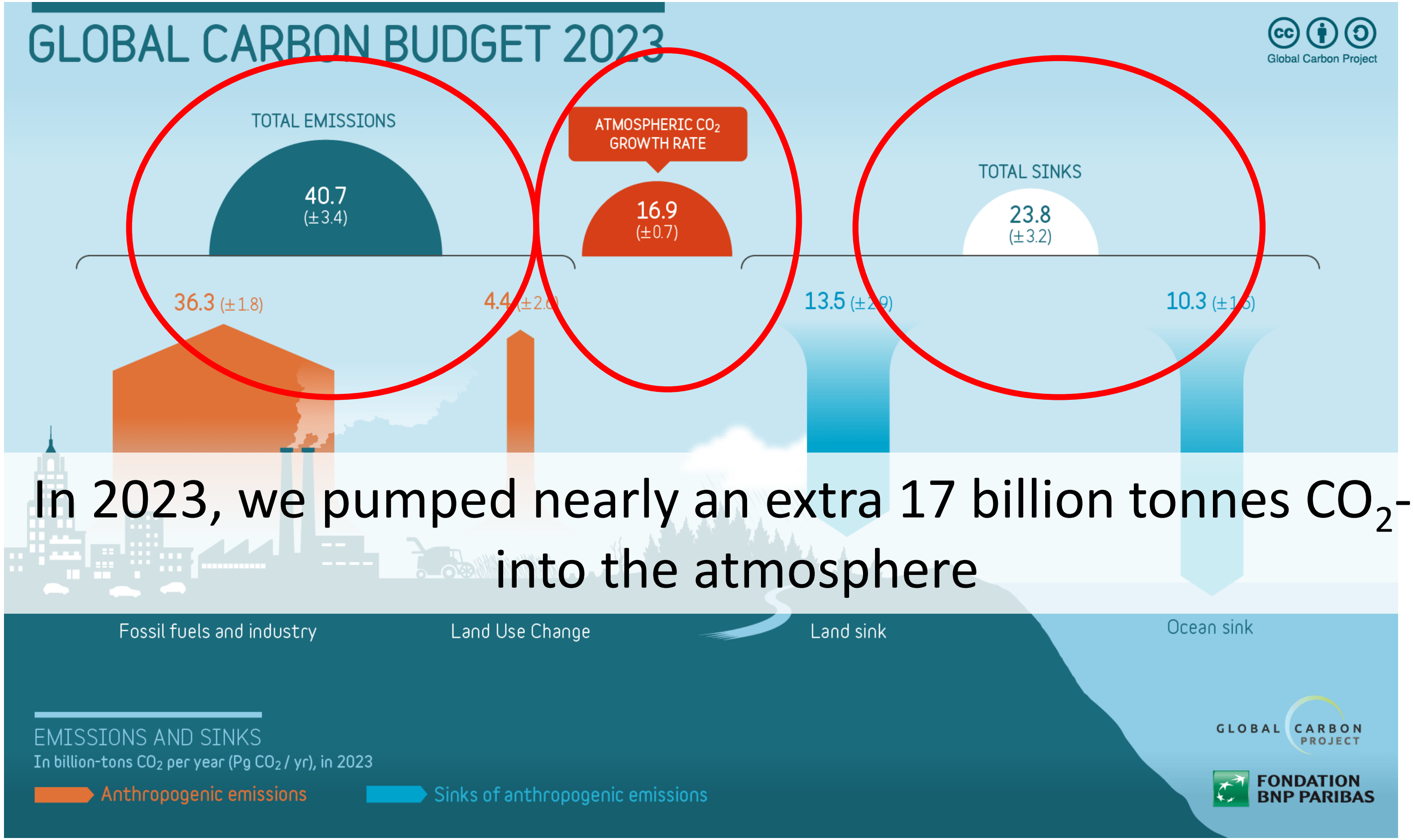
Pathways for on-farm reductions in carbon emissions

Dr. Karen Christie-Whitehead

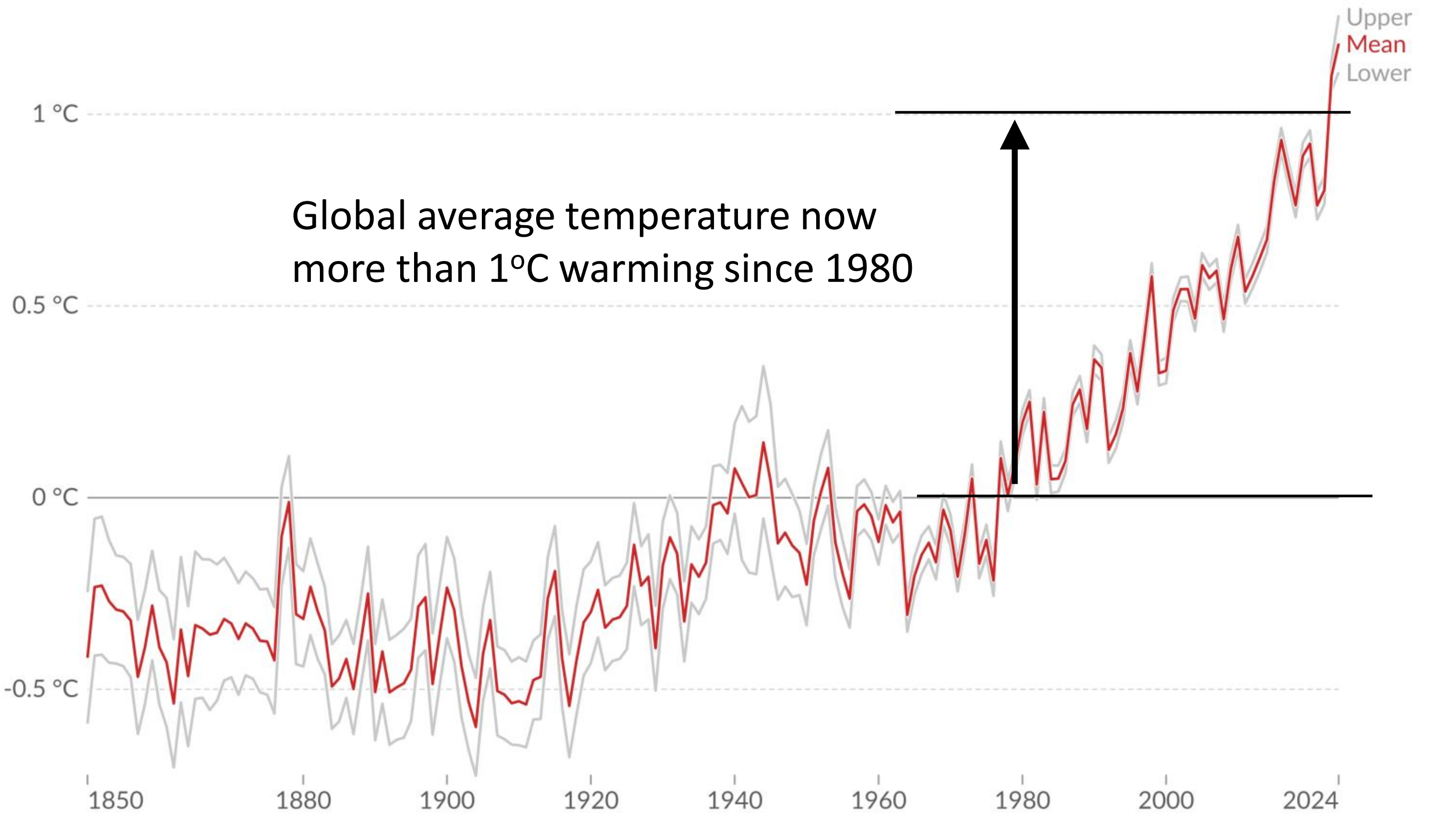
Why do we need to reduce GHG emissions?



In 2023, we pumped nearly an extra 17 billion tonnes CO_2-e into the atmosphere

Average temperature anomaly, Global

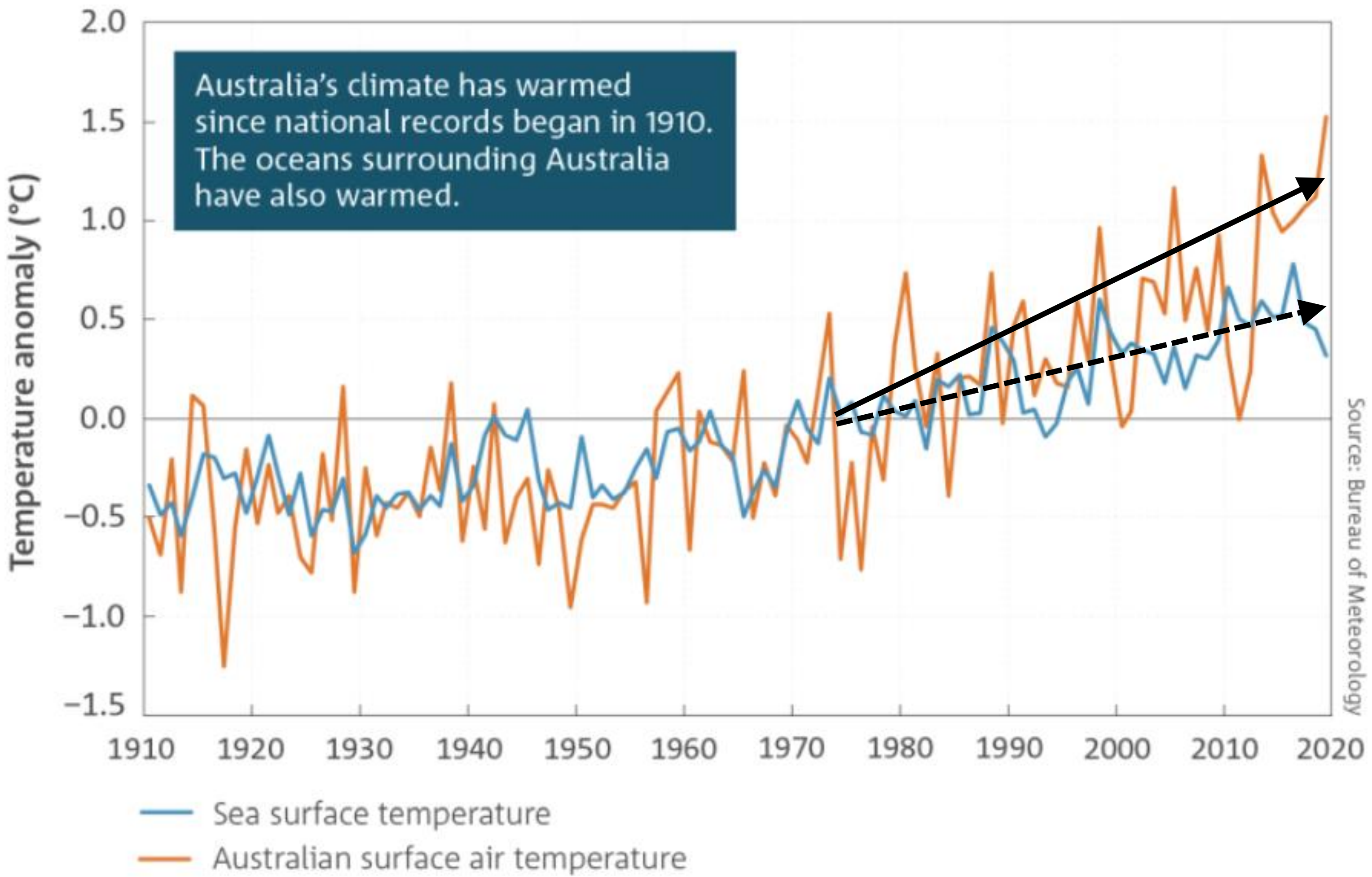
Global average land-sea temperature anomaly relative to the 1961-1990 average temperature baseline.



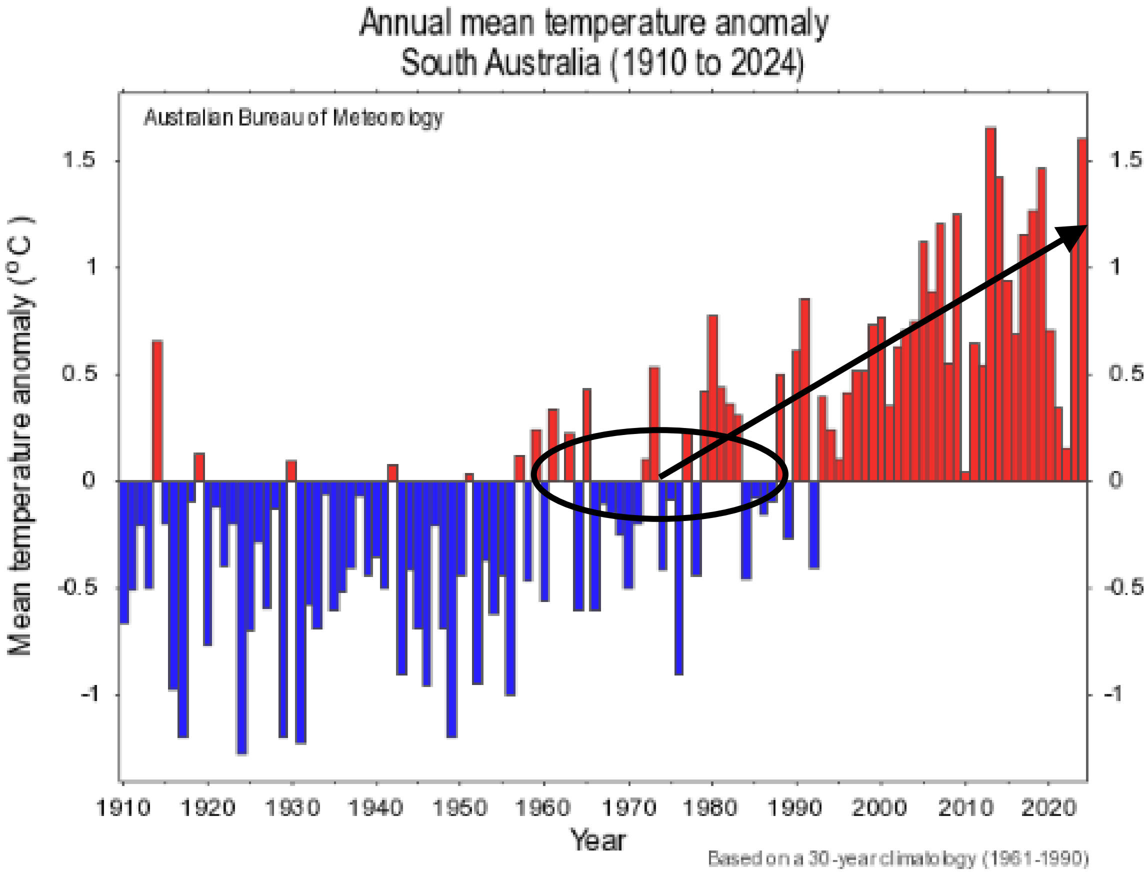
Data source: Met Office Hadley Centre (2024)

OurWorldinData.org/co2-and-greenhouse-gas-emissions |

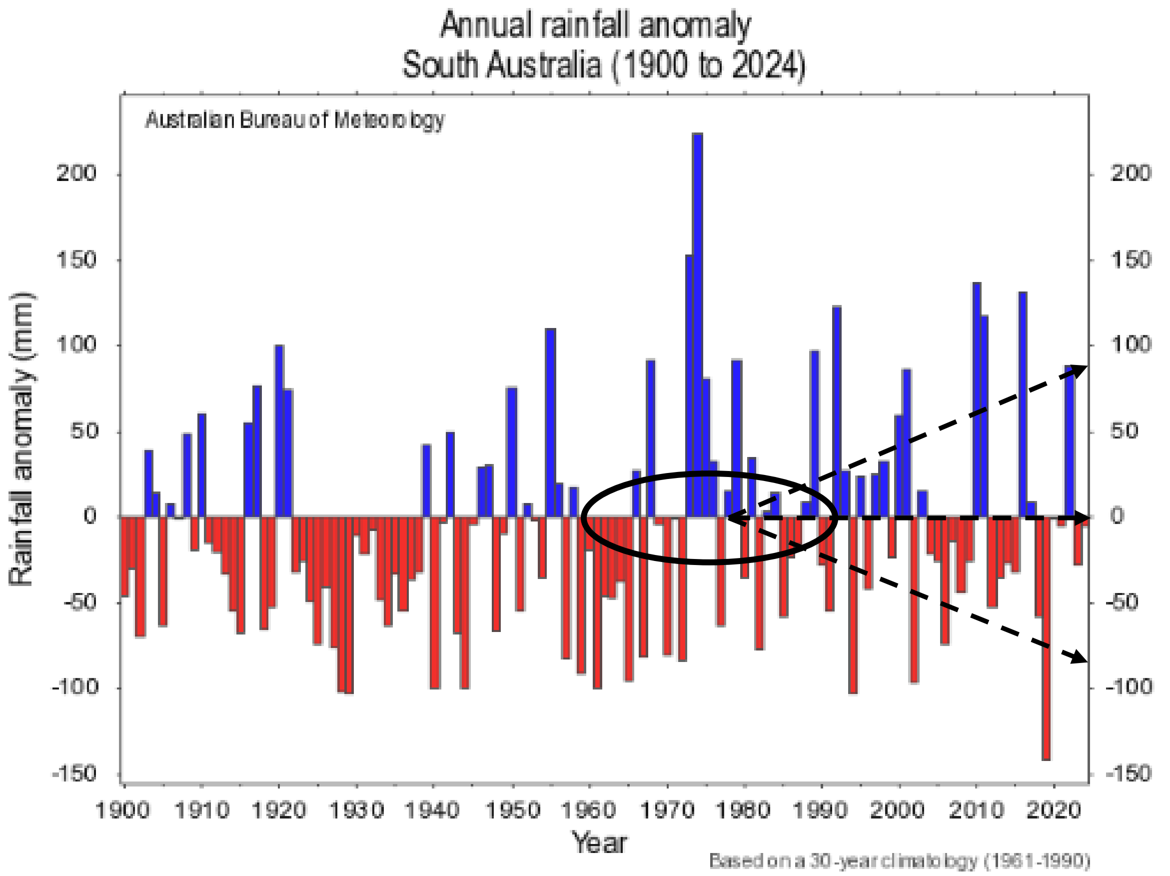
Note: The gray lines represent the upper and lower bounds of the 95% confidence interval.



https://www.climatechangeinaustralia.gov.au/en/changing-climate/climate-trends/australian-trends/



http://www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=tmean&area=sa&season=0112&ave_yr=0&ave_period=6190



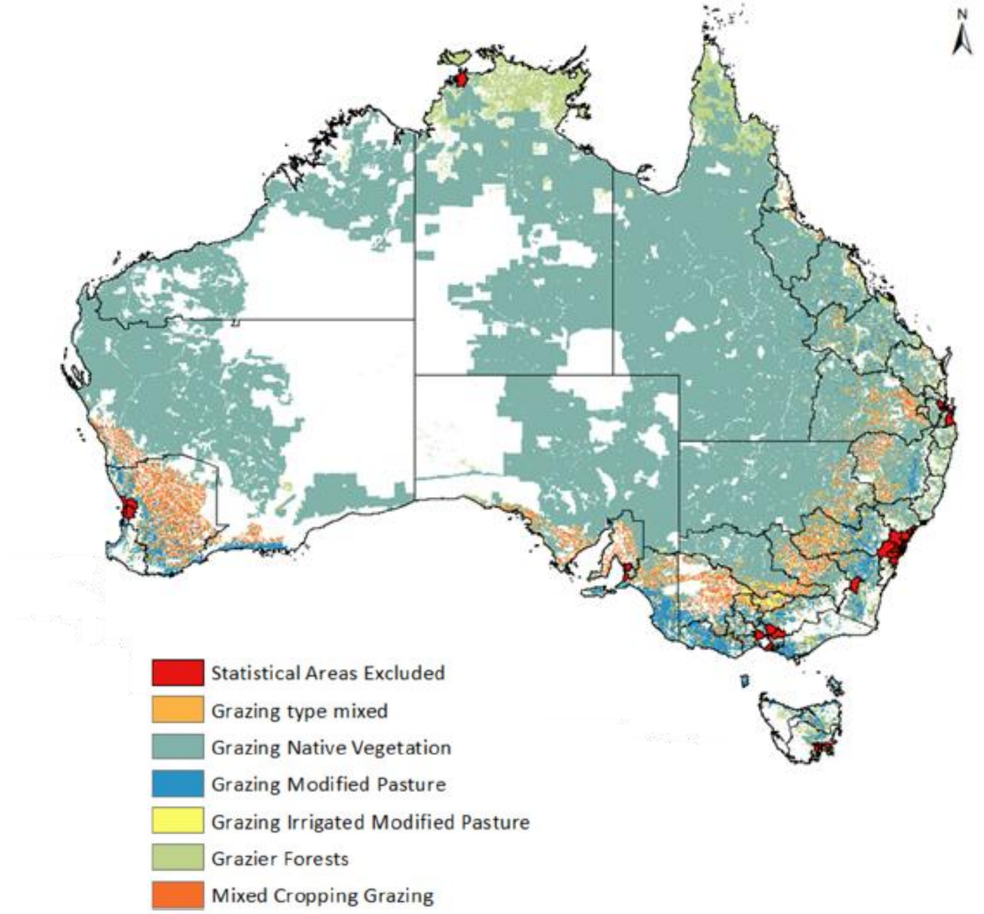
http://www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi?graph=tmean&area=sa&season=0112&ave_yr=0&ave_period=6190

Why do we need to reduce GHG emissions?

- Greenhouse gas emissions are lost “opportunities”
- Methane represents a lost energy source that could be rediverted into product
- Optimising key inputs such as nitrogen-based fertilisers to reduce nitrous oxide and carbon dioxide emissions
- Maximising stock productivity
- Loss of tree carbon -> animal welfare (shade/shelter) for your stock, habitat for native animals, vegetation biodiversity, aesthetics
- Loss of soil carbon -> lower nutrients, lower water-holding capacity
- Access to markets, social licence, risk of being ‘taxed’ for export products, price premiums, bank loans etc

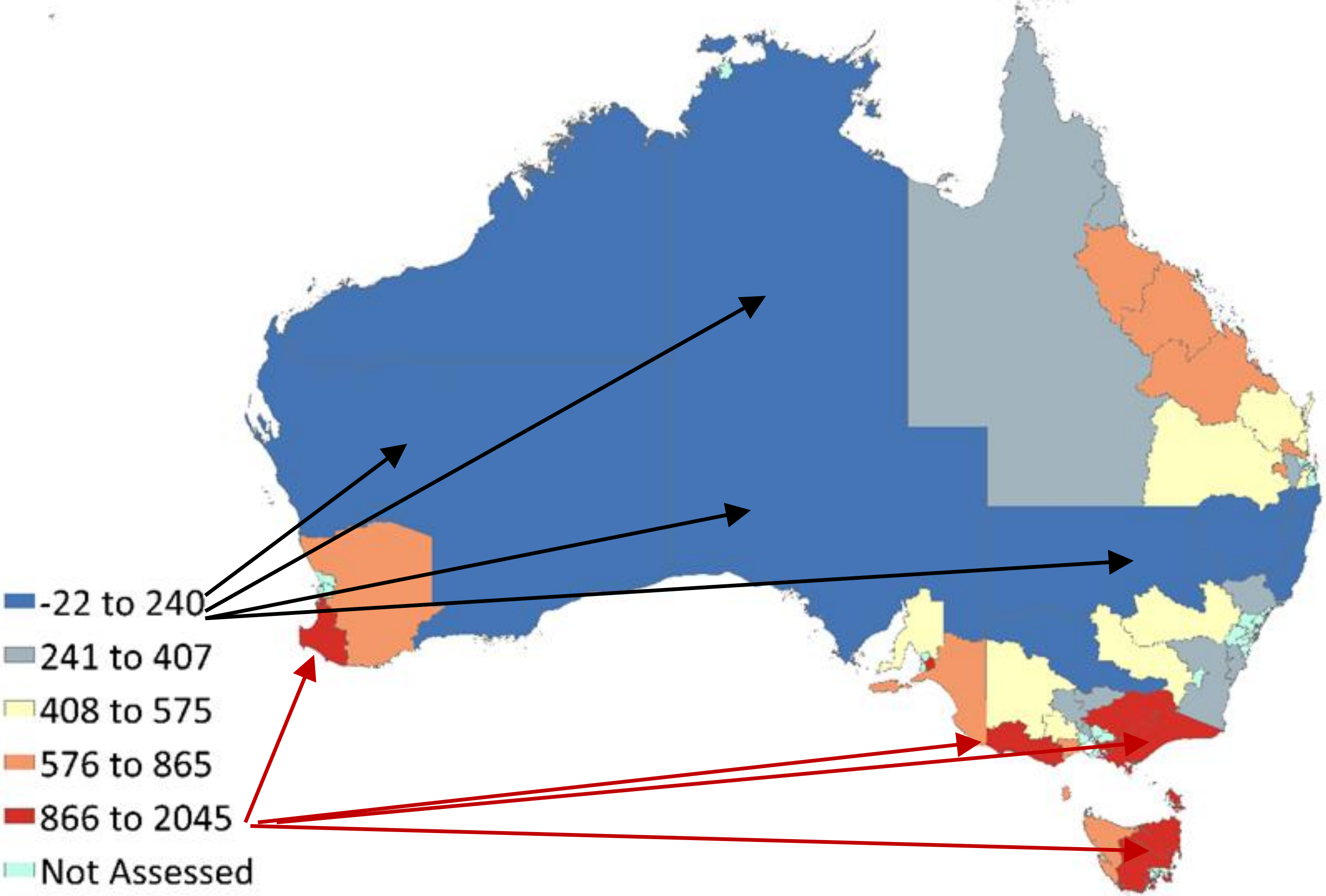
Is the livestock sector *en route* to net zero?

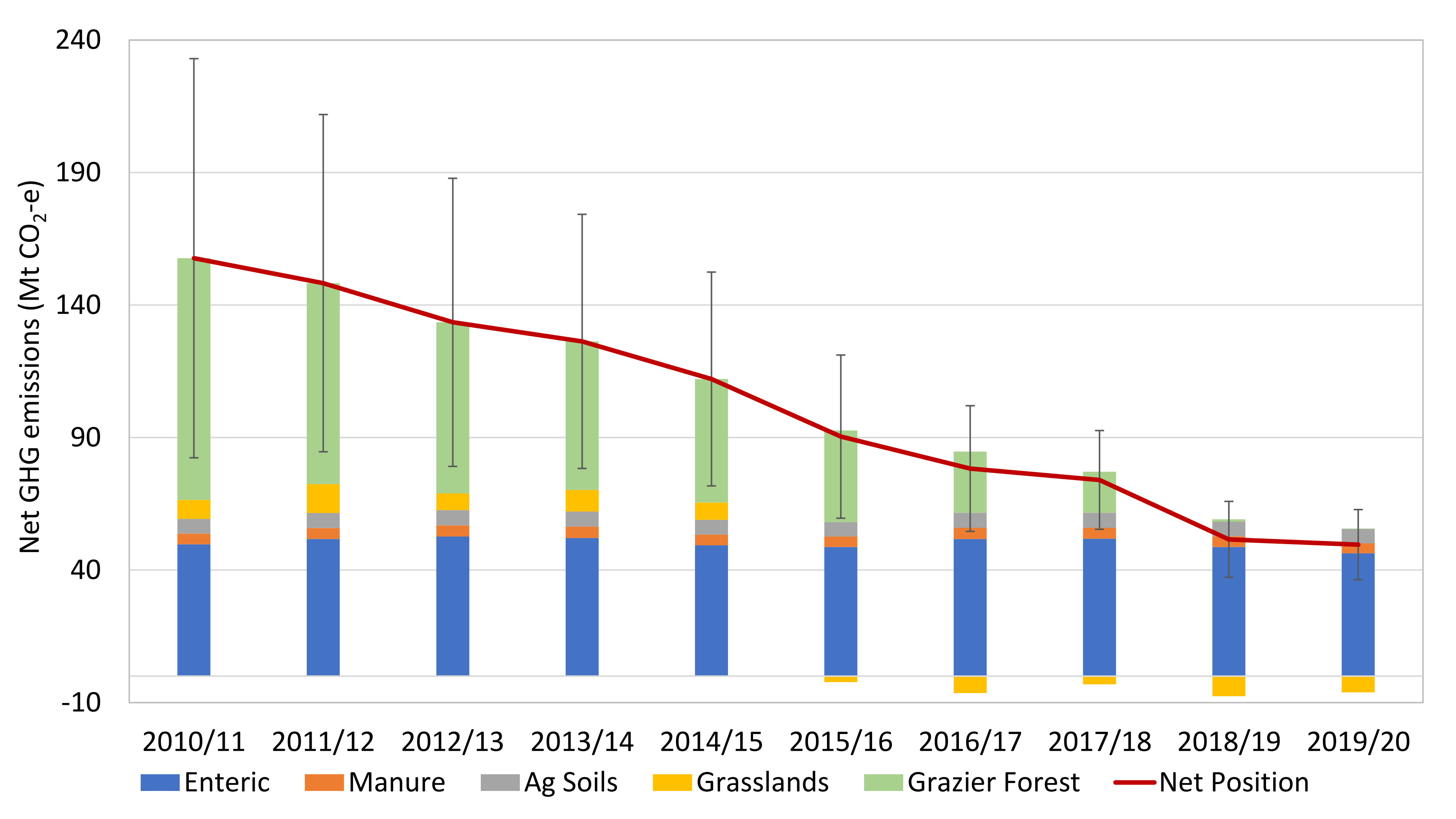
- 46 statistical (SLA4) areas examined
- 99.5% of Australia's red meat enteric methane emissions
- Estimated livestock/soils emissions and grasslands emissions/sinks from national inventory data (**net source**)
- Estimated changes in tree vegetation carbon sequestration using FLINTpro (**net sink (*or source if being lost*)**)
- Difference is **net emissions**



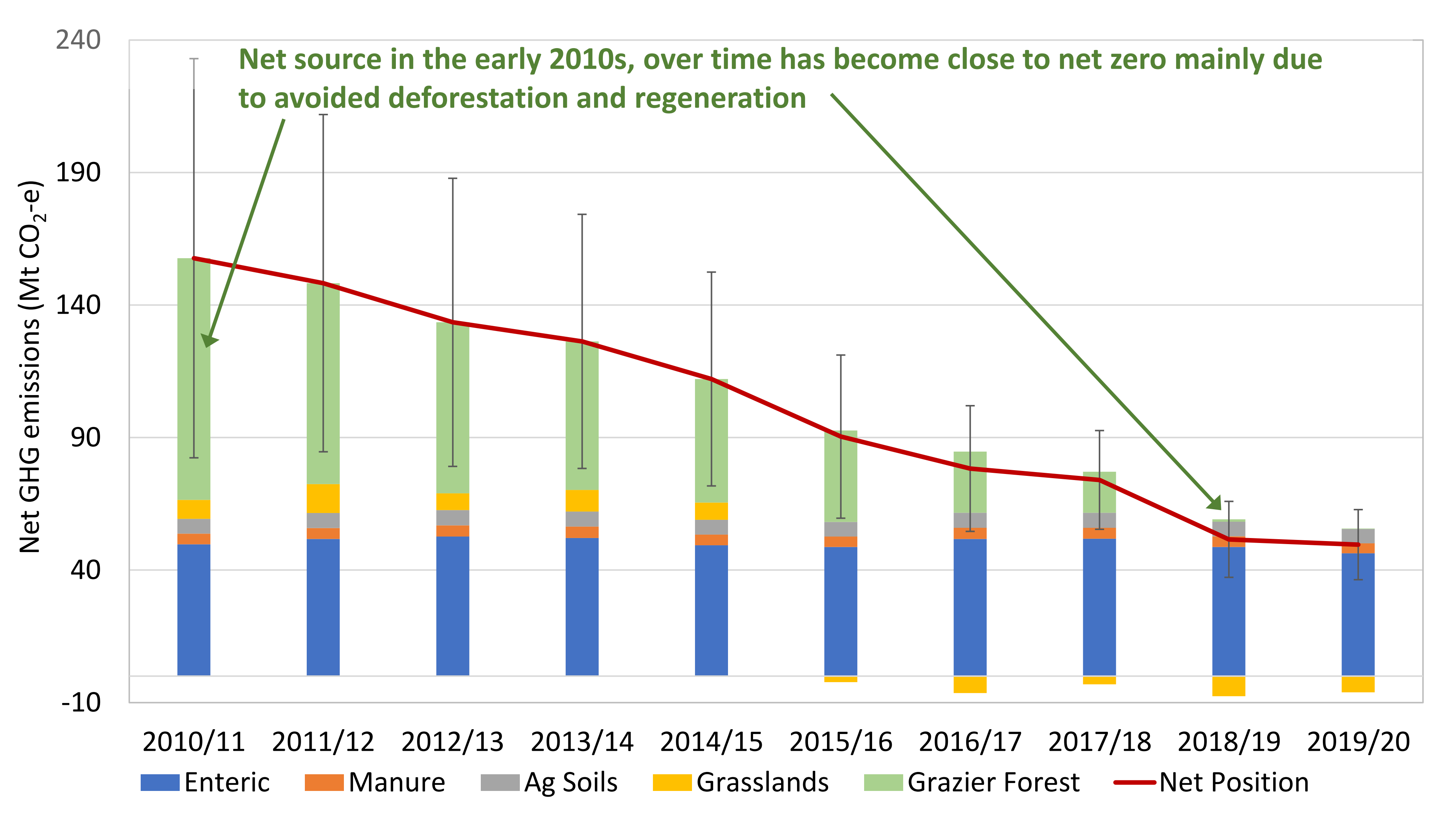
Bowen Butchart et al (2024)

Average net emissions per hectare (2010-20)





240
190
140
90
40
-10
Net GHG emissions (Mt CO_2-e)
2010/11
2011/12
2012/13
2013/14
2014/15
2015/16
2016/17
2017/18
2018/19
2019/20
Enteric
Manure
Ag Soils
Grasslands
Grazier Forest
Net Position



Net source in the early 2010s, over time has become close to net zero mainly due to avoided deforestation and regeneration
Net GHG emissions (Mt CO_2-e)
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190
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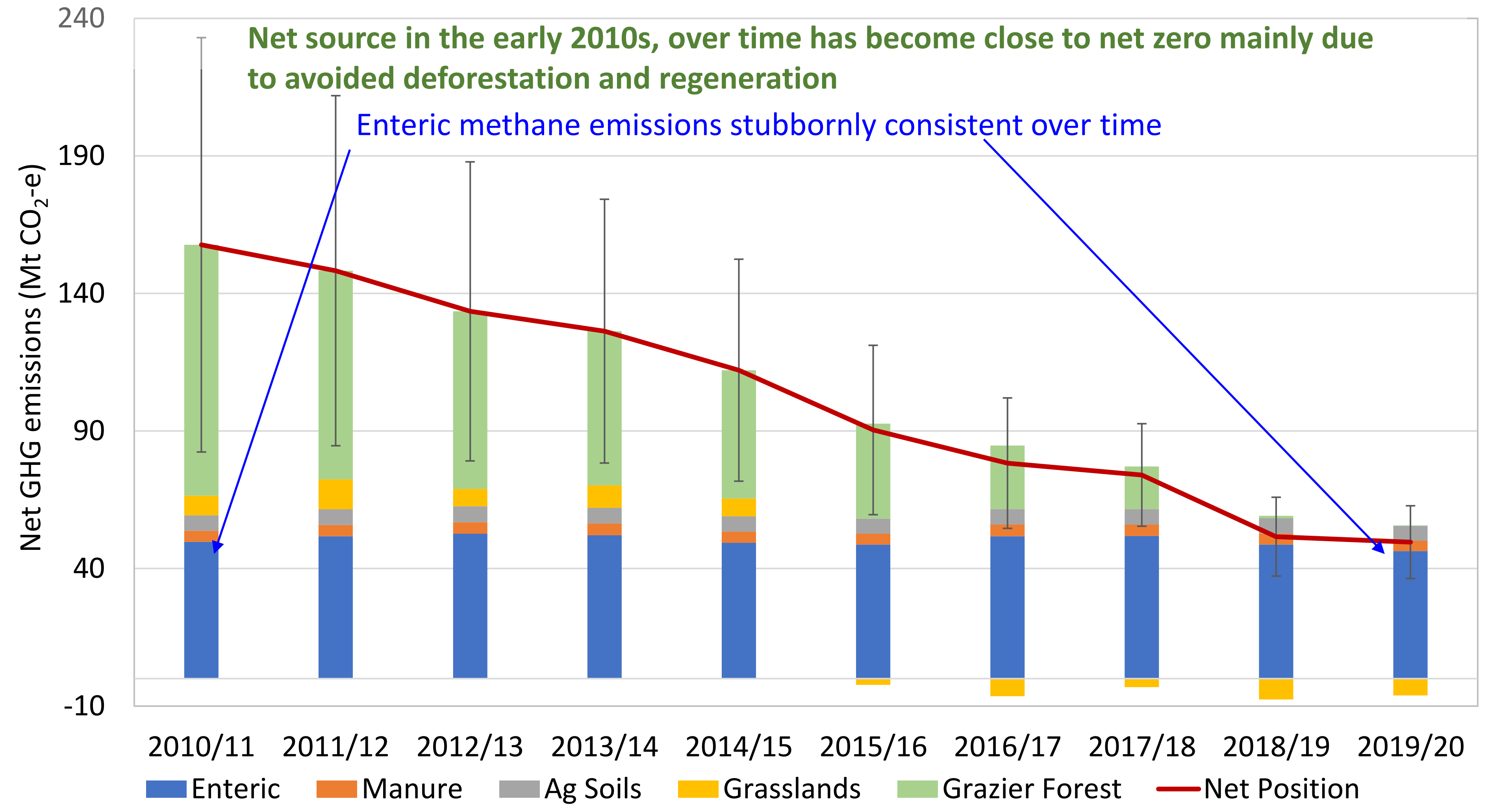

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Enteric methane emissions stubbornly consistent over time
Net GHG emissions (Mt CO_2-e)
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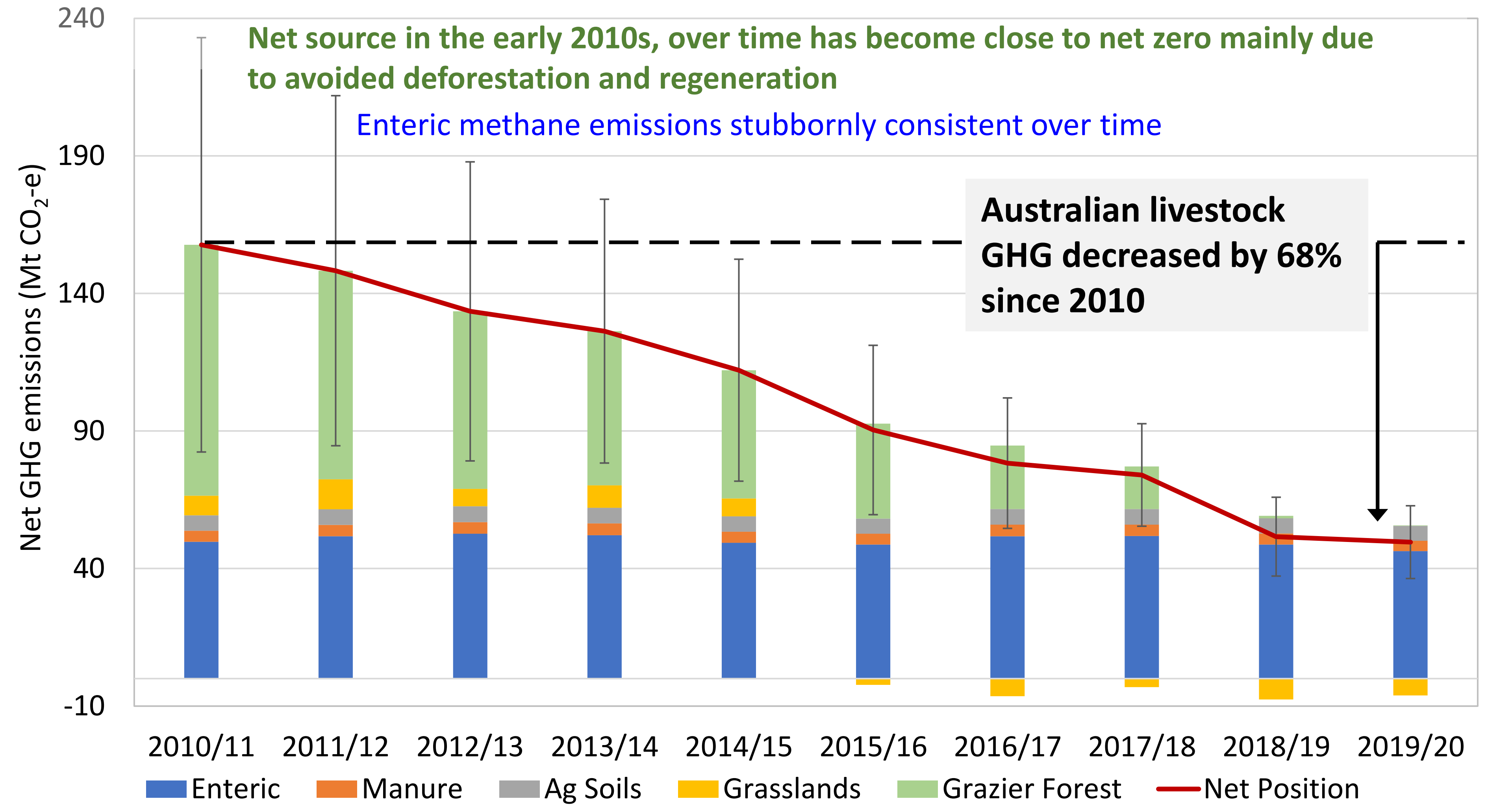

Net source in the early 2010s, over time has become close to net zero mainly due to avoided deforestation and regeneration
Enteric methane emissions stubbornly consistent over time
Australian livestock GHG decreased by 68% since 2010
Net GHG emissions (Mt CO_2-e)
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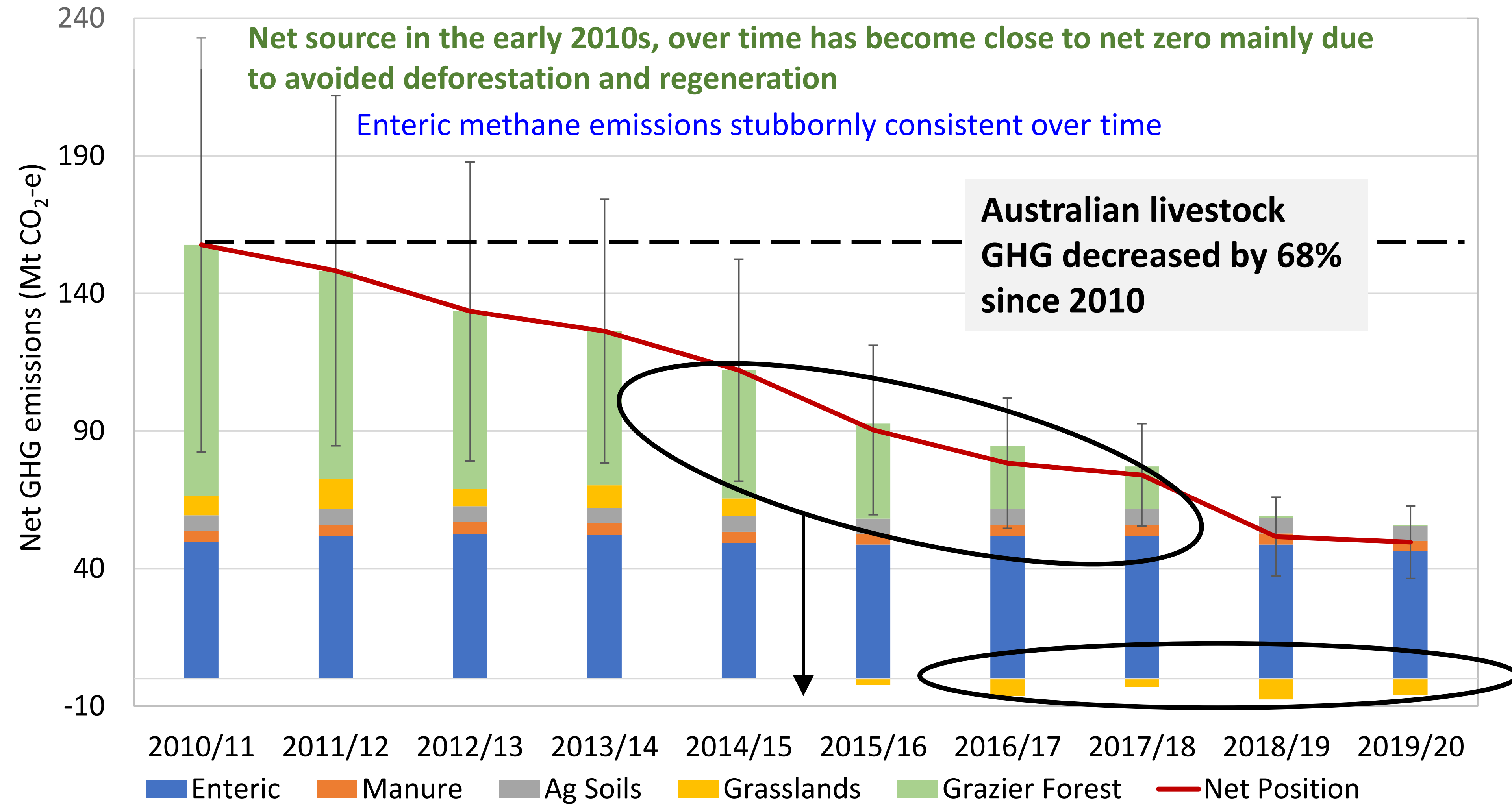

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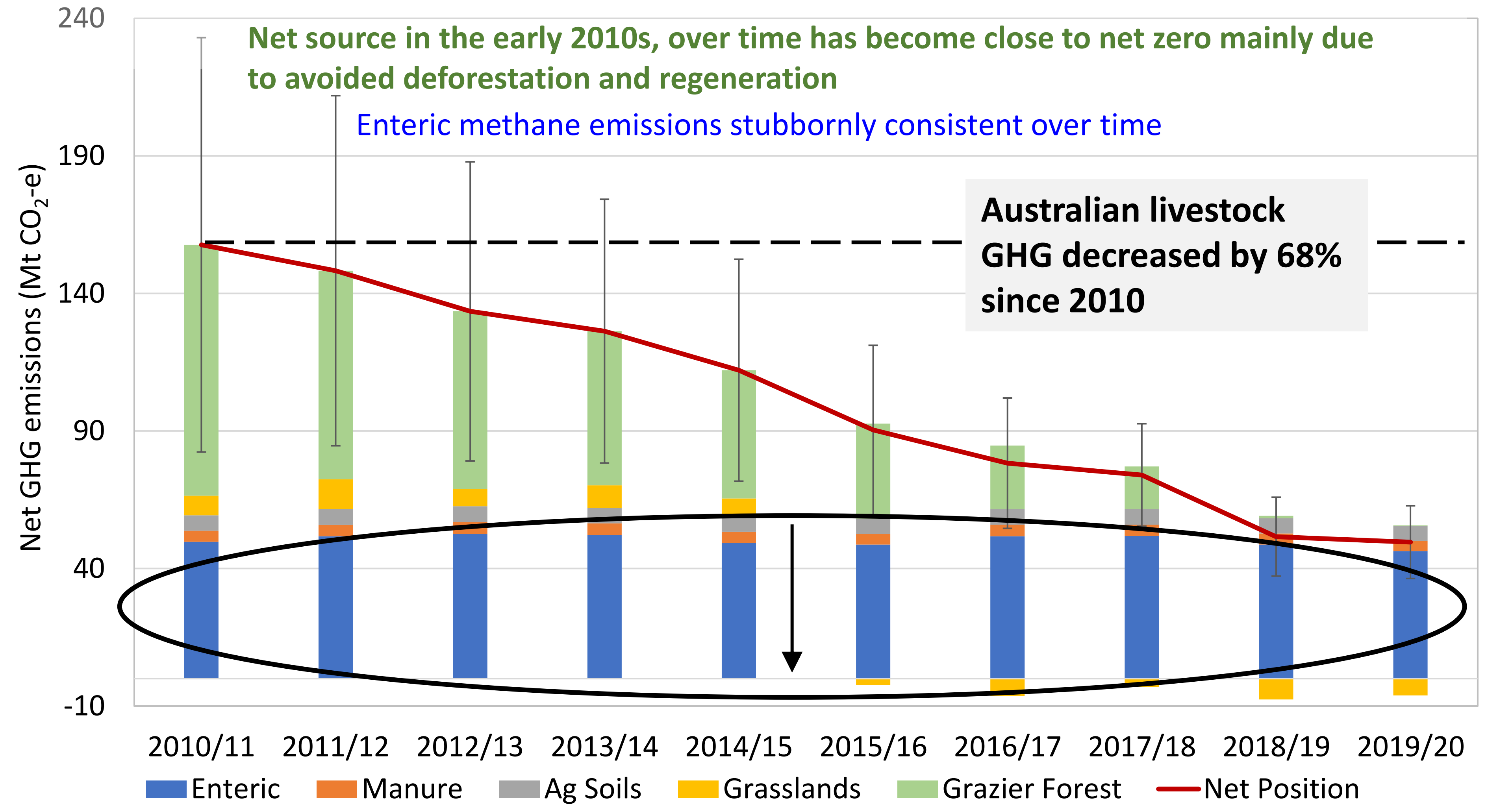

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Grazier Forest
Net Position

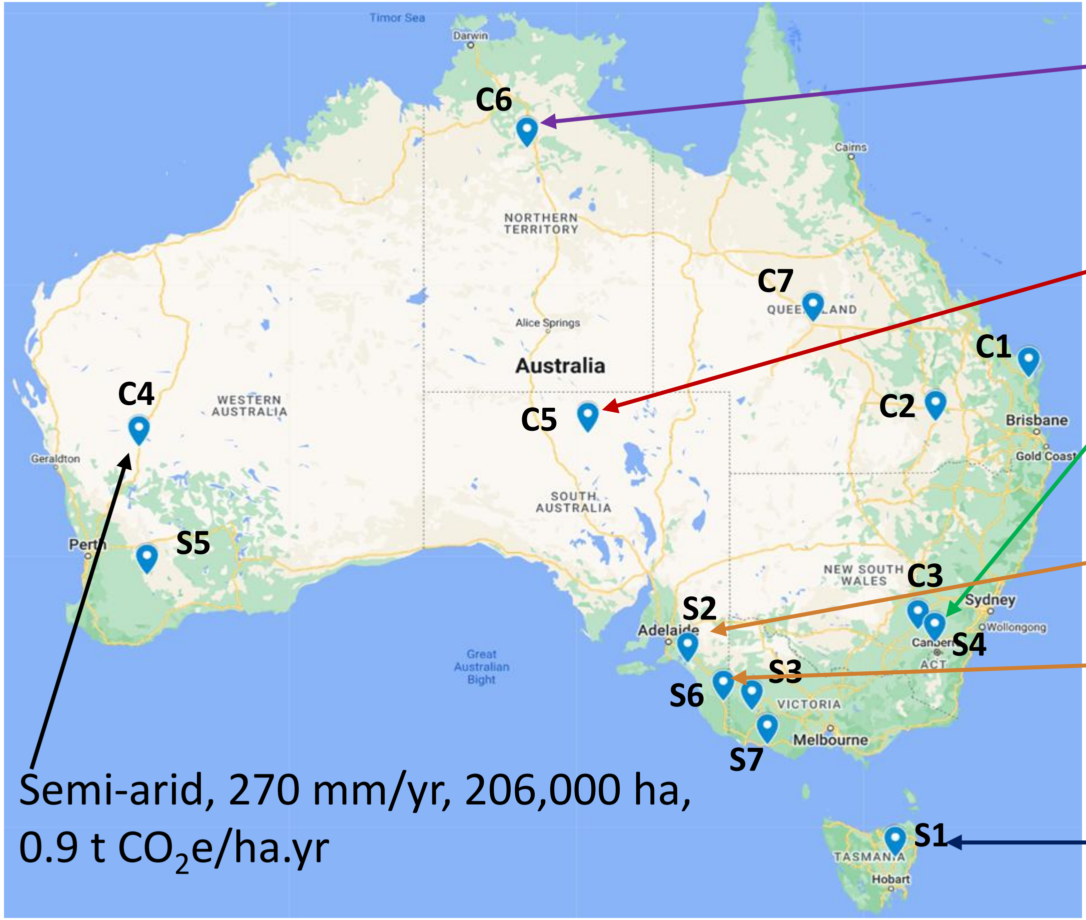
Sustainable Pathways to CN30

Aim: Explore a range of interventions to reduce net farm GHG emissions while improving production, profit and biodiversity relative to current baseline

Methods:
Long-term 30-year simulations; 6 cattle and 7 sheep farms
Biophysical models (GrassGro and CLEM)
Tree carbon sequestration (FLINTpro)
Biodiversity in tree vegetation (LOOC-B)
Greenhouse gas emissions (SB-GAF)
Simple pasture/carbon model- > ± 5% change in pasture production led to a soil carbon change
Economics (gross margin)
Low and high carbon ACCU prices (+ biodiversity $)
Low and high meat prices for meat (10-yr 25th & 75th median $)
Single price for wool production (10-yr 50th median $)
Common prices for some inputs (fertiliser, fuel, husbandry, levies), farm-specific for others (pasture management)

Bhattarai et al (2025)

Sustainable Pathways to CN30



Humid tropics, 670 mm/yr, 231,000 ha, 2.7 t CO_2e/ha.yr

Arid, 150 mm/yr, 498,000 ha, 0.5 t CO_2e/ha.yr

Temperate, 800 mm/yr, 250 ha, 8.2 t CO_2e/ha.yr

Mediterranean, 470 mm/yr, 900 ha, 6.3 t CO_2e/ha.yr

Mediterranean, 630 mm/yr, 2,000 ha, 2.8 t CO_2e/ha.yr

Cool temperate, 500 mm/yr, 7,777 ha, 7.8 t CO_2e/ha.yr

Semi-arid, 270 mm/yr, 206,000 ha, 0.9 t CO_2e/ha.yr

Sustainable Pathways to CN30

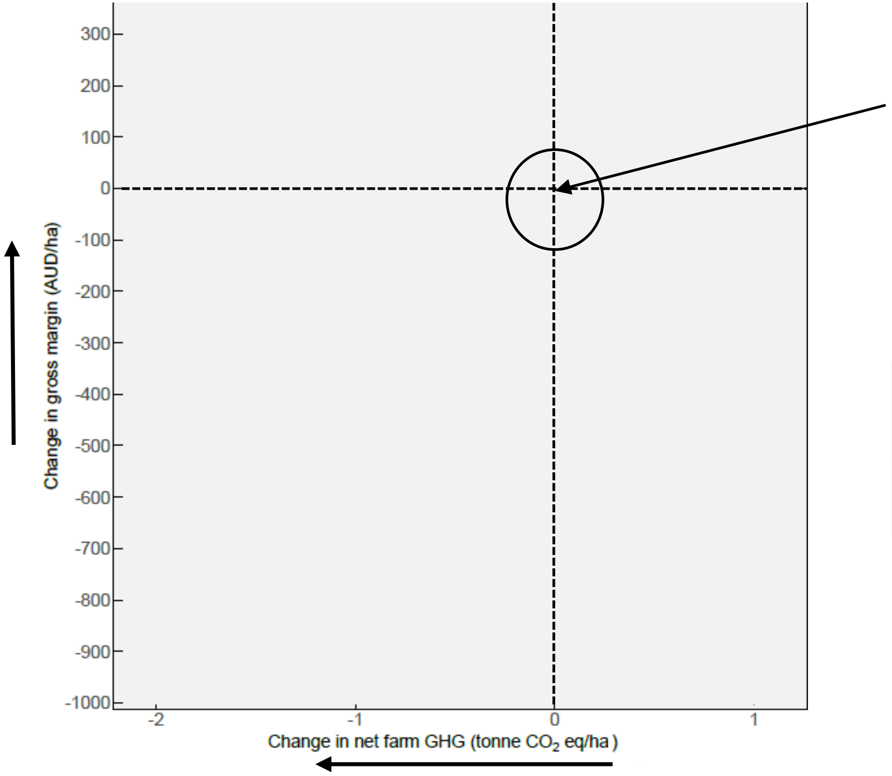
Common-themed across all farms

- 10% tree plantation: 10% grazing area removed and planted to environmental plantings, model decreased livestock numbers by ~ 10%
- 10% and 50% LWG: increased the daily LWG of non-replacement animals from birth to sell sooner but at same LW as baseline. 10% assumed through better grazing and genetics, 50% required additional supplementation
- 10% and 25% methane reduction: assumed all weaned stock consuming anti-methanogenic pastures
- 18% and 37% methane reduction: assumed all weaned stock fed either 3NOP or *Asparagopsis* daily with a grain supplement

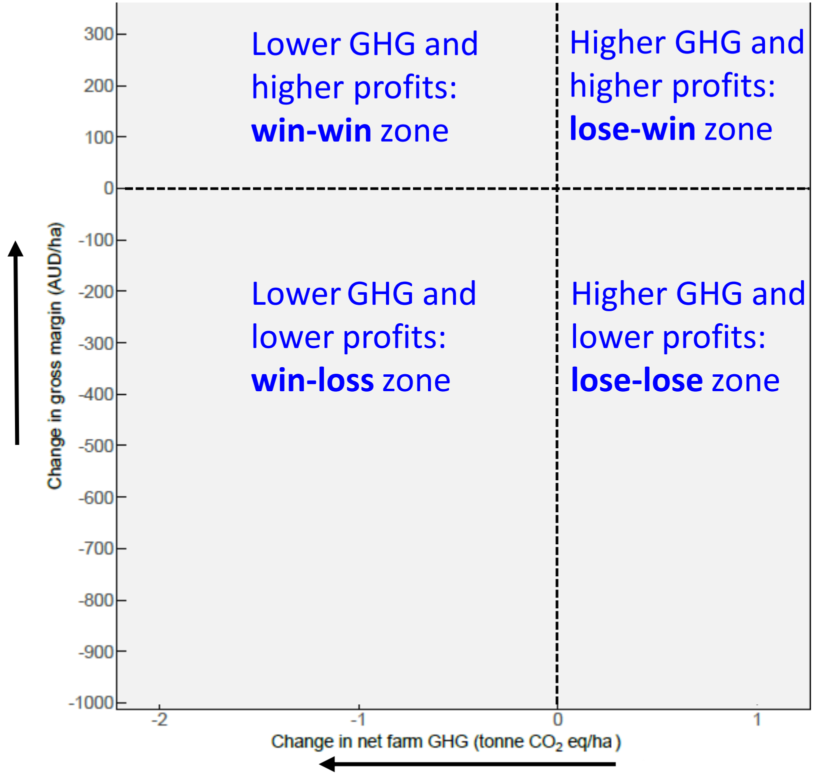
Sustainable Pathways to CN30

Farm-specific examples (generally only done on a single farm):

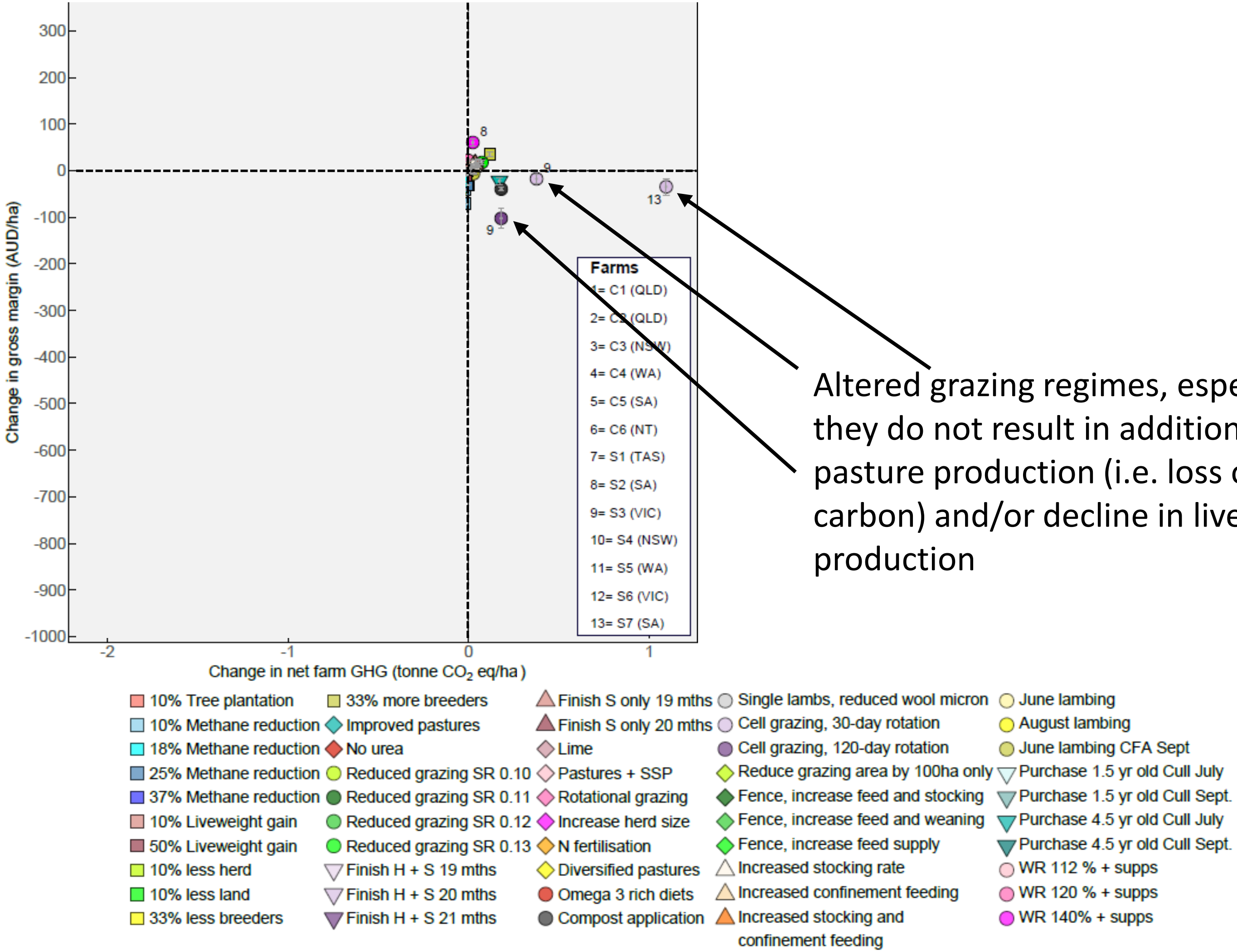
- Reduce to single-lambing ewes combined with decreasing wool micron
- Fencing off riverbanks or creek beds to allow natural regeneration of native tree species for carbon and biodiversity improvements
- Significant increase or decrease in herd size (rangeland cattle farms)
- Altering lambing dates
- Wildlife-proofing boundary paddocks to remove browsing pressure (deer, wallabies etc)- using this extra pasture to increase weaning rates or stocking rates
- Feedlotting longer over summer/autumn
- Altered grazing regimes (30-day or 120-day rotations)
- Replacing inorganic MAP fertiliser with compost
- Altering finishing ages/weights of young stock
- Altering purchase age/time for replacement ewes
- Alternative options to build soil carbon through pasture and grazing management


300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
Change in gross margin (AUD/ha)
-2
-1
0
1
Change in net farm GHG (tonne CO_2 eq/ha)
Baseline position of each farm
(profit and net GHG emissions)

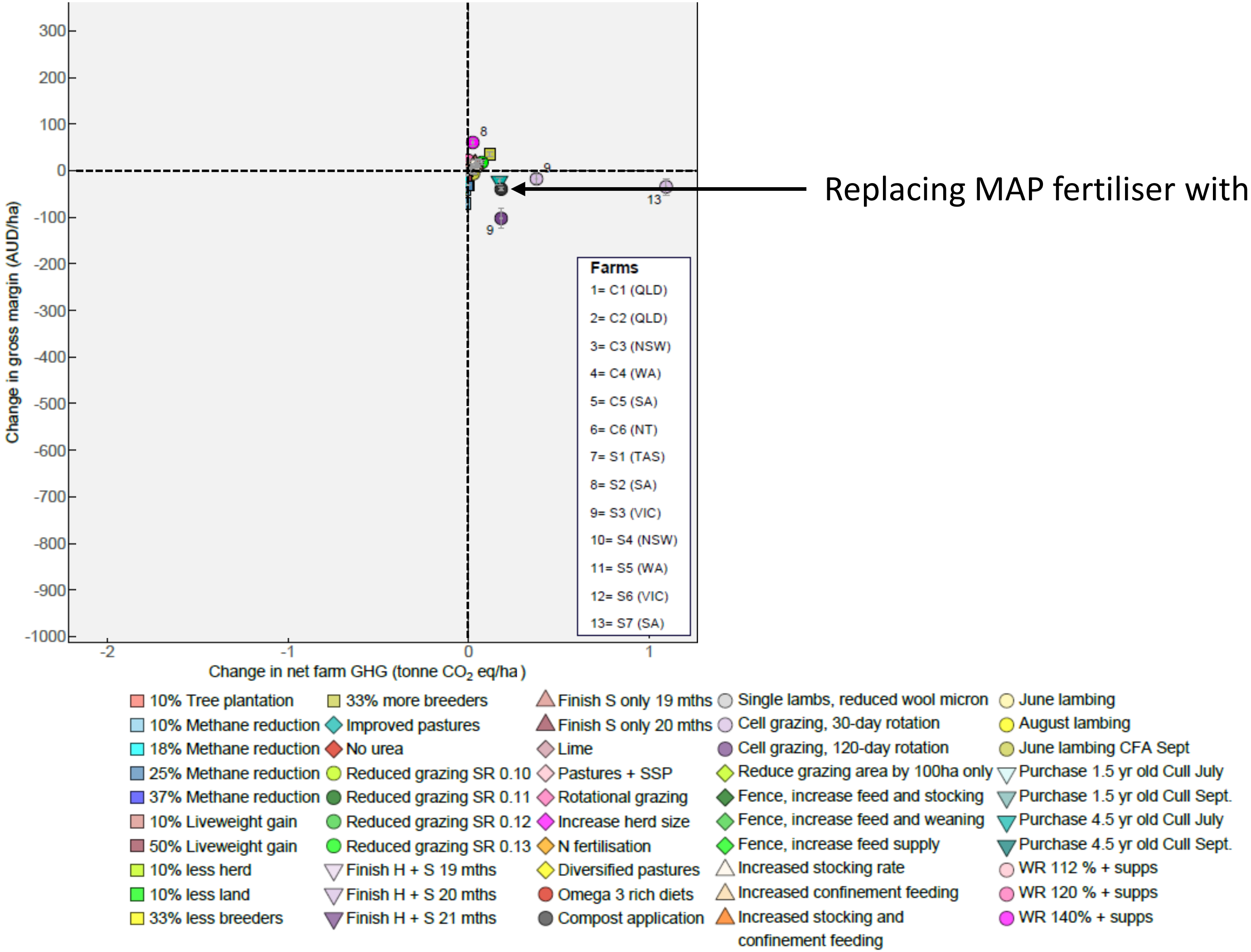

13
High meat, carbon and biodiversity $
Low meat, carbon and biodiversity $


Lower GHG and higher profits: **win-win** zone
Higher GHG and higher profits: **lose-win** zone
Lower GHG and lower profits: **win-loss** zone
Higher GHG and lower profits: **lose-lose** zone
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-2
-1
0
1

300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
Change in gross margin (AUD/ha)
-2
-1
0
1
Change in net farm GHG (tonne CO_2 eq/ha)
8
9
13
9
lose-lose zone
Farms
1= C1 (QLD)
2= C2 (QLD)
3= C3 (NSW)
4= C4 (WA)
5= C5 (SA)
6= C6 (NT)
7= S1 (TAS)
8= S2 (SA)
9= S3 (VIC)
10= S4 (NSW)
11= S5 (WA)
12= S6 (VIC)
13= S7 (SA)
10% Tree plantation
10% Methane reduction
18% Methane reduction
25% Methane reduction
37% Methane reduction
10% Liveweight gain
50% Liveweight gain
10% less herd
10% less land
33% less breeders
33% more breeders
Improved pastures
No urea
Reduced grazing SR 0.10
Reduced grazing SR 0.11
Reduced grazing SR 0.12
Reduced grazing SR 0.13
Finish H + S 19 mths
Finish H + S 20 mths
Finish H + S 21 mths
Finish S only 19 mths
Finish S only 20 mths
Lime
Pastures + SSP
Rotational grazing
Increase herd size
N fertilisation
Diversified pastures
Omega 3 rich diets
Compost application
Single lambs, reduced wool micron
Cell grazing, 30-day rotation
Cell grazing, 120-day rotation
Reduce grazing area by 100ha only
Fence, increase feed and stocking
Fence, increase feed and weaning
Fence, increase feed supply
Increased stocking rate
Increased confinement feeding
Increased stocking and confinement feeding
June lambing
August lambing
June lambing CFA Sept
Purchase 1.5 yr old Cull July
Purchase 1.5 yr old Cull Sept.
Purchase 4.5 yr old Cull July
Purchase 4.5 yr old Cull Sept.
WR 112 % + supps
WR 120 % + supps
WR 140% + supps



Altered grazing regimes, especially if they do not result in additional pasture production (i.e. loss of soil carbon) and/or decline in livestock production



Replacing MAP fertiliser with compost

lose-win zone
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
Change in gross margin (AUD/ha)
-2
-1
0
1
Change in net farm GHG (tonne CO_2 eq/ha)
8
9
13
9
Farms
1= C1 (QLD)
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50% Liveweight gain
10% less herd
10% less land
33% less breeders
33% more breeders
Improved pastures
No urea
Reduced grazing SR 0.10
Reduced grazing SR 0.11
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Finish H + S 19 mths
Finish H + S 20 mths
Finish H + S 21 mths
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Finish S only 20 mths
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Pastures + SSP
Rotational grazing
Increase herd size
N fertilisation
Diversified pastures
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Compost application
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Fence, increase feed and stocking
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Fence, increase feed supply
Increased stocking rate
Increased confinement feeding
Increased stocking and confinement feeding
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WR 112 % + supps
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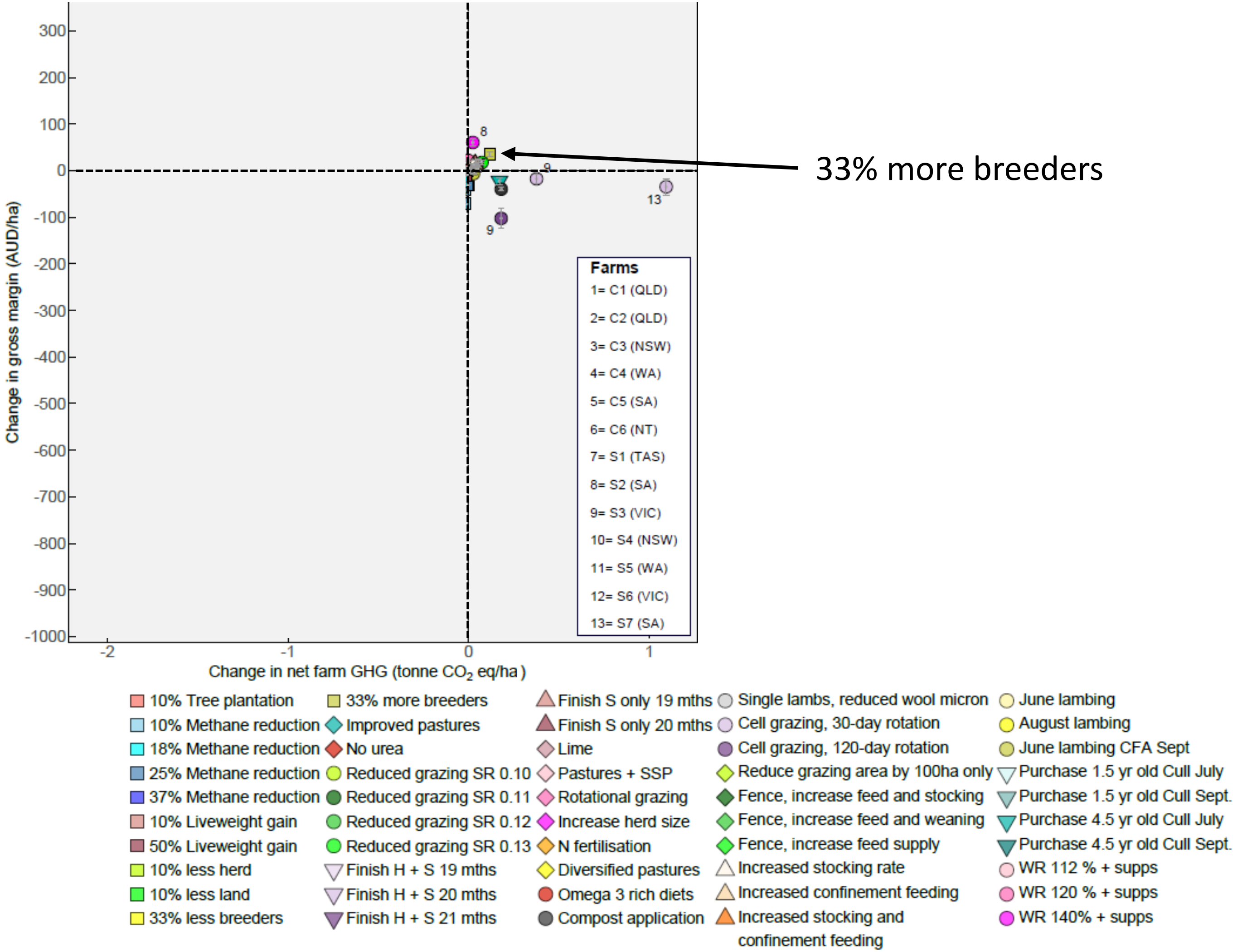
33% more breeders
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
Farms
1= C1 (QLD)
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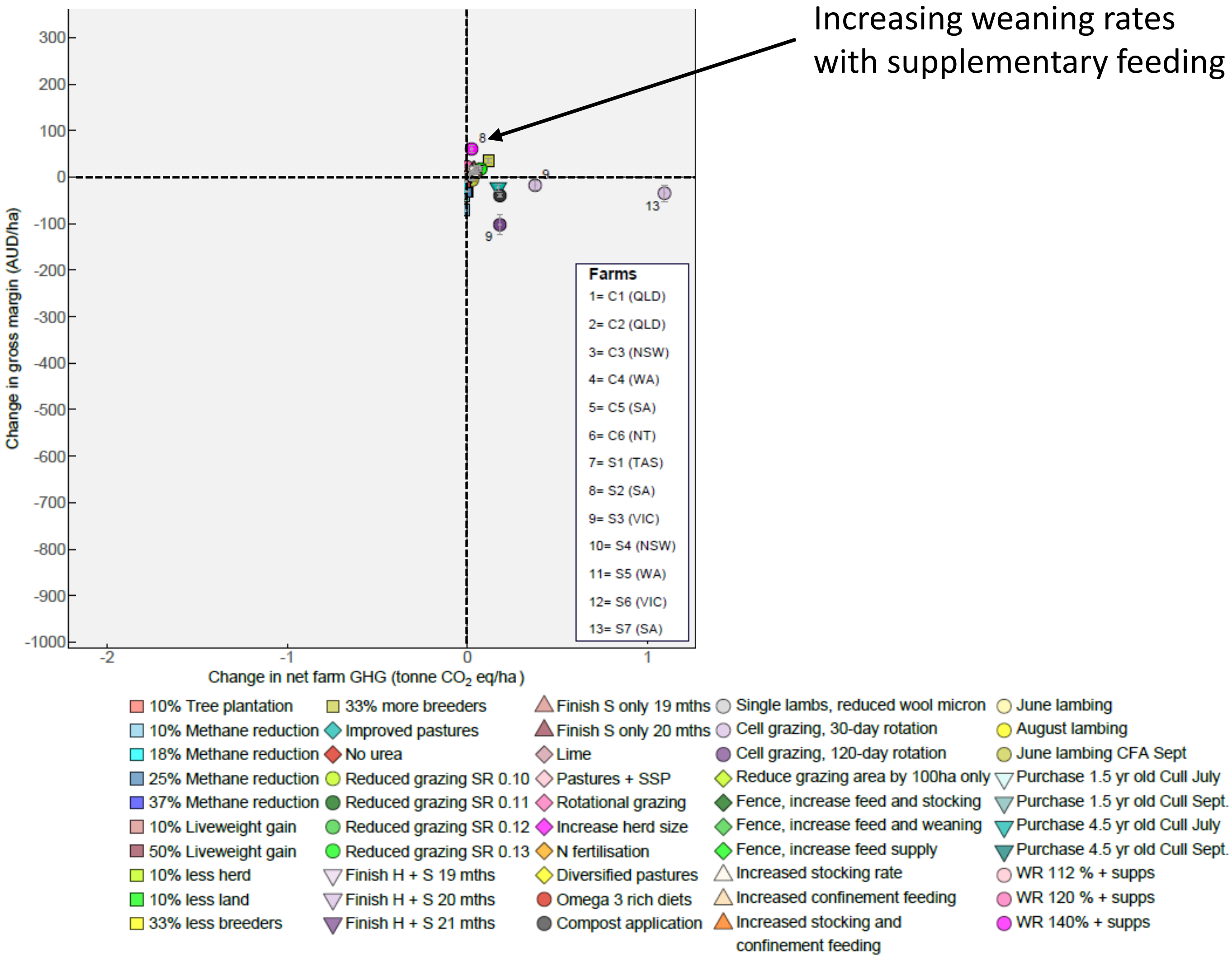

Increasing weaning rates
with supplementary feeding
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
Farms
1= C1 (QLD)
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3= C3 (NSW)
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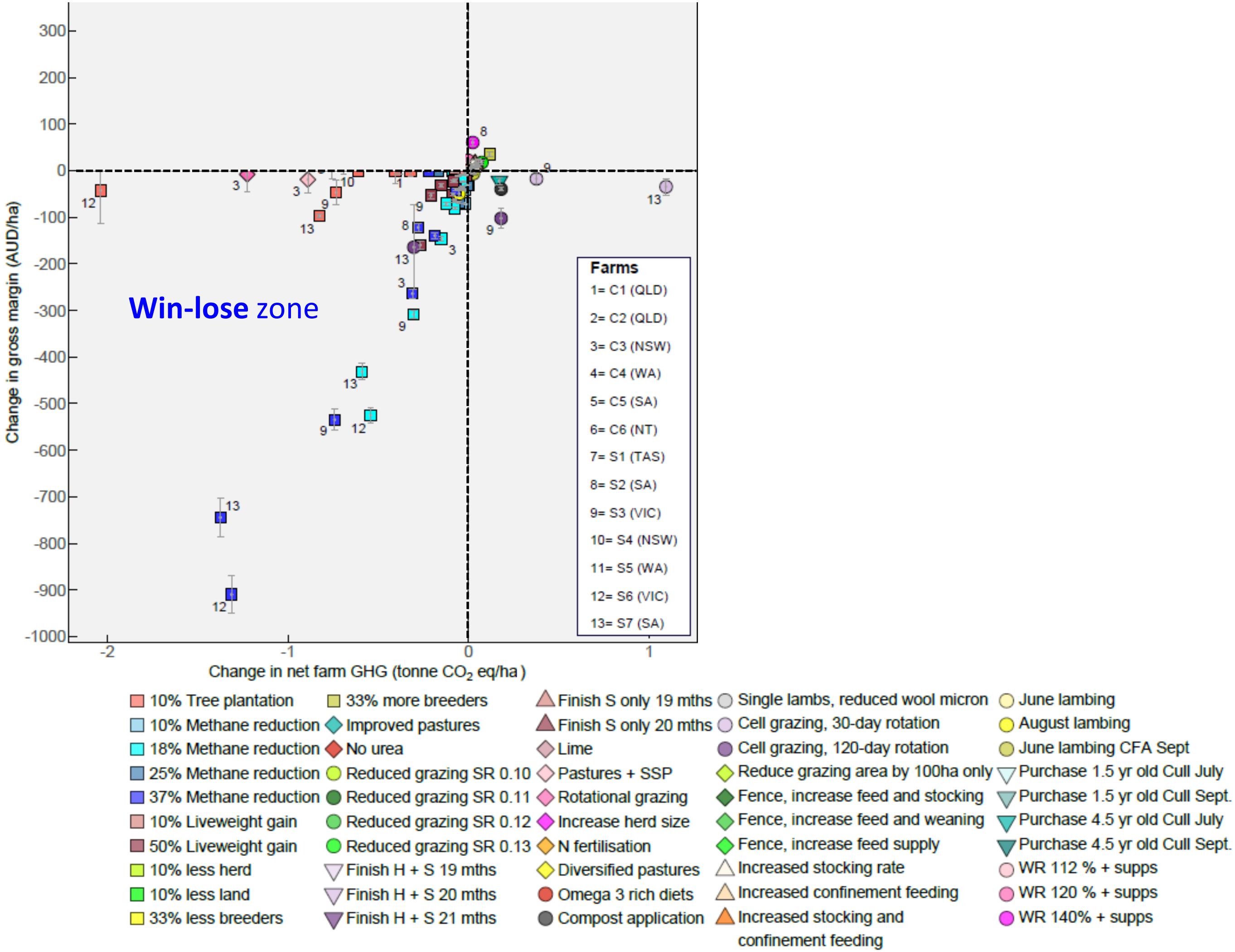

Win-lose zone
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-2
-1
0
1
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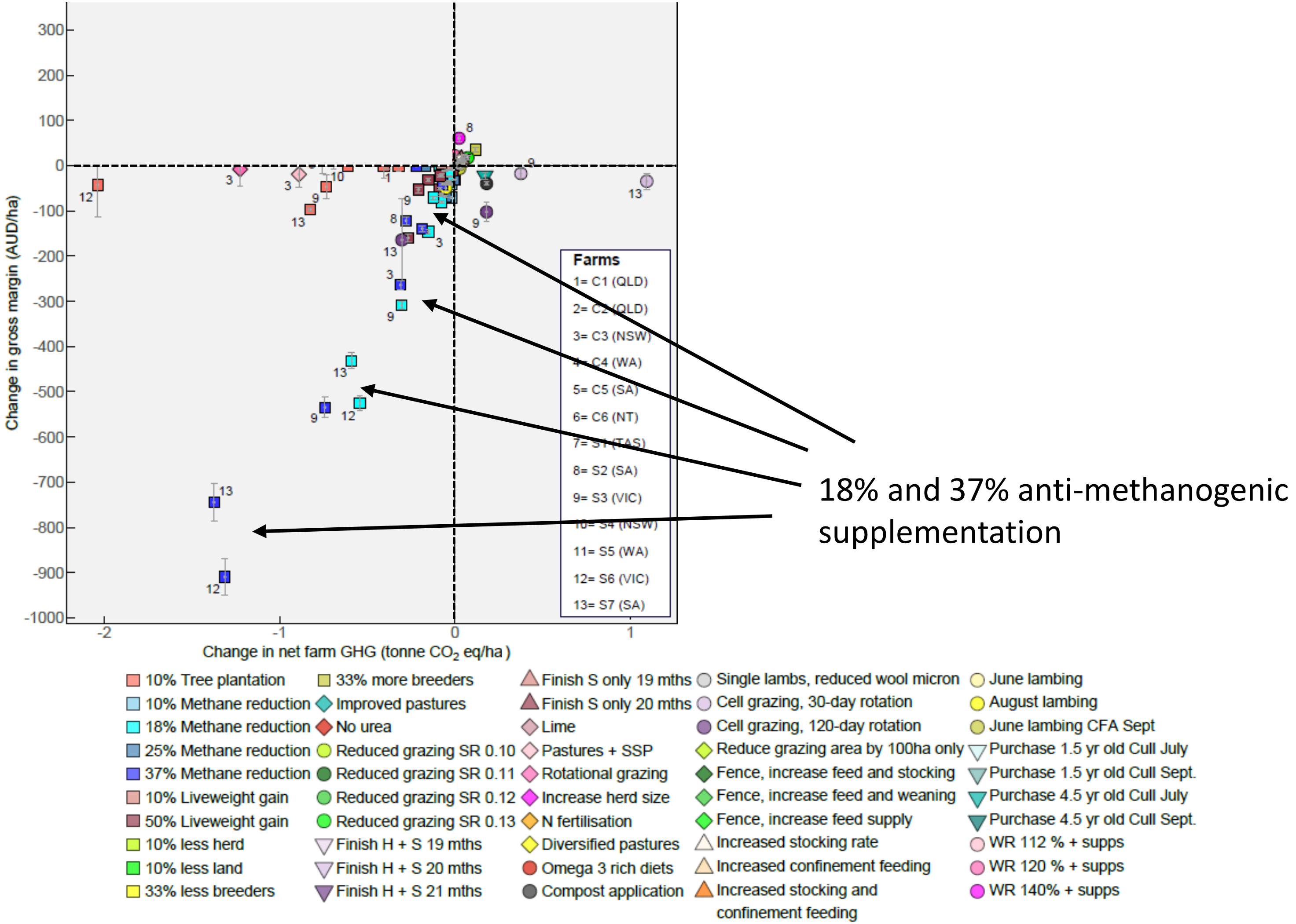
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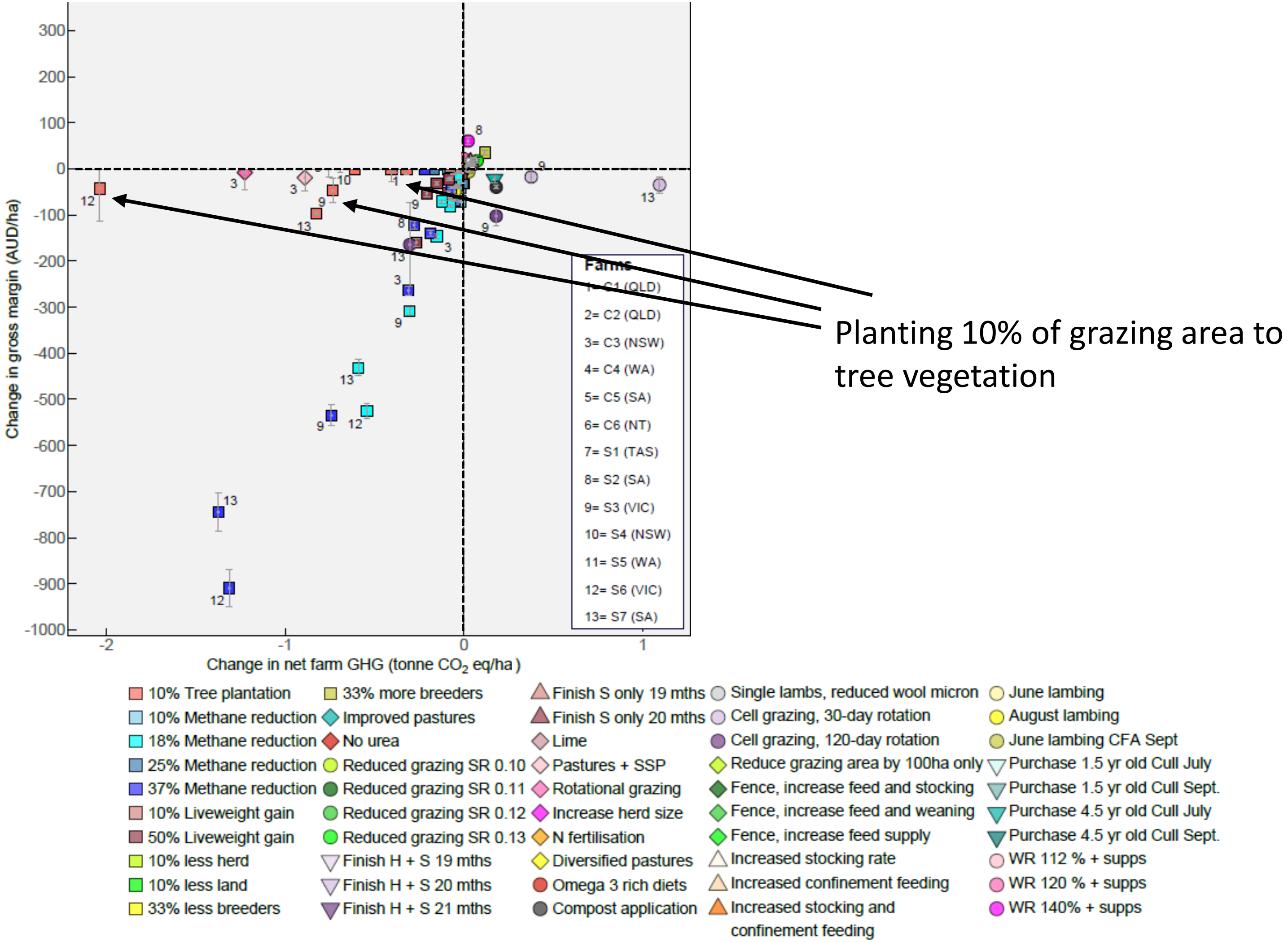
Diversified pastures
Omega 3 rich diets
Compost application
Single lambs, reduced wool micron
Cell grazing, 30-day rotation
Cell grazing, 120-day rotation
Reduce grazing area by 100ha only
Fence, increase feed and stocking
Fence, increase feed and weaning
Fence, increase feed supply
Increased stocking rate
Increased confinement feeding
Increased stocking and confinement feeding
June lambing
August lambing
June lambing CFA Sept
Purchase 1.5 yr old Cull July
Purchase 1.5 yr old Cull Sept.
Purchase 4.5 yr old Cull July
Purchase 4.5 yr old Cull Sept.
WR 112 % + supps
WR 120 % + supps
WR 140% + supps
18% and 37% anti-methanogenic supplementation



Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO2 eq/ha)
Farms
1= C1 (QLD)
2= C2 (QLD)
3= C3 (NSW)
4= C4 (WA)
5= C5 (SA)
6= C6 (NT)
7= S1 (TAS)
8= S2 (SA)
9= S3 (VIC)
10= S4 (NSW)
11= S5 (WA)
12= S6 (VIC)
13= S7 (SA)
Planting 10% of grazing area to tree vegetation
10% Tree plantation
10% Methane reduction
18% Methane reduction
25% Methane reduction
37% Methane reduction
10% Liveweight gain
50% Liveweight gain
10% less herd
10% less land
33% less breeders
33% more breeders
Improved pastures
No urea
Reduced grazing SR 0.10
Reduced grazing SR 0.11
Reduced grazing SR 0.12
Reduced grazing SR 0.13
Finish H + S 19 mths
Finish H + S 20 mths
Finish H + S 21 mths
Finish S only 19 mths
Finish S only 20 mths
Lime
Pastures + SSP
Rotational grazing
Increase herd size
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WR 112 % + supps
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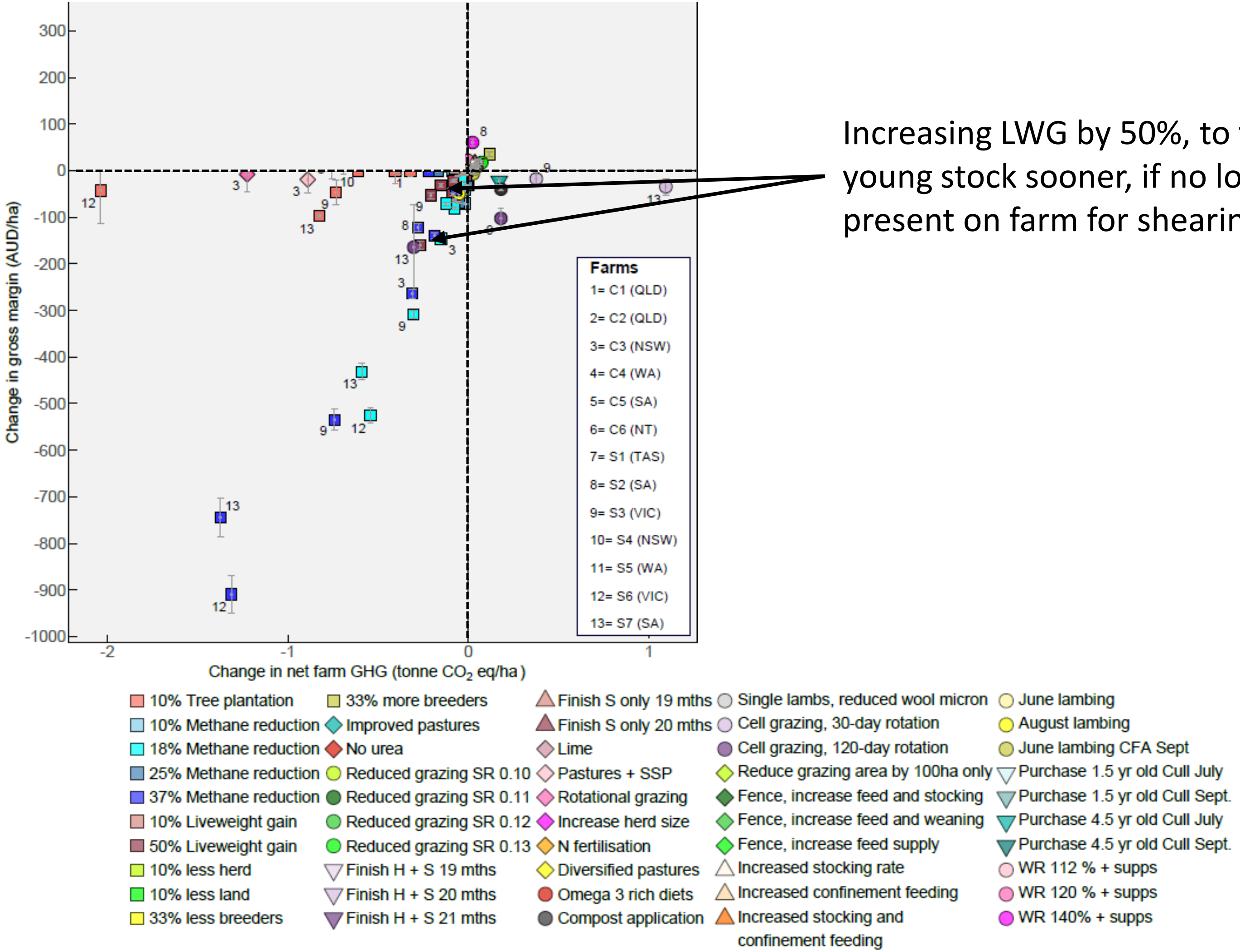
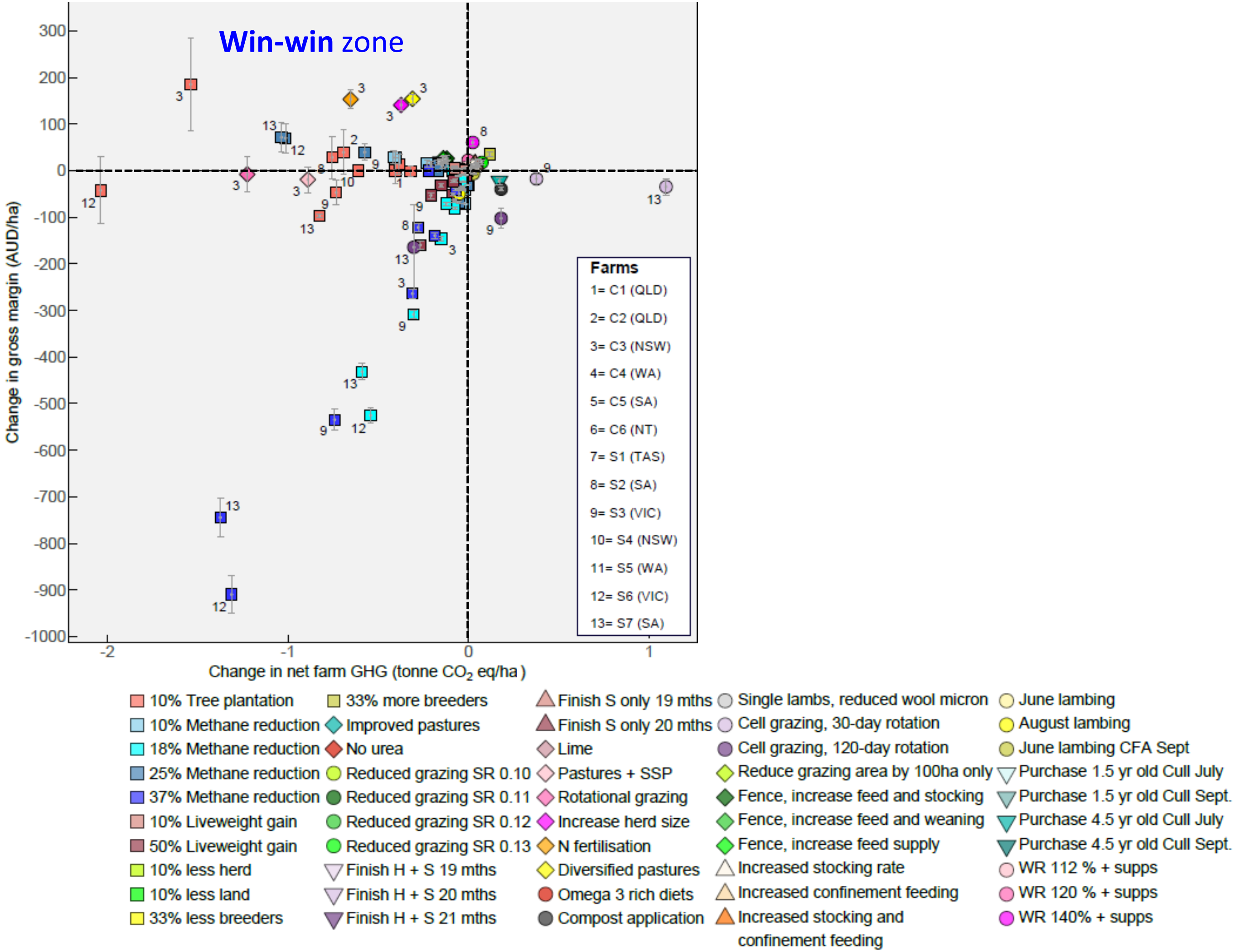
WR 140% + supps



Increasing LWG by 50%, to finish young stock sooner, if no longer present on farm for shearing



Win-win zone
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
Farms
1= C1 (QLD)
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10= S4 (NSW)
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10% less land
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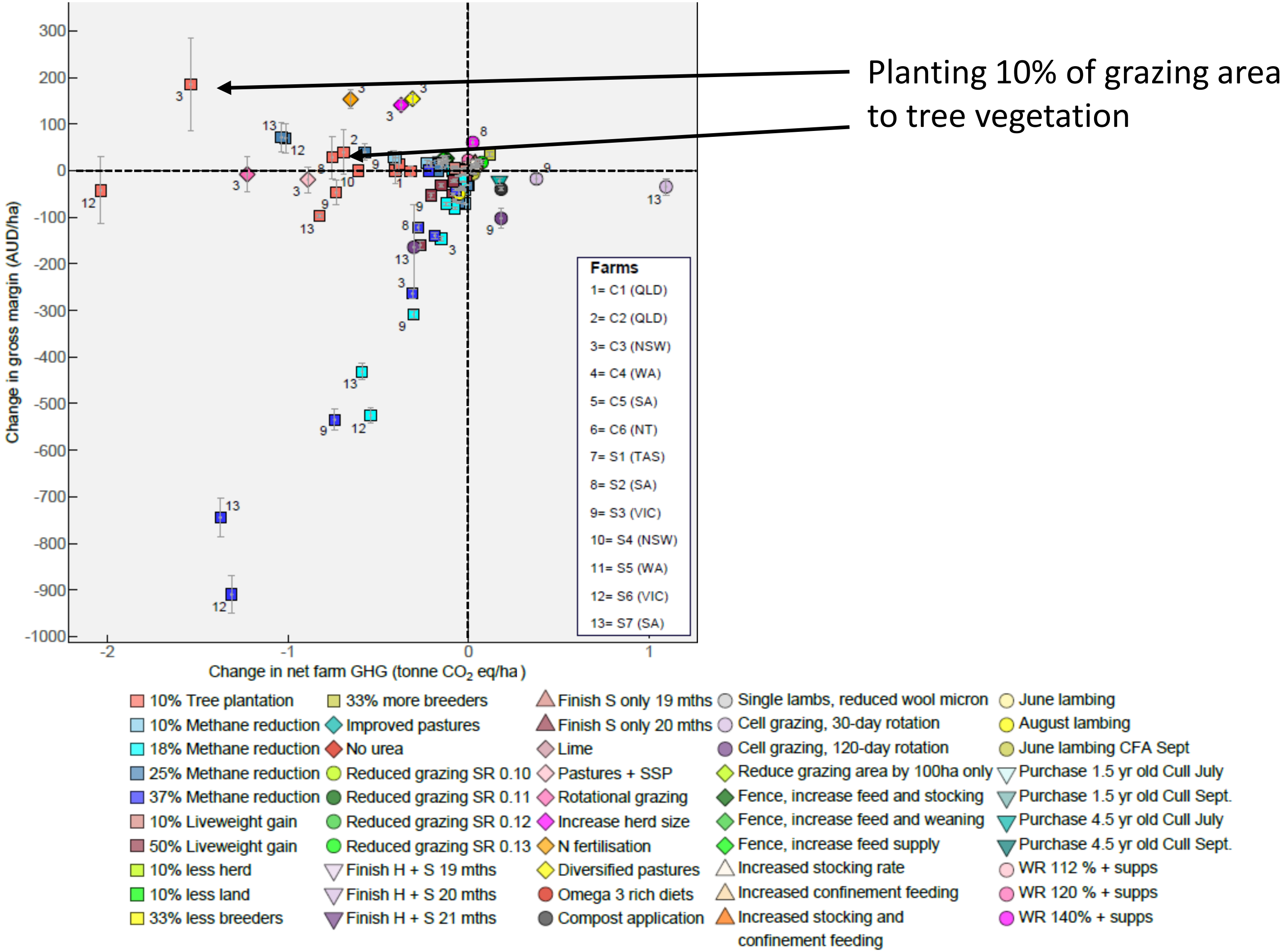
WR 120 % + supps
WR 140% + supps


Planting 10% of grazing area to tree vegetation
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
Farms
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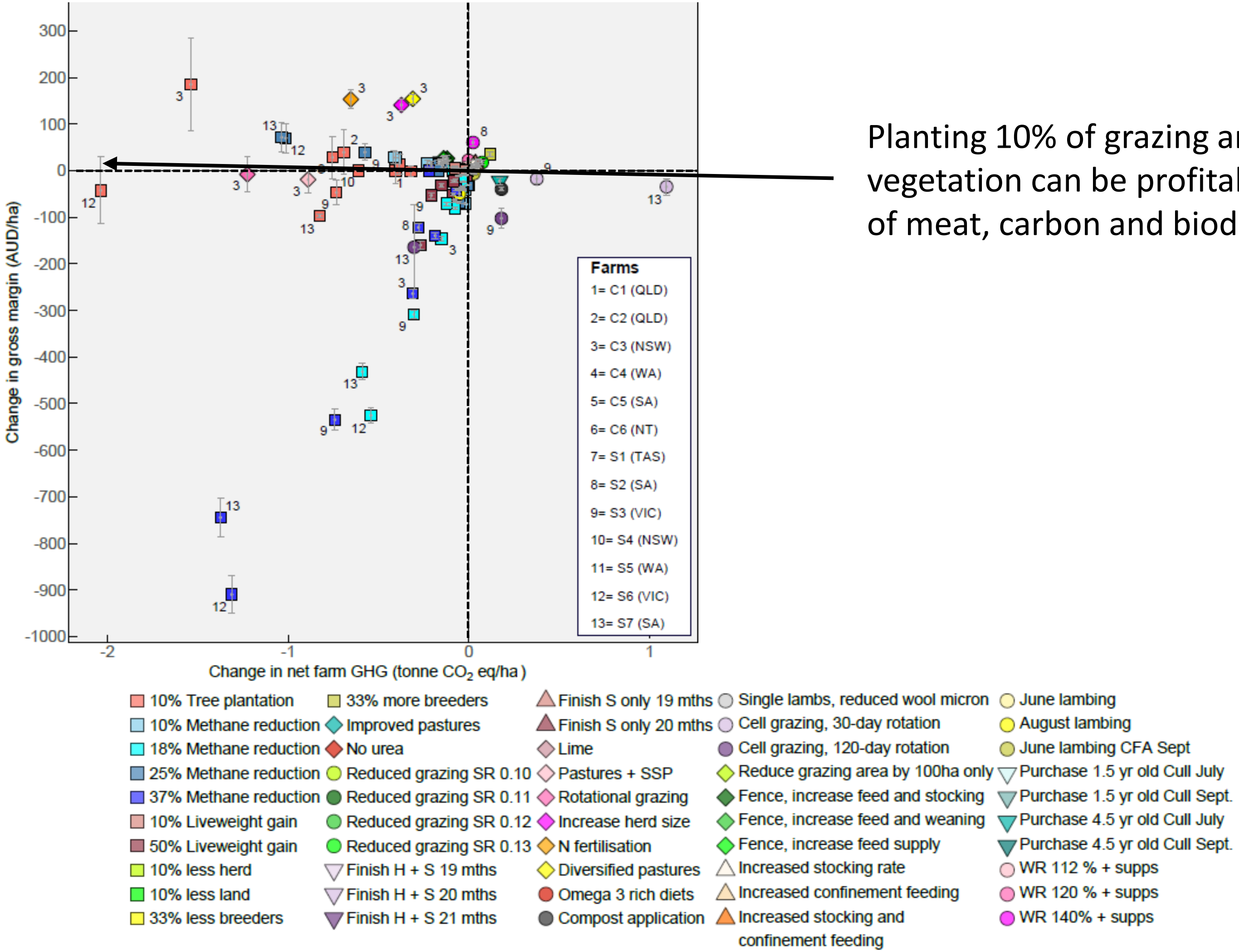
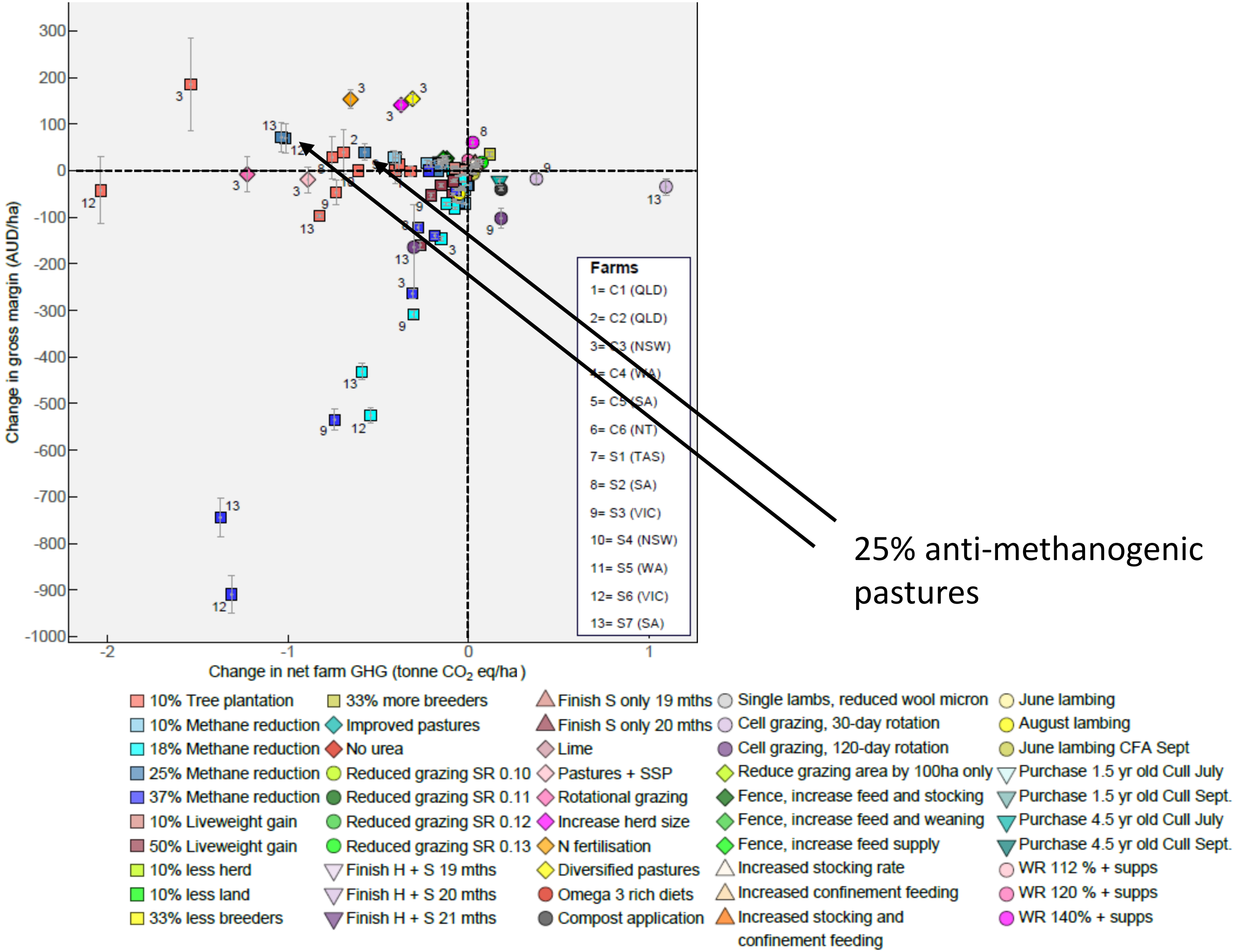


Planting 10% of grazing area to tree vegetation can be profitable if the price of meat, carbon and biodiversity are high



25% anti-methanogenic pastures
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO_2 eq/ha)
Farms
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10% less herd
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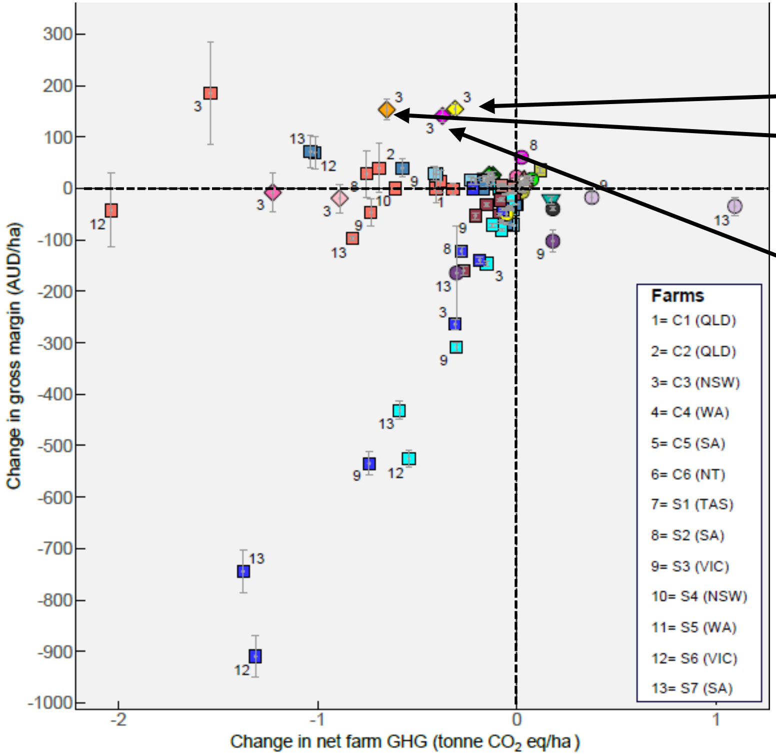
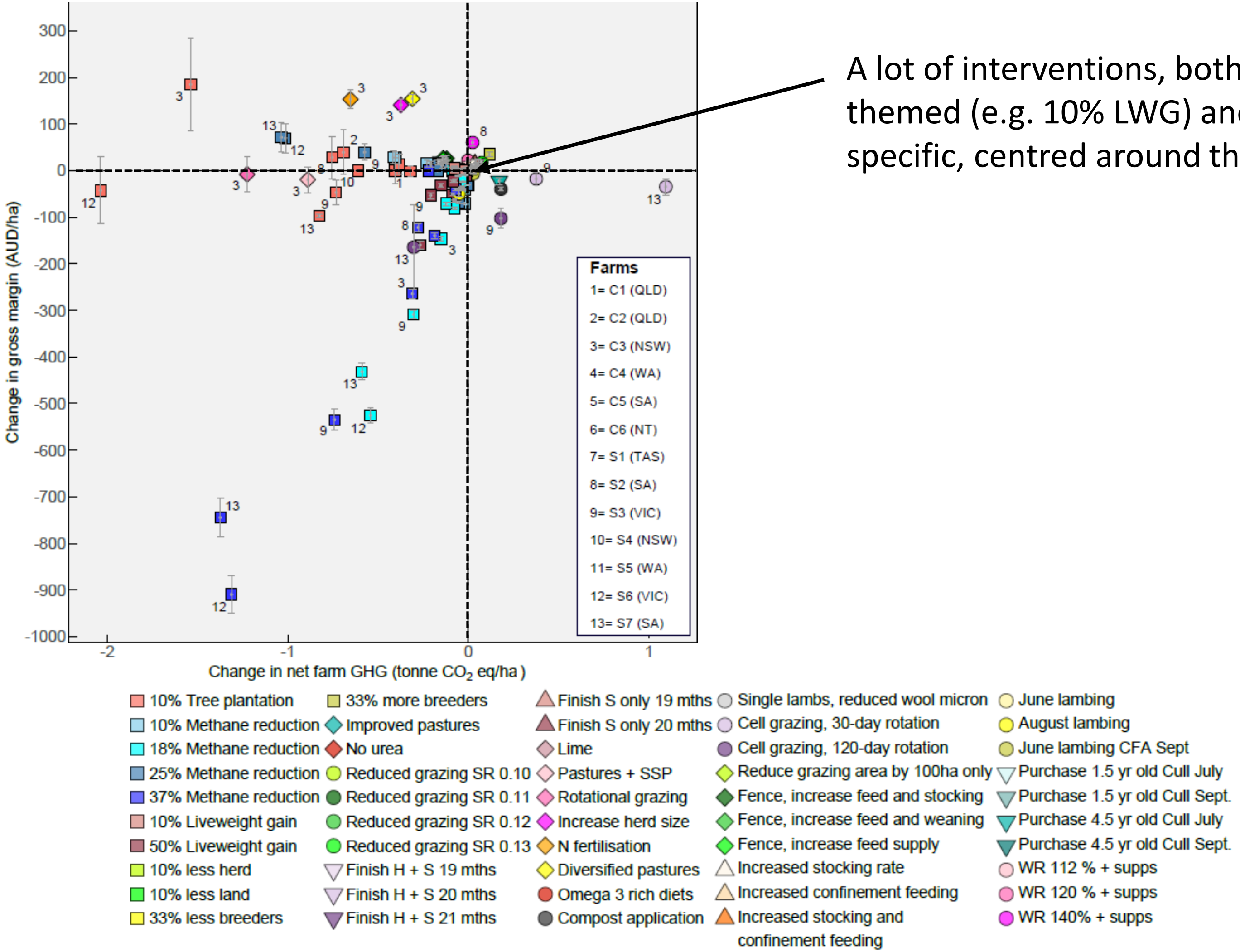


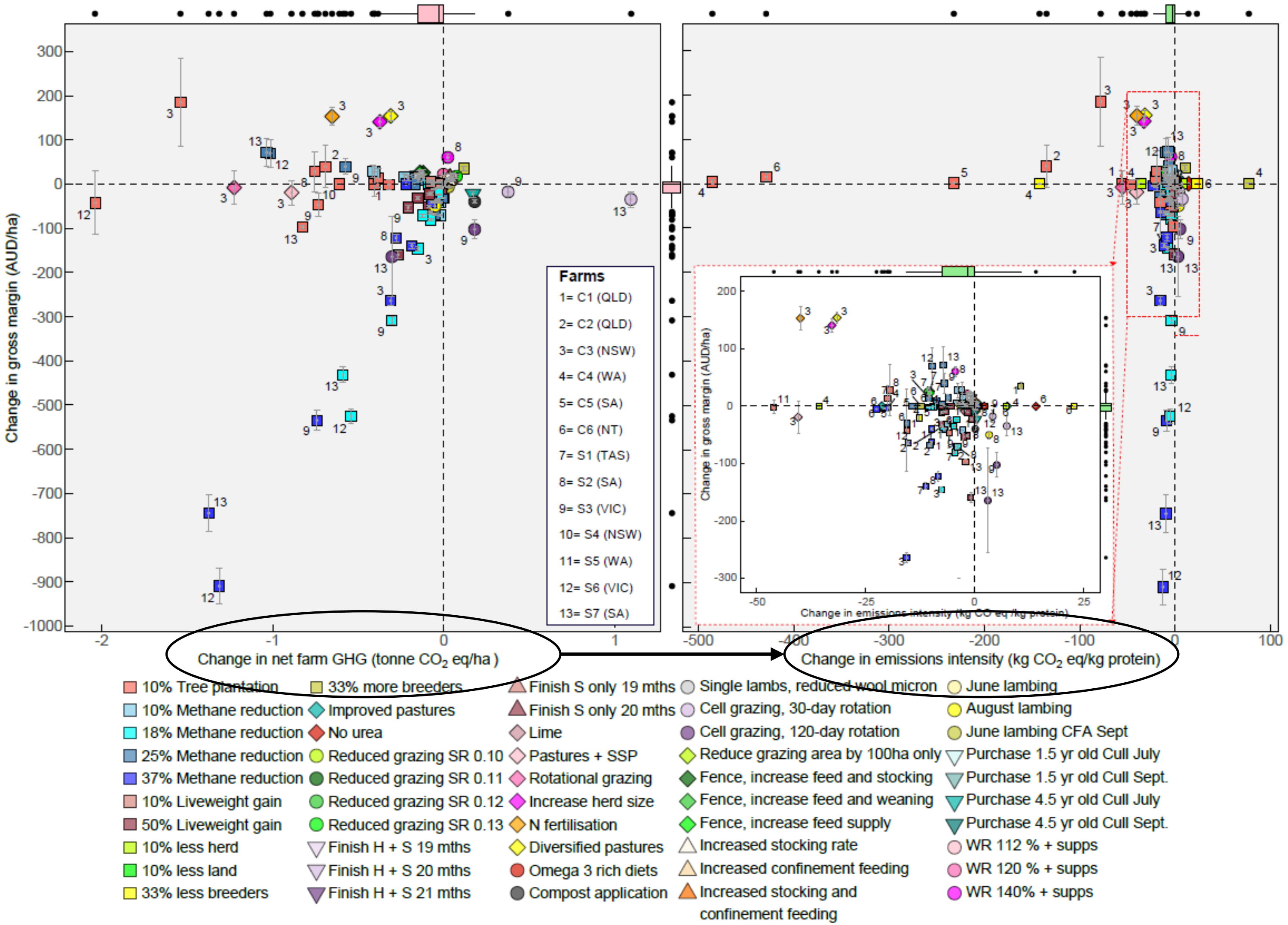
N fertilisation or diversification of pastures – grow more feed can mean more carbon sequestered in soils (retained same herd, just finished stock sooner)

Interestingly, the increased herd size also resulted in a net decline in GHG emissions, more carbon sequestered than emissions from extra livestock

Must be noted, this is a newly purchased run-down farm with plenty of scope to improve soil carbon



A lot of interventions, both common-themed (e.g. 10% LWG) and farm-specific, centred around the baseline



Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO2 eq/ha)
Change in emissions intensity (kg CO2 eq/kg protein)
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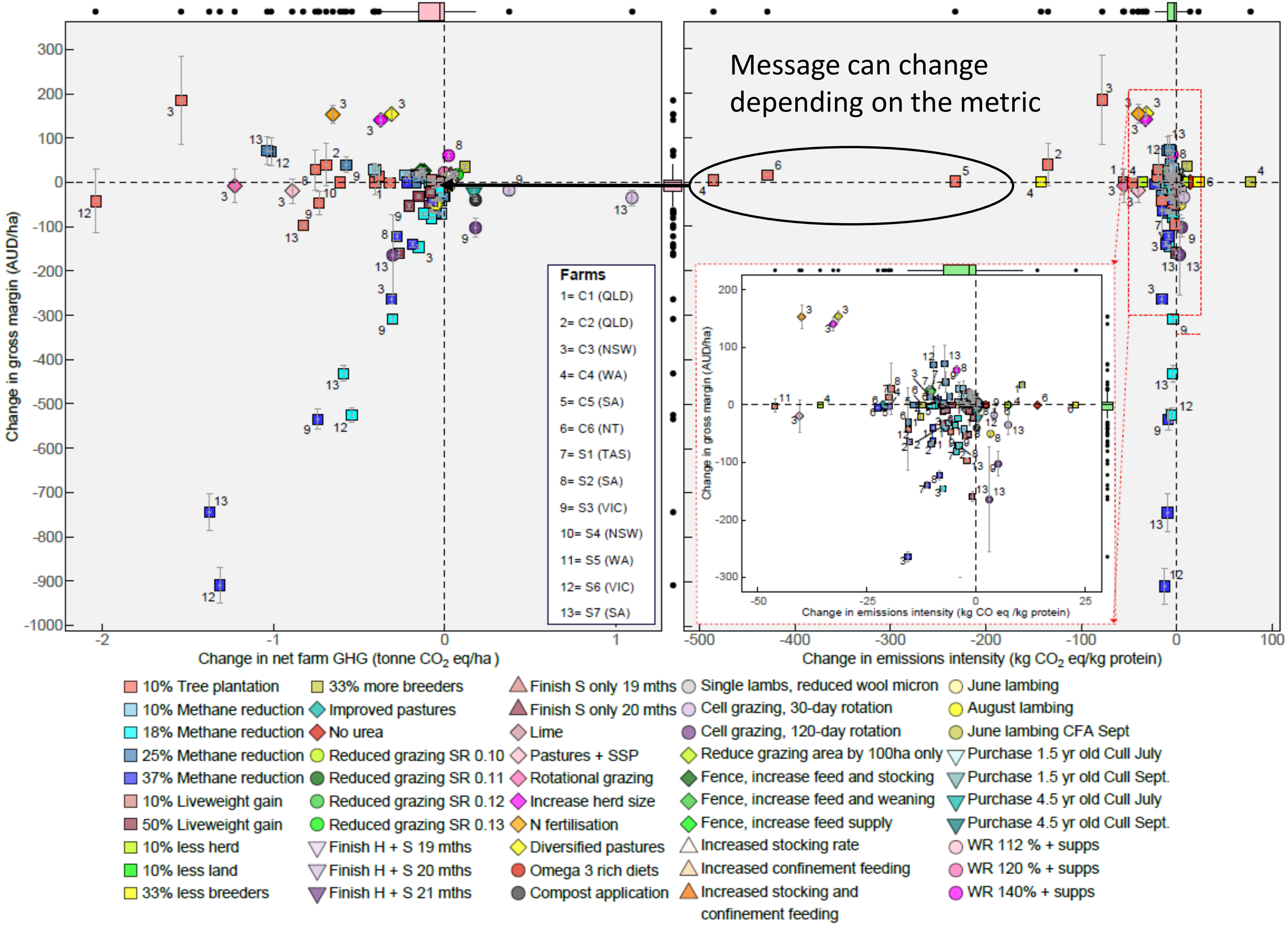

Message can change depending on the metric
Change in gross margin (AUD/ha)
Change in net farm GHG (tonne CO2 eq/ha)
Change in emissions intensity (kg CO2 eq/kg protein)
Farms
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WR 112 % + supps
WR 120 % + supps
WR 140% + supps
Change in emissions intensity (kg CO eq /kg protein)
Change in gross margin (AUD/ha)

Take home messages

- The Australian livestock sector has significantly reduced net GHG emissions, but mostly through avoided deforestation and building of soil carbon- this needs to continue
- Planting trees on farm is good for carbon sequestration, but it can also result in substantial benefits for biodiversity (turning around recent losses)
- Range of factors need to be considered if tree-plantings are profitable for your farm (i.e. ACCU/ biodiversity prices, can you retain similar stock numbers/production, co-benefits of trees etc.)
- Anti-methanogenic diet additives can reduce GHG emissions, but costs of implementation must be significantly lower than we modelled. We also didn’t account for management/practicalities
- Anti-methanogenic pastures had good promise, especially if no additional cost and fit into your current feedbase
- Farm specific interventions were quite variable in terms of quadruple bottom line
- The greatest benefit may come from practice changes that address an underlying economic, environmental and/or production deficit

Tools and resources

- https://www.utas.edu.au/tia/research/research-projects/project/livestock-production/carbon-storage-partnership
- https://www.youtube.com/@matthewharrison6233
- https://looc-c.farm/ and https://looc-b.farm/
- Bowen Butchart et al (2024) https://doi.org/10.1016/j.agsy.2024.104168
- Harrison et al (2021) https://www.researchgate.net/publication/353367793
- McDonald et al (2023) https://www.sciencedirect.com/science/article/pii/S0301479723019345
- MLA's CarbonEDGE program
- MLA's Profitable Grazing Systems program (in development)

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Quotes from case study farmers

- *I could see how the modelling helps us determine **which options are really worth pursuing**. I see this as a decision-making tool for what we will do on farm*
- ***Life is always about trade-offs**. Nothing comes for free. Especially related to profit. That is something we think of everyday. **Every decision comes at a cost**. There is very rarely an optimum. It is about trading one thing for another*
- *It is nice to reduce GHG with trees but **main reason we plant is for livestock, biodiversity and looks better** although we know they are difficult to quantify*
- *This project has **contributed to my knowledge of carbon and biodiversity**. The results align with my intuition. In fact, we have **already made the some of the changes indicated by the modelling**. Very important to make decisions based on evidence*
- *I will use these **results as a stepping stone to another project**. Have learnt a lot – but need it to sink in. How do we quantify what is going on on-farm now? **Cannot prosecute farmers for producing methane***