990 to 2016

Most deforestation occurs for grazing purposes



AGEIS

AUSTRALIAN EMISSIONS

Projections:

11.4% to 43.6% increase in agricultural emissions by 2030

The Department of the Environment and Energy (2017) projections:

Agriculture

- 2020: 73 Mt
- 2030: 78 Mt

Land Use & Land Use Change: land clearing between 30 and 40 Mt through 2030

The Centre for International Economics Projections (2013)

Agriculture (excluding LULUCF)

- 2030: 112 Mt
- 2050: 133 Mt

Globally agricultural production and emissions are increasingly decoupled

39% and 44% reduction in EI from crop and animal products, respectively

AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

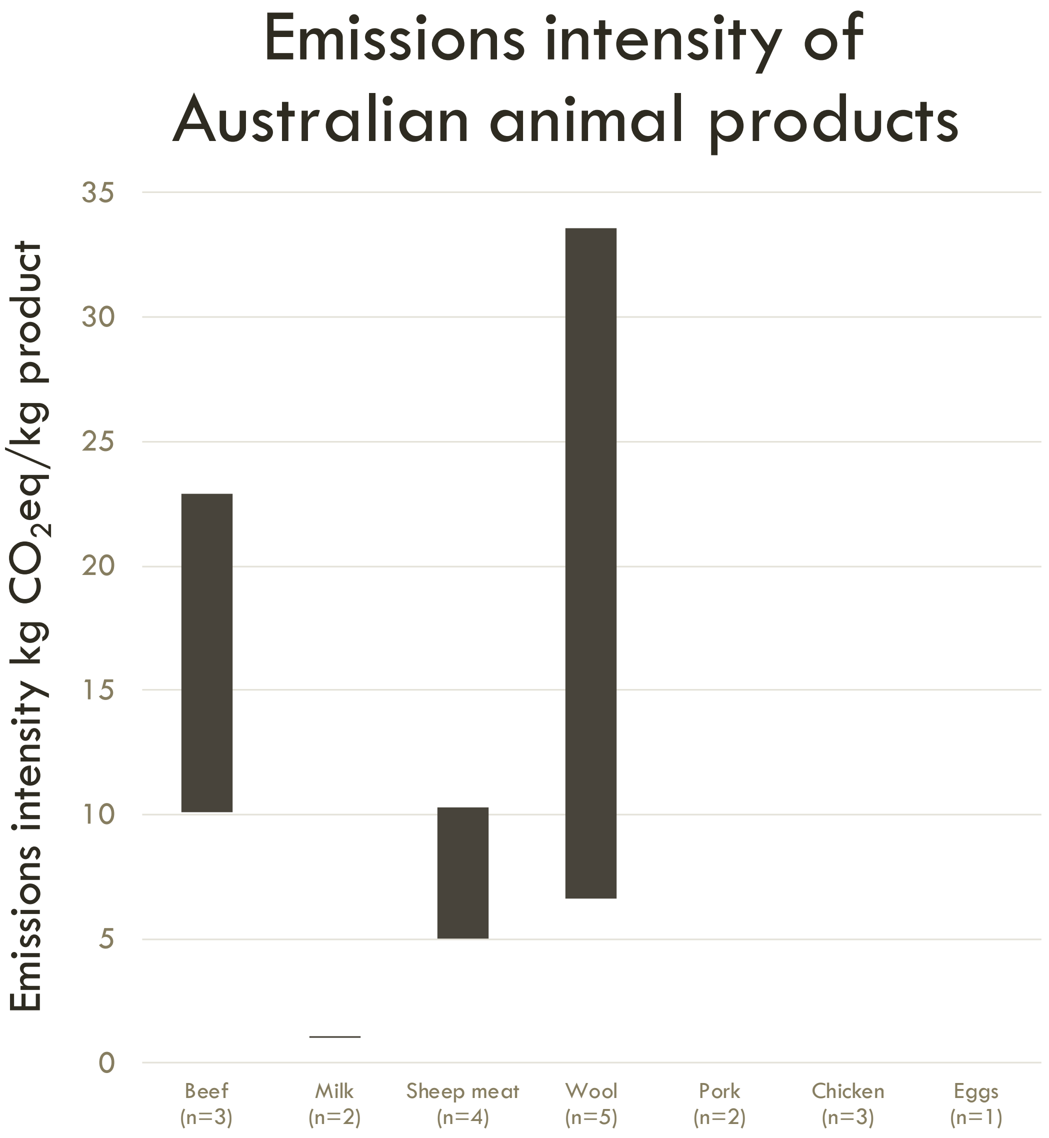
Major GHG:

Enteric methane (excl land use)

- Beef and sheep: often >70% EI
- Milk: 55-57% EI

Estimated annual emissions of beef and sheep meat in 2015 were 68.6 Mt

- enteric methane (≈55%)
- land use change (≈35%)



Mayberry et al 2018, Eady *et al.* 2011b, 2012, Ridoutt *et al.* 2011, Wiedemann *et al.* 2016a, 2016b, 2015c, Peters 2010, Clune 2017, Gollnow *et al.* 2014, Christie 2012, Biswas *et al.* 2010, Brock et al 2013

AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

Pork: 2.1 to 4.5

Major GHG: Manure methane 66% (n=1)

Estimate of annual emissions: 2.52 Mt

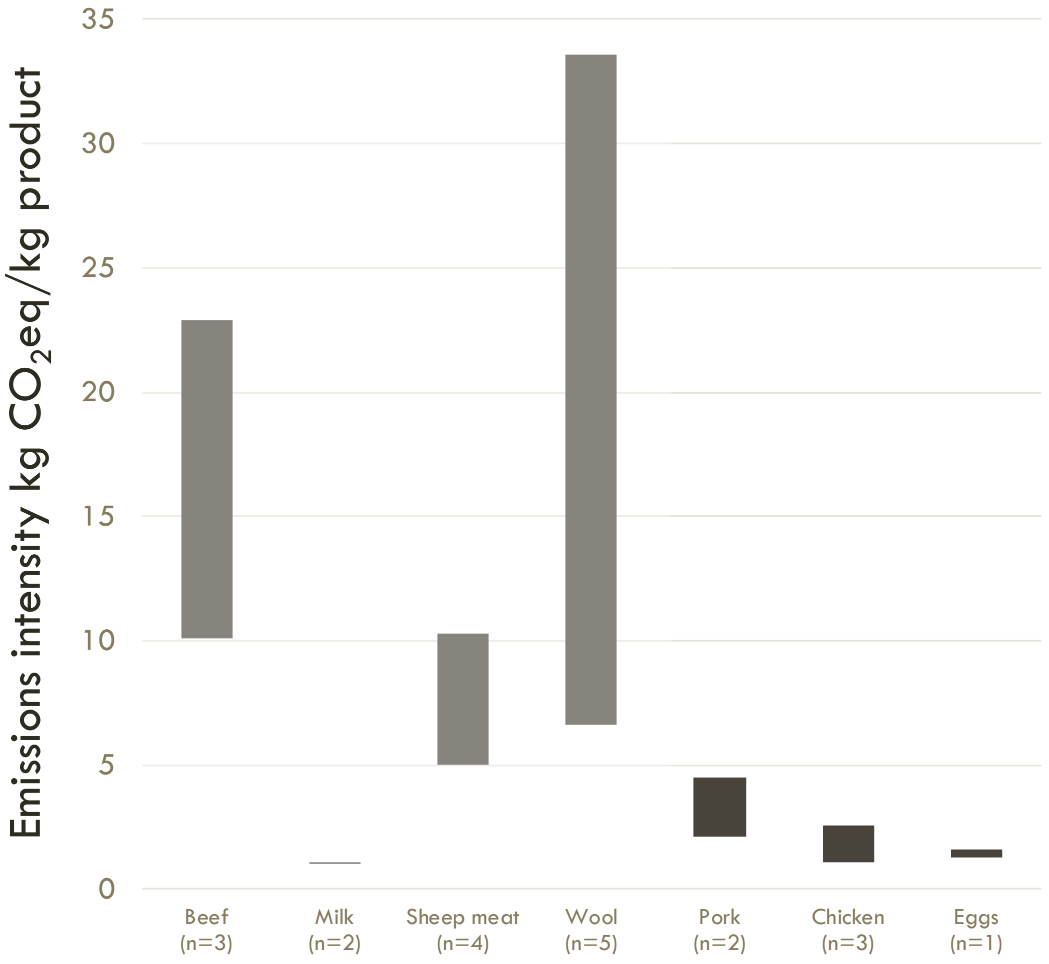
Chicken: 1.1 to 2.6

Major GHG sources:

- Feed production
- Housing (energy and manure)

Estimate of annual emissions: 3.75 Mt

Emissions intensity of Australian animal products



Wiedemann *et al.* 2016c, Eady *et al.* 2011a, Wiedemann *et al.* 2017, Hall 2014, Bengtsson and Seddon 2013, Wiedemann and McGahan 2011

AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

Wheat:

Major GHG sources:

- Manufacture and transport of fertilisers (20-30%)
- N_2O emissions in some systems

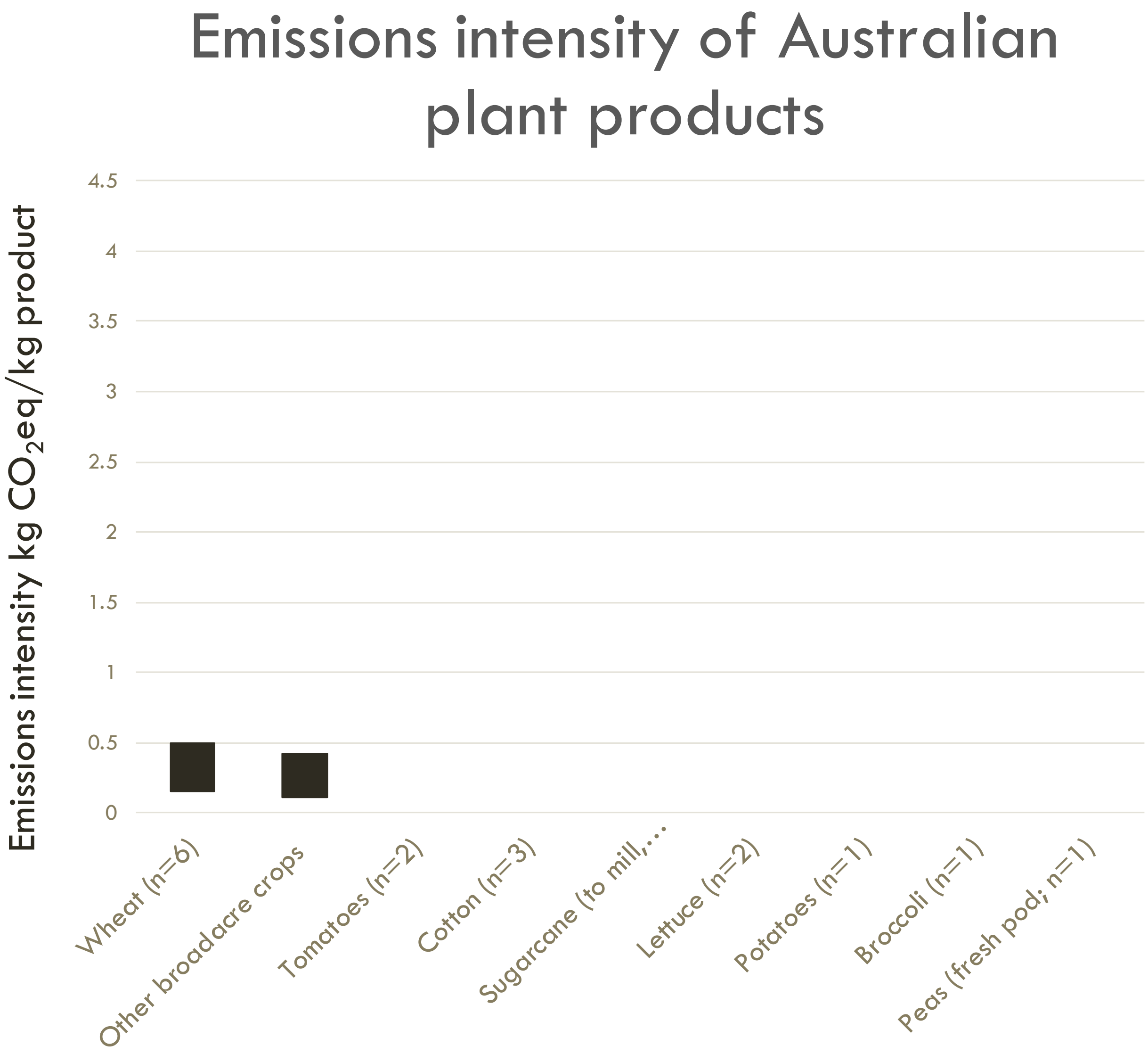
Estimate of annual emissions: 8.8 Mt

Other broadacre:

- 110 to 260 kg CO_2e/t barley
- 222 to 286 kg CO_2e/t canola
- 325 kg CO_2e/t corn

Major GHG source:

N fertiliser



Muir et al 2013, Brock et al 2016, Eady et al 2011a, 2012, Simmons and Murray 2012

AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

Cotton:

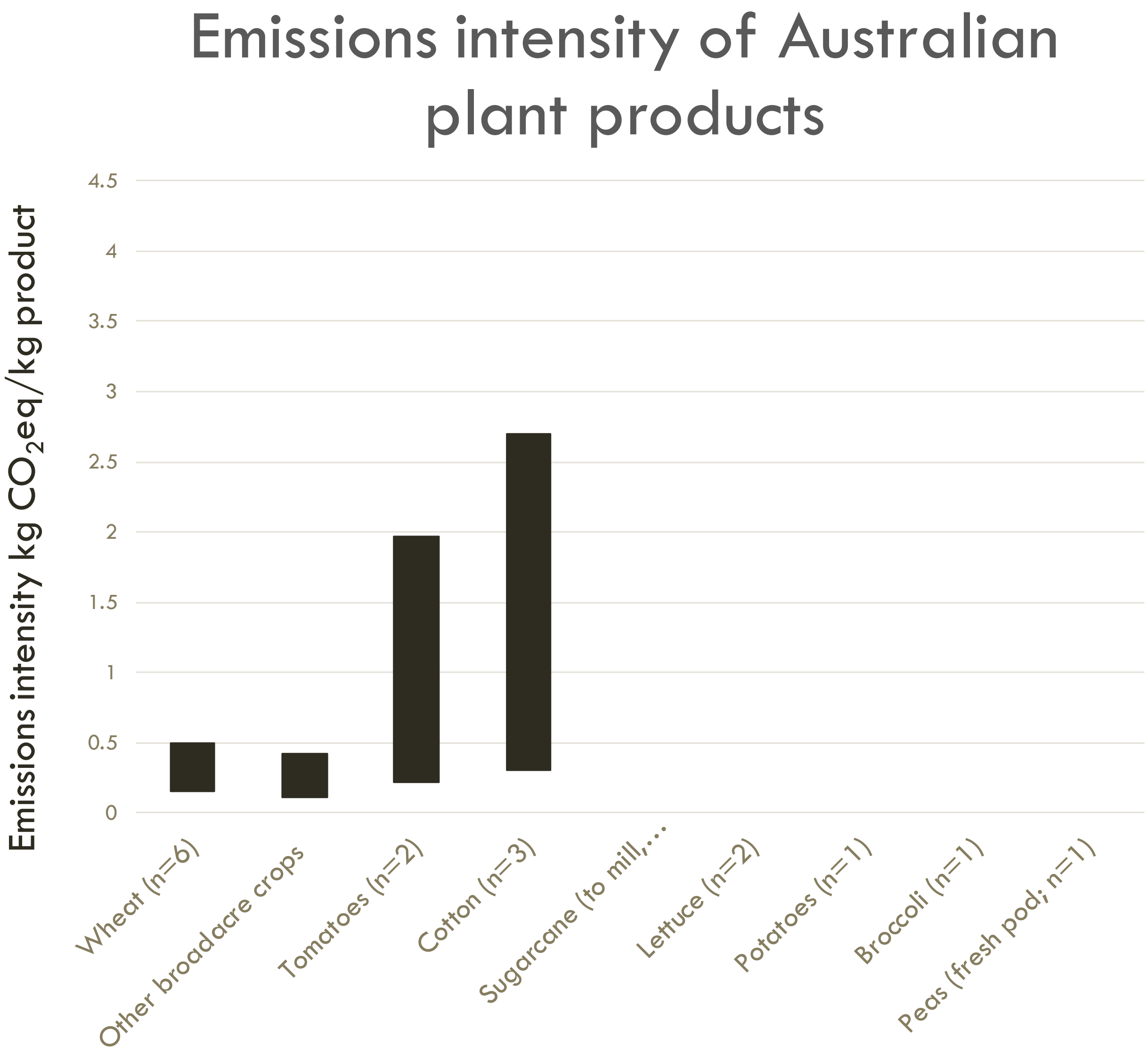
Major GHG sources:
- Soil N_2O emissions
- Irrigation

Estimate of annual emissions: 0.15 Mt

Tomatoes:

Major GHG source:
Greenhouse energy comprised 83-85% in medium to high-tech systems

Estimate of annual emissions: 0.07 Mt



Tan *et al.* 2013, Maraseni *et al.* 2010a, 2010b, Page 2012

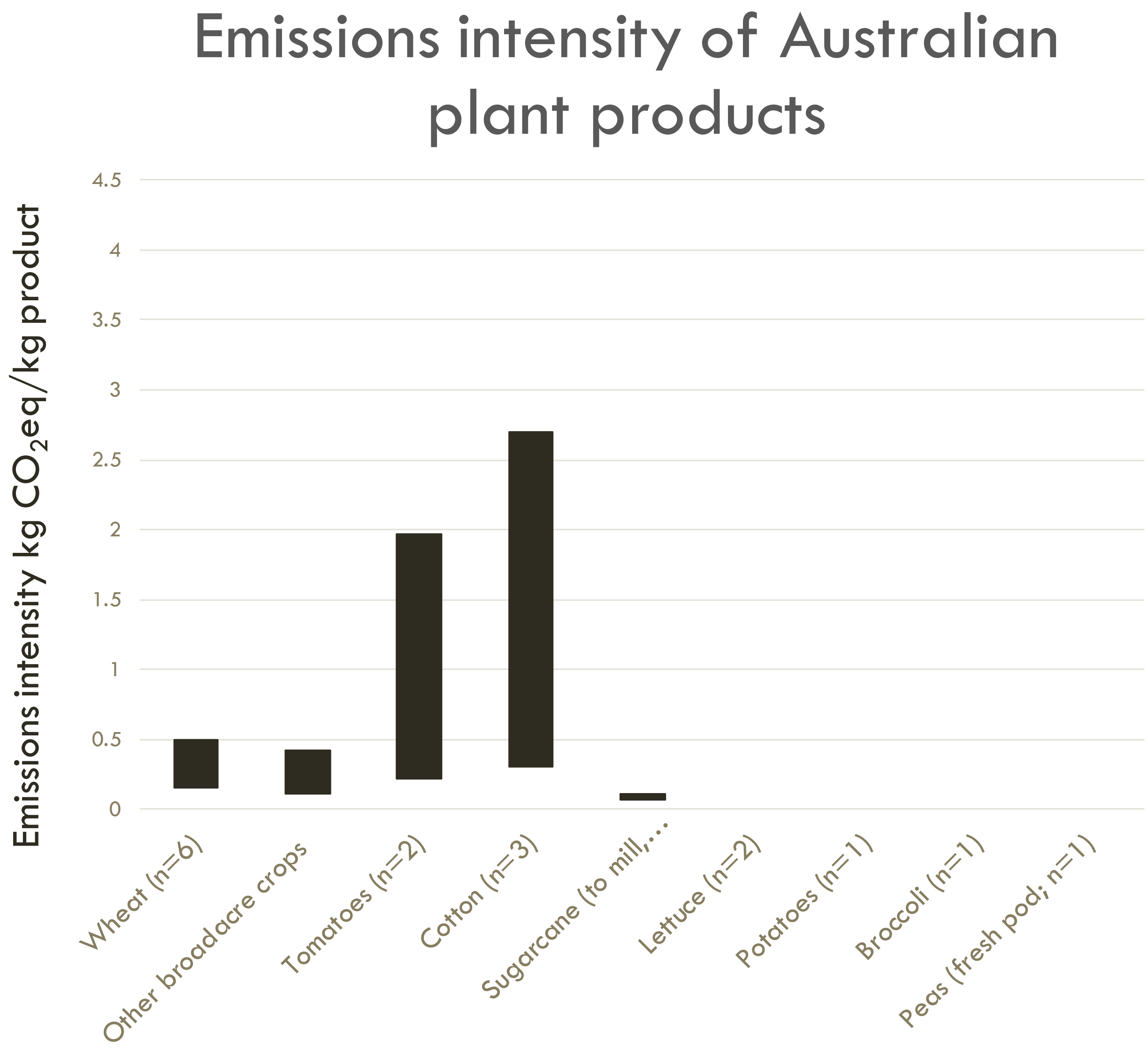
AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

Sugarcane:

Major GHG source: Soil N_2O

Estimate of annual emissions:

- 2.8 Mt CO_2eq (sugarcane to mill)
- -1.5 Mt CO_2eq energy from bagasse



Renouf *et al.* 2008, 2010, https://asmc.com.au/industry-overview/

AUSTRALIAN AGRICULTURAL SECTOR-BASED EMISSIONS INTENSITIES

Other Vegetables

Major GHG source:

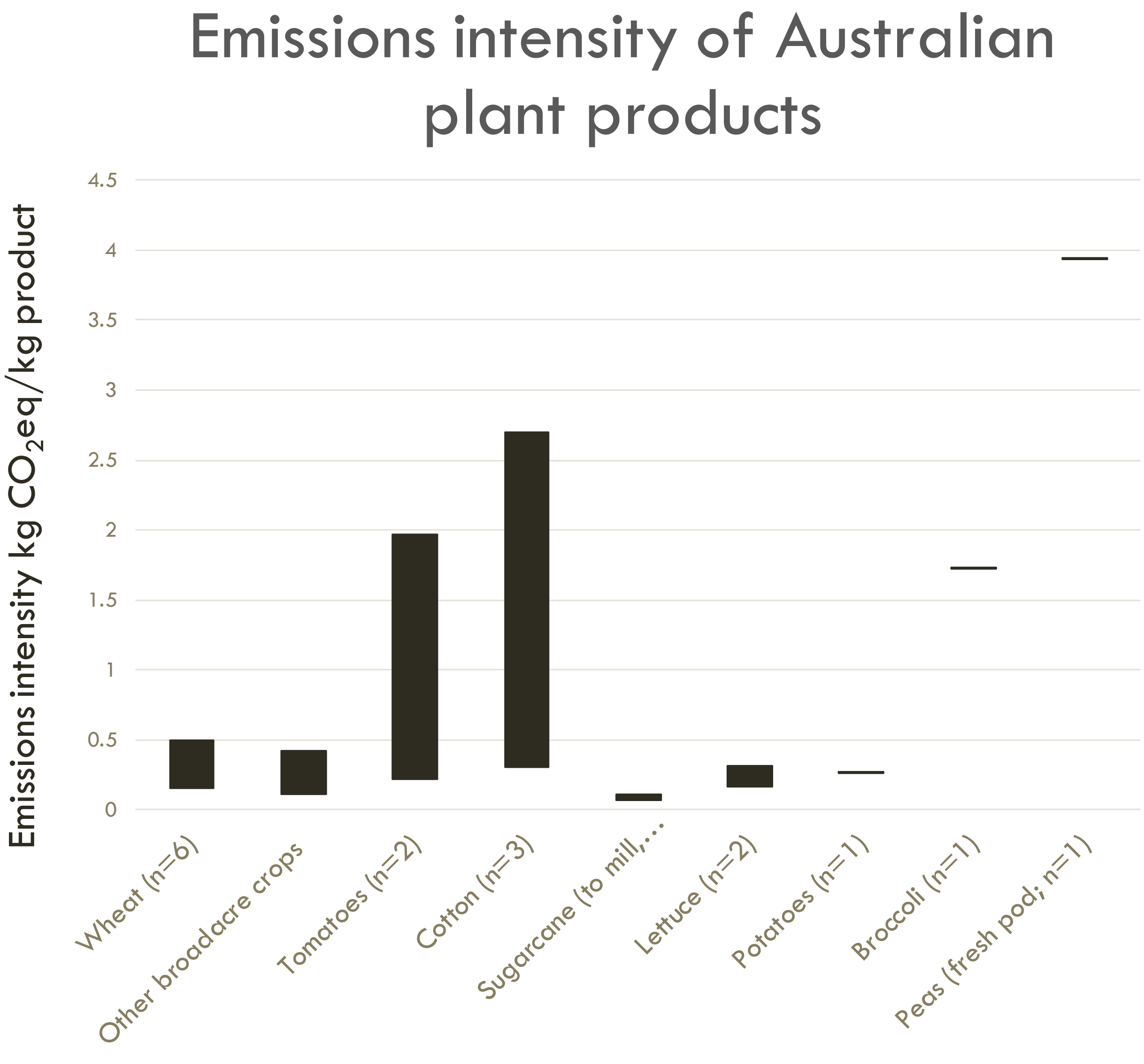
- Irrigation (often >50%, can be >70%)
- N_2O emissions (20-25% in some cases)

Lettuce (Irrigation 47% N_2O 18.8%)

- Estimate of annual emissions: 0.09 Mt CO2eq

Potatoes (Irrigation 40.7%, N_2O 22.2%)

- Estimate of annual emissions: 0.3 Mt CO2eq



Maraseni et al. 2010b, Gunady *et al.* 2012

MITIGATION OPTIONS

Efficiency of production:

- Reduces emissions intensity
- Typically associated with increase farm profitability, so most commonly implemented

Increased crop yield

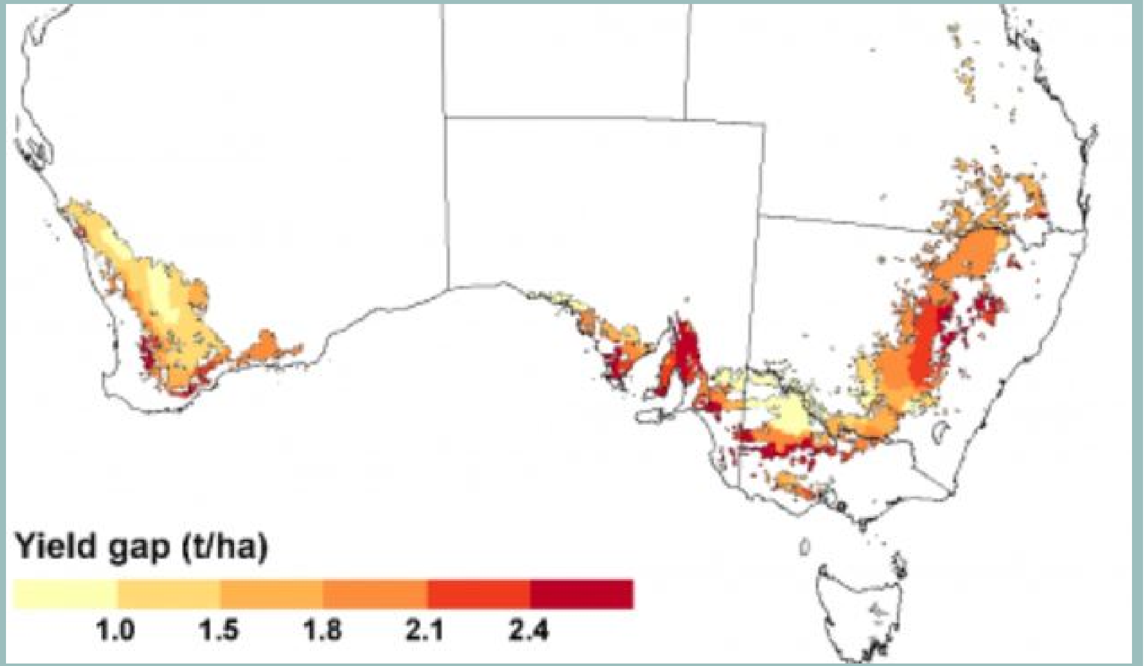
- Nutrient deficiencies
- Weeds
- Disease
- Socio-economic factors

Increased livestock productivity

- Animal management (e.g. replace low producing animals, increase fecundity, reduce mortality)
- Improved feed efficiency
- High quality diets

MITIGATION OPTIONS

Efficiency of production:



http://yieldgapaustralia.com.au/

Cropping systems:

- Closing the yield gap
  - Double production on many farms
  - Reduction in EI of wheat was 80% in WA and 93% in QLD
- Increased yields by 20% reduced EI by 26% in WA

Hochman *et al.* 2016, Simmons and Murray 2017

MITIGATION OPTIONS

Efficiency of production:

Livestock systems:

- Supplemental feeding in n. Australia reduced methane EI by 24.8%
- Several options on a NZ dairy farm reduced emissions 27%
- 40% reduction in methane EI of milk from 1980 to 2010, from ~33.6 to ~19.9 g CH_4/kg milk

Charmley et al 2008, Beukes *et al.* 2010, Moate et al 2016

MITIGATION OPTIONS

Efficiency of production:

ABC

Waste:

- In pork systems it is estimated that reductions in feed waste of 5% reduces GHG 10%
- Losses of bananas in northern QLD due to retailer requirements represent an annual loss of 0.016 Mt CO_2eq
- composting olive waste achieved −12.4 kgCO_2eq per t

White et al 2011, El Hanandeh 2015, Australian Pork Limited 2019

MITIGATION OPTIONS

Efficiency of production:

Limitations

Increasing production (stocking rate, etc) commonly leads to increased total emissions

- 40% reduction in methane EI of milk from 1980 to 2010 associated with a 1.6% reduction in total dairy methane emissions.

In some cases increasing intensification can increase business risk and reduce resilience

- E.g. increased reliance on purchased feeds

Increased intensification leads to more cropland being used to grow animal fed

- Competition for Australia’s limited arable land
  - Cropping emissions attributed to feedlots 3.4% in 2005 and 5.7% in 2015
- Can influence emissions intensity of animal products

Moate et al 2016, Christie 2012, Wiedemann and Watson 2018, Mayberry 2018

MITIGATION OPTIONS

Enteric Methane:

Red meat (beef & sheep)

Dairy

CSIRO, https://www.scienceimage.csiro.au/image/1898

Implementable (to varying degrees):

- High quality diet (low 20%)
- Dietary additives ≈25%
- Breeding <10%, whole-farm reduction of 4%

More research required:

- Rumen manipulation: Unknown
- Vaccines: Unknown

DIETARY STRATEGIES

Improving diet quality

- Leucaena in tropical systems reduced EI by 23%
- Increases in dietary fat can reduce methane by 20%
- Approved ERF methodology that has not been used

Additives

- Nitrates: 7% - 31%
- 3-NOP: 31.9% methane reduction, 14% whole-farm reduction

Harrison *et al.* 2015, Beauchemin and McGinn 2006, Lund *et al.* 2014; Velazco *et al.* 2014, Alvarez-Hess *et al.* 2019

DIETARY STRATEGIES

Limitations:

- Expense
- Careful application
- 3-NOP not yet approved
- Not applicable to pasture-only systems
  - Could be used in most dairies (1.7 million cows)
  - Not applicable for most of the life of beef/sheep (25 million cows, 71 million sheep)

MITIGATION OPTIONS

Enteric Methane:

Red meat (beef & sheep)

Reducing demand for ruminant meat

One serve/week, reduced GHG by 58%

Non-ruminant red meat (e.g. kangaroo)

- 16 Mt CO_2eq reduction replacing 7 m cows, 36 m sheep

Meat alternatives:

Lowest impacts with insect and soymeal substitutes

Highest impacts with synthetic meat

Limitations

- Widespread implementation
- Vegetal substitutes
  - Cannot be grown on much of the land used for grazing in Australia
  - Would be associated with loss of soil carbon with conversion to crops

Springmann et al 2018, Wilson and Edwards 2008, Smetana et al 2015

MITIGATION OPTIONS

Manure Methane:

Piggeries

Dairies

Potential:

Anaerobic digestion (AD):

- 60% to 64% leading to EI of 1.6 and 1.4 kg CO_2eq/kg LW
- Application to all appropriated sized farms would reduce
  - Emissions of farms with AD by 75% to 84%,
  - Average emissions of all farms by 51%
  - EI from 3.9 kg to less than 1.0 kg CO_2eq/kg

Limitations:

- AD best for larger operations (e.g. 500 sows)
- Can require system-level changes for dairies
- Particular technical issues need to be addressed case by case

Deep litter systems:

- Emissions reductions of 40% to 80% over conventional piggeries

Australian Pork Limited 2019, Phillips *et al.* 2016, Wiedemann *et al.* 2016, Wu *et al.* 2013

MITIGATION OPTIONS

Manure Methane:

Piggeries, dairies, poultry producers, potentially feedlots

Blantyre Farms, https://www.aginnovators.org.au/news

Implementation:

- 2018: 13.5% of pork from farms with biogas capture
- Used in abattoirs, reducing post-farmgate emissions
- Used in at least one Australian dairy and one egg producer
- Potential in other intensive systems, such as feedlots

Feasibility:

- Offset energy costs and can provide new income
- Eligible for ACCUs
  - 88.4% of issued Ag ACCUs, 0.48 Mt CO_2eq reduction
  - Facilitate large capital investments required

Baxter 2019, Cooke 2017, Tait 2017, Watts and McCabe 2015

MITIGATION OPTIONS

Nitrous oxide

Livestock

Soil (major emissions from crops)

Livestock

- Manure
  - AD reduces N_2O emissions from manure, until land applied
  - Use of inhibitors and amendments
- Urinary Nitrogen
  - Adjusting energy:protein of diet to reduce N losses in urine
  - Inhibitors on urine patches (e.g. DCD in New Zealand)

- Soil
  - Replace inorganic fertiliser
    - Legumes
    - Compost/manure
  - Enhanced fertilisers/Inhibitors
  - Precision Agriculture

MITIGATION OPTIONS

Nitrous oxide : Potential

Centre for Digital Agriculture, Curtin University

Legumes and cover crops:

Chickpeas before wheat 21% reduction in N_2O

Fertiliser substitutes:

More research required on net effects compost and manure

Precision agriculture:

In WA and QLD variable rate application (20% N reduction), 30% to 34% reduction in N_2O emissions.

Enhanced fertilisers/Inhibitors:

- range of 8–57%, up to 83% with DMPP in subtropical cereal. Offset by ammonia volatilisation emissions.
- Slow release brown-coal urea fertiliser in silver beets, 29% reduction in N_2O emissions
- An inhibitor reduced emissions a further 5% over reduction that occurred due to efficiency improvements in a NZ dairy system
- Nitrogen fixing bacteria, US corn (35% of producers would save 6 Mt CO2eq of direct N_2O emissions)

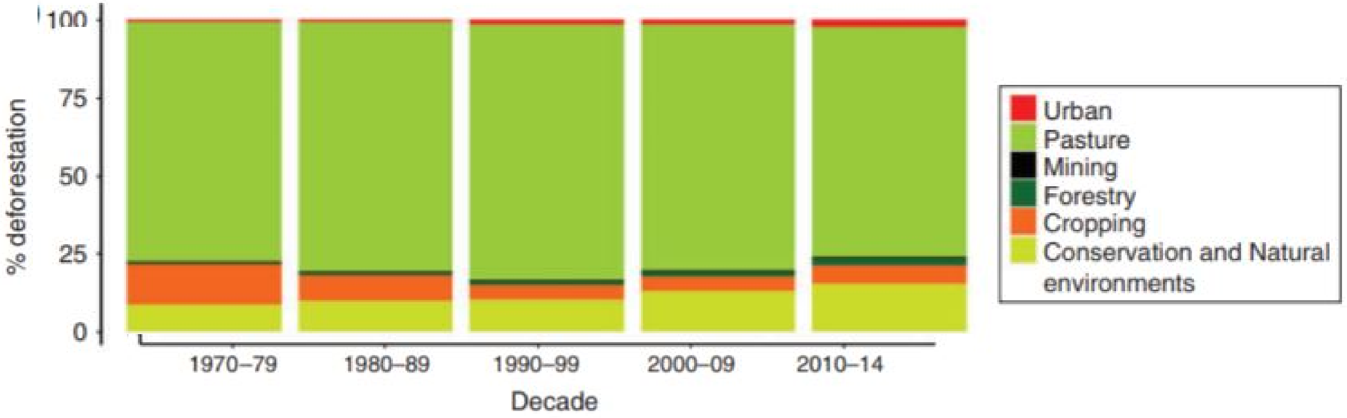
Muir *et al.* 2013, Simmons and Murray 2017, Engelbrecht 2013, Scheer, 2016, Saha *et al.* 2019, Montes *et al.* 2013 Maraseni *et al.* 2010

MITIGATION OPTIONS

- Land-based CO_2: minimising deforestation

ABC

- Reduction in deforestation since 2000 is associated with a reduction of 37.6 Mt CO_2eq
- Increasing production efficiency reduces demand for new agricultural land
- Drivers that could increase deforestation
  - Climate change impacts reducing production
  - Increasing demand for purpose grown biofuels



Evans 2016, AGEIS

MITIGATION OPTIONS

Land-based CO_2: Soil Carbon potential

Cropping:

- Sequestration of 0.2 to 0.3 t/year (0.7-1.1 t CO_2eq) compared to conventional
  - Minimum tillage
  - Stubble retention

Pasture: Potential is in degraded areas

- 16.1 Mt CO_2eq/year (0.09 t C/ha/year) by ceasing overgrazing on 11.2% of pasture
- 11 800 t CO_2e were sequestered over 33 years, offsetting all emissions of a wool farm over that period
- Large areas mean:
  - small improvements result in large total impacts
  - important to maintain carbon stocks where high

Co-benefits:

Agronomic improvements that increase productivity

Lam et al 2013, Robertson & Nash 2013, Conant & Paustian 2002, Doran-Browne et al 2016

MITIGATION OPTIONS

Land-based CO_2: Soil Carbon: Limitations

- Finite
- Reversible
- Projected reductions in rainfall, particularly in currently water limited areas
- In cropping systems, may stocks may still be declining
- Higher N_2O emissions in high carbon soils
- Using pasture increases carbon but also methane
- Management and monitoring relatively costly, low per/ha carbon sequestration and risks due to drought, etc.
- Difficult to increase economically
  - Stocking reductions
  - High applications of compost/manure with associated transport costs

Smith 2014, Sanderman 2009, Meyer et al 2018, Meyer 2016

MITIGATION OPTIONS

Land-based CO_2: Incorporating trees and perennials on farm

Beverley Henry http://www.woolindustries.org

Effects dependant on stocking and sequestration rates

- Sequestration rates vary substantially based on site, species, and age of trees
- Sequestration rates of 2.3-2.7 t C/ha allowed for 20% tree coverage to offset low and moderate stocking rates
- sequestration rates above 19 t C/ha allowed for 7% to 13% tree coverage of a QLD farm to offset 0.5 head/ha
- 19 300 $MtCO_2eq$ sequestered in trees over 33 years, (only 15% tree cover needed, nearly 50% coverage)
- Sequestration from planting kikuyu offset 80% emissions despite a 32% increase in stocking

Doran-Browne 2016, 2018, Eady *et al.* 2011b

MITIGATION OPTIONS

- Land-based CO_2: Incorporating trees

Reforestation potential:

- In northern rangelands: the fastest sequestration option was maturation of regrowth forest (0.36 t C/ha/year). Across 22.7 million hectares, 8.2 Mt (30 Mt CO_2eq)/year sequestered

Co-benefits of trees:

- Address multiple land issues such as salinity, erosion, etc.
- Can improve biodiversity
- Productivity benefits of shade and wind breaks

Limitations of trees:

- Financial case not unclear and risky (viable at carbon price estimates between $15 and $132)
- Site specific information required
- Appropriate risk discounting for drought, bushfire, etc

Dean *et al*. 2012, Harper et al 2007, Sinnett 2016

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

Biofuels/bioenergy can provide negative emissions

Michael Condon, https://www.abc.net.au/site-archive/rural/content/2007/s2201467.htm

High-diversity grasslands

- Bioenergy yields that were 238% greater than monoculture after a decade.
- Carbon negative, sequestration (4.4 t/ha/yr) exceeds fossil CO_2 release during biofuel production (0.32 t/ha/yr)
- Can be produced on agriculturally degraded lands reducing competition with food production

Successional herbaceous vegetation, once established

- Rivals that of purpose-grown crops (−851 ± 46 g CO_2eq/m2/year.
- Fertilized, these communities can produce about 63 ± 5 GJ of ethanol energy per hectare per year.

Mallee

- Net negative emissions of -15.3 kg CO_2eq/GJ and -2771.4 kg CO_2eq/ha/year when below ground carbon sequestration and LUC emissions included
- Production of 206.3 GJ/ha/year

Tilman 2006, Gelfand 2013, Yu and Wu 2010

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

Biofuels/bioenergy can provide negative emissions in certain circumstances

General Requirements for the technology:

- regulatory environment is stable and supportive of the technology
- feedstock is cheaply and readily available
- transmission distances are relatively low
- cost of alternative sources of power are high

Growing feedstock for biofuels/bioenergy:

- planting on marginal land can potentially avoid food-fuel conflict and indirect land-use change effects
- The direct carbon costs can be minimised by avoiding tillage and lands with large existing carbon stocks
- need for information on cultivation of productive native species where growth is limited by abiotic stressors
- Site specific information and address trade-offs (e.g. highly productive non-native vs. biodiversity)

Brooksbank *et al.* 2014, Robertson 2017

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

Off-farm emissions: Fertiliser

Could lead to large reduction in life cycle emissions of wheat and other broadacre crops

- Current developments
- Haber-Bosch with renewables
  - Yara Pilbara: Every kg of H_2 would make 5.6 kg of NH_3 and save over 5.5 kg CO_2 production. (28,000 tonnes/year)
  - Port Lincoln, SA Thyssenkrupp plant (18,000 tonnes/year)
- Nitrogen fixing bacteria additions in furrow
  - Reduces fertiliser requirements
- Other research
  - Bio-electrochemical production (electrolysis, catalysts, ect)
  - Genetically modified crops that fix their own N

Lui et al 2017, Milton et al 2017, Vicente and Dean 2017

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

On-farm emissions: Irrigation & Greenhouses

Bargara cane farm, GEM energy: https://www.gemenergy.com.au/case-studies/bargara-cane-farm/

Several horticulture crops had irrigation as a source of more than 50% of emissions, in cotton it was 30%.

- Queensland cotton growers would avoid about 1274 kg CO2e/ha (reduce EI to about 1970 kgCO_2/t).
- Tasmania farmers contribute 4.4 times less GHG emissions, on average, for the same produce
- Economics depend on energy use profile, connection rules, and feed in tariff.
- Eligible for small scale renewable energy certificate and bonus from clean energy finance corporation.

Maraseni *et al.* 2010a, Maraseni *et al.* 2010b, Allen 2015

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

On-farm emissions: Irrigation & Greenhouses

Use of renewable energy for greenhouses

- Sundrop farm reported to save 14,000 tonnes of CO_2eq per year, which would be about 21% of the tomato industries annual emission of 66,000 tonnes CO_2eq
- Municipal and industrial waste to energy plant uses digestate and heat to grow blueberries as additional income stream

Maraseni *et al.* 2010a, Maraseni *et al.* 2010b, Allen 2015

MITIGATION OPTIONS

Renewable Energy and Replacing Fossil Fuels:

On-farm emissions: Waste potential

- Reductions in fossil fuels:
  - poultry manure, grid: 60%
  - NZ piggery, grid 50%, payback: 3 years
  - Wine grape waste, oils 100%, LPG 69% payback 4.5 years

- Reductions in CO_2eq:
  - Using olive waste to produce pellets for domestic hot water: −1057 kg CO_2eq
  - grape waste: 72% (9813 tonnes)
  - Suncoast gold macadamias shells: over 9500 t

- Replacing more intensive products:
  - replacing eucalypt feedstock with bagasse (in pulp production) saves about 1000 Mt CO_2eq per t bagasse

Brooksbank *et al.* 2014, Kiatkittipong et al 2009

DISCUSSION

Potential reductions in relation to expected emissions growth due to increases in production

2030 Emissions trajectories
11.4% to 43.5% increase

Agriculture
- EI reductions of 63% from 1996 to 2006 (2% year)

Red Meat:
- Average annual reduction of 5.05% in total emissions from 2005 to 2015, due to reduced deforestation.
- Continued annual reductions of 1.04% to 3.95% to maintain current emissions with projected growth

Milk
- Average annual improvement in methane EI is 1.33%
- If rate maintained 13.3% reduction in EI to 2030

Wheat
- Trends in emissions from wheat not available
- Stalling wheat yields in some regions suggest gains in EI may be challenging in a changing climate

Horticulture and other irrigated crops
- Large potential reductions with renewable irrigation and greenhouses powered by renewables

DISCUSSION

- Summary

Livestock:

- Now: Improving efficiency, restricting deforestation, implementing new technologies, and focus on degraded land
- Long-term: enteric methane for extensive systems

All:

- Blurring lines between inventory categories (agriculture-energy-waste), perhaps industrial as well: waste companies growing blueberries with heat, farmers generating energy (producing bioproduct precursors, digestate/fertilisers), emissions that were in waste moving to inputs
- If society decides to eat less meat where/how will Australia's protein be grown
- What are the barriers to getting the available options implemented

THANK YOU

Dr. Rachelle Meyer

meyer.r@unimelb.edu.au

Next College Seminar: Weds 12 June at 11am
Adam Bumpus: *Energy Entrepreneurial Ecosystems: Challenges to Clean Energy Entrepreneurship and What 2021 Looks Like* (VCTF seminar series), @ College

Talaheni Farm, PICCC http://piccc.org.au/research/wfsam/subproject/carbon-neutral-wool

LITERATURE CITED

- Australian Government Department of Environment and Energy. 2016 National Greenhouse Gas Inventory Trend. Australian Greenhouse Emissions Information System. http://ageis.climatechange.gov.au/NGGITrend.aspx
- Brock et al 2016
- Centre for International Economics. 2013. Australian Agricultural Emissions Projections to 2050. Prepared for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education. Sydney.
- Commonwealth of Australia Department of the Environment and Energy. 2017. Australia's 7th National Communication on Climate Change. A Report under the United Nations Framework Convention on Climate Change. Australia.
- Maraseni, TN, et al. 2010. An assessment of greenhouse gas emissions from the Australian vegetables industry. J. of Env. Sci. & Health, Part B. 45(6): 578-588.
- Maraseni, TN et al. 2010b. An assessment of greenhouse gas emissions: implications for the Australian cotton industry. The Journal of Agricultural Science. 148(5): 501-510.
- Muir et al 2013
- Renouf, MA, et al 2010. Life cycle assessment of Australian sugarcane production with a focus on sugarcane growing. The International Journal of Life Cycle Assessment. 15(9):927-937.
- Simmons and Murray 2017
- Tan, et al 2013