Pathways towards carbon neutral grazing systems

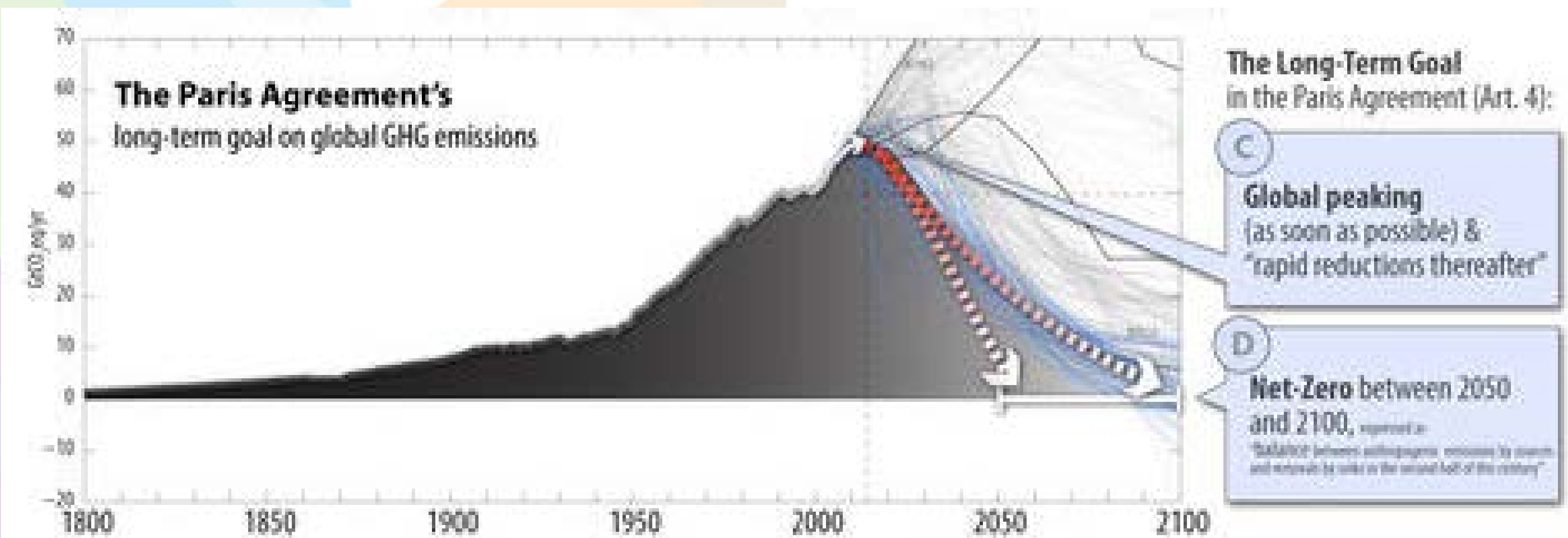
Richard Eckard

Primary Industries Climate Challenges Centre

THE UNIVERSITY OF MELBOURNE

International Policy Drivers
COP21 Paris Agreement

- Reach global peaking GHG emissions as soon as possible
  - Achieve a **climate neutral** world by 2050
    - Assumed as net zero GHG, but not required
    - Methane may not need to be zero?
  - COP26
    - Increased 2030 ambition
    - Proposed 30% reduction in methane



Carbon Neutral Agriculture
Supply chain responses to Paris Agreement

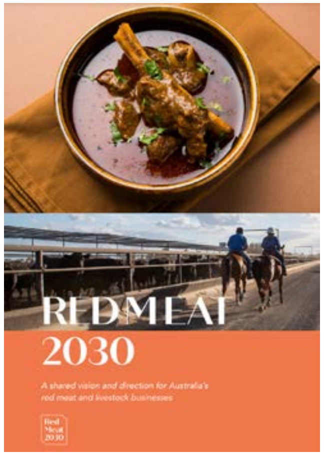
- Fonterra
  - Climate-neutral growth to 2030 for pre-farmgate emissions from a 2015 base year
- Unilever
  - Reducing the GHG impact of their products by 50% by 2030, compared to baseline of 2010
- Mondelez
  - Reduce absolute GHG from manufacturing 15%
  - 100% renewable energy
- Nestle
  - Zero environmental impact in our operations
- JBS
  - Net-zero GHG by 2040 and zero deforestation across its global supply chain by 2035
- **Heineken**
  - Carbon neutral barley-malt supply chain
- **Rabobank**
  - Carbon neutral supply chains
- **NAB**
  - Net zero financed emissions by 2050
  - NAB + Rabo = >50% of agri debt market
- Mars
  - Reduce GHG across our value chain 27% by 2025 and 67% by 2050 (from 2015 levels)
- Kellogg Company
  - 65% reduction by 2050
  - 100% renewable energy
- Pfizer
  - 60 to 80% by 2050
- Wilmar international
  - 89.72% less GHG from 2013 to 2020
  - 100% renewable energy
- Olam
  - Reduce GHGs by 50% by 2030 both in our own operations and in our supply chain
  - By 2050, we aspire to be carbon positive in operations, requiring a 5% emissions reduction per year from 2031 – 2050

- Of the 100 largest economies 69 are companies and 31 are countries
- Government policy may now be less influential than market forces

Industry and market drivers
Livestock Industry Responses

- Australian Red Meat Industry (RMAC 2030 strategy)
  - Australian red-meat can be carbon neutral by 2030 (CN30)
- Mato Grosso do Sul (MS), Brazil
  - "MS carbon neutral" initiative
  - Carbon neutral Brazilian Beef
- New Zealand
  - Climate Change Response (Zero Carbon) Amendment Act 2019
    - Net zero by 2050
- California SB 32
    - 40 % less methane by 2030 over 1990
- Global Methane Pledge at COP26
    - 30% less methane by 2030 by 105 countries

carbon neutral brazilian beef



Industry and market drivers
Carbon Neutral Agriculture

- Livestock
  - Arcadian Organic & Natural's Meat Co's
  - Flinders + Co Meats
  - NAPCO
- Wine
  - Ross Hill
  - Tulloch
  - Cullen

International Policy Drivers
Border Adjustment Tariffs

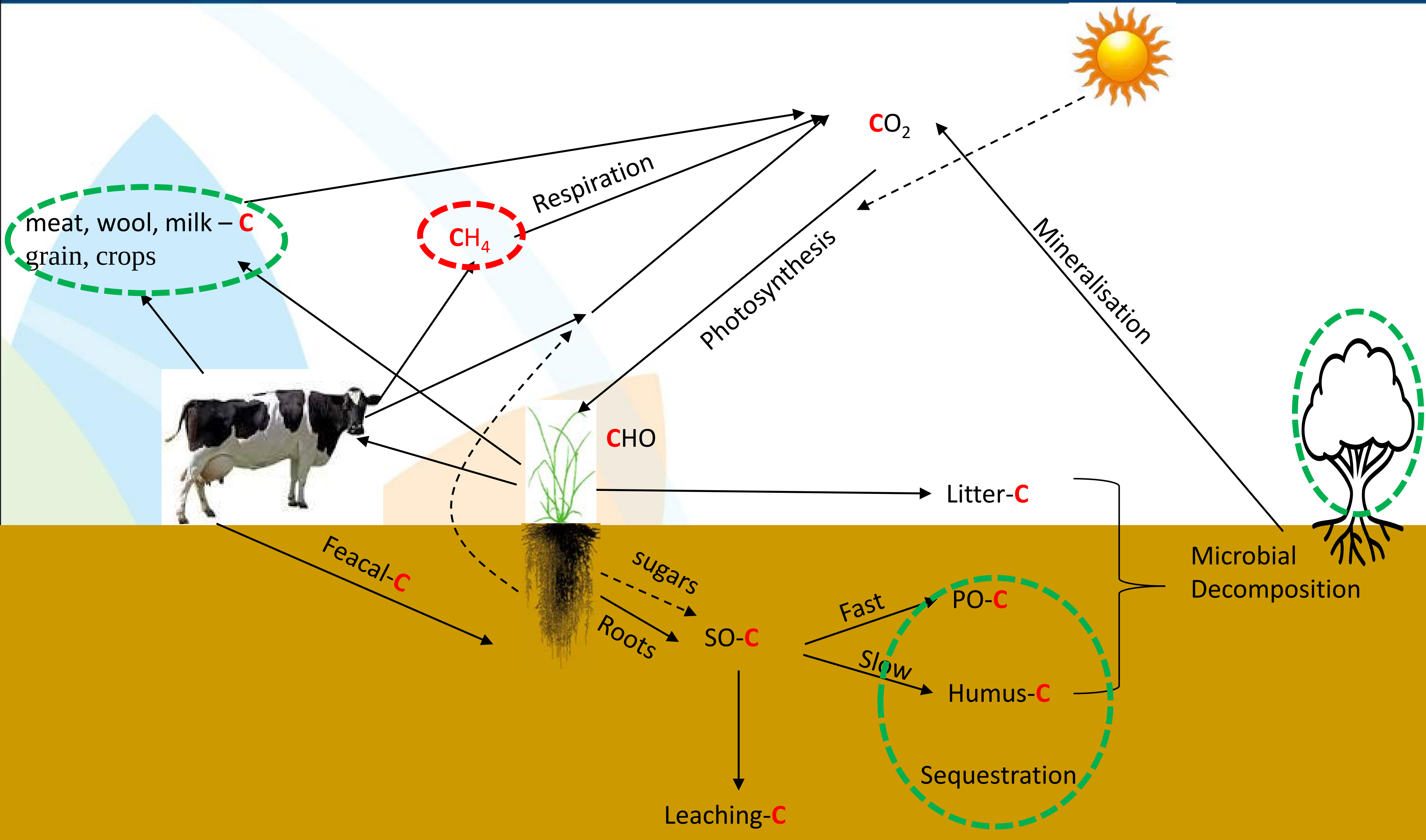
- USA: President Joe Biden
  - "Failing to curb emissions means America will tax your exports"
  - "to ensure his climate policies do not place US workers and companies at an unfair disadvantage" – Financial Times 26 April 2021
- The EU's Carbon Border Adjustment Mechanism (CBAM)
  - "The European Parliament… approval to… start taxing imports from countries without a carbon price… by 2023" – Financial Times 11 March 2020

- Around 70% of Australian Agricultural product is exported
  - Australian ranked **last** on the Climate Change Performance Index (CCPI)
- Our only choice is:
  - *Does the carbon tax get paid outside Australia, or can we keep the revenue within our agricultural sector?*

Carbon Farming, Carbon Neutral

- Carbon Farming
  - Management principles that minimise GHGe, maximise carbon sequestration in the landscape, **while** improving the productivity and resilience of agricultural systems
    - Aus definition
- Carbon Neutral (net zero)
  - Management that minimises GHGe, and **offsets** the balance of emissions through sequestration of an equivalent amount of carbon dioxide in soils or vegetation
    - On an year-by-year basis

The Carbon Cycle in Agriculture



~Half of all products/compounds in farming is carbon

After Eckard (2009)

Carbon Neutral vs Carbon Account

- Carbon account/audit (CA)
    - Net Emissions (NE = t CO_2e/ business unit)
  - All GHG from boundary of the farm enterprise
  - All GHG upstream
  - All Soil and tree sinks
- Carbon footprint (CF)
    - Emissions intensity (EI = t CO_2e/t product)
  - Same method as CA

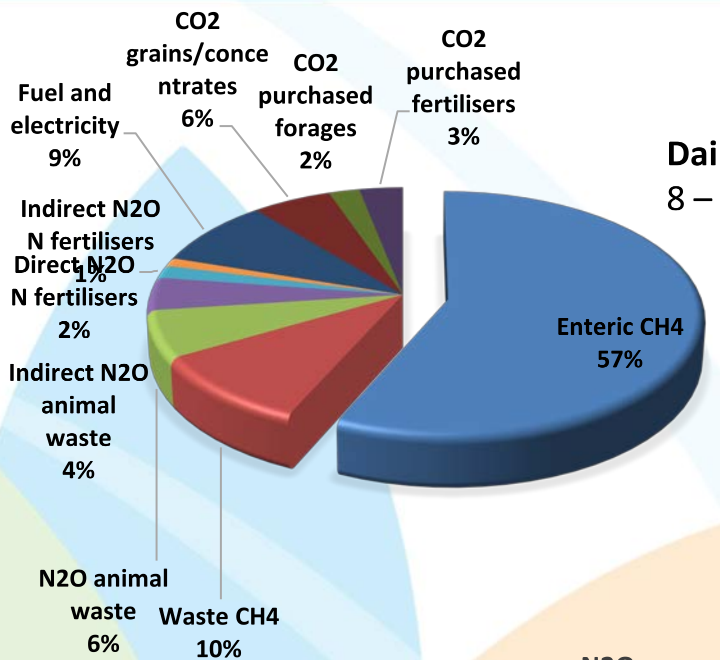
Marketing carbon neutral or carbon credits

- Demonstrate carbon neutrality
  - Access to premium markets e.g. carbon neutral wool
  - Future compliance, meeting supply chain targets, trade barriers
- Trading carbon credits – diversified income
  - Regulatory market
    - Sell ACCUs to government on ERF/CSF
    - Government retires the ACCU -> Sector could technically still claim this
  - Voluntary markets
      - e.g. Gold Standard, Verra, ERF secondary market
    - Selling to private entity esp. outside of Australia
    - Leaves the sector / country -> sector/country cannot use this as their offset

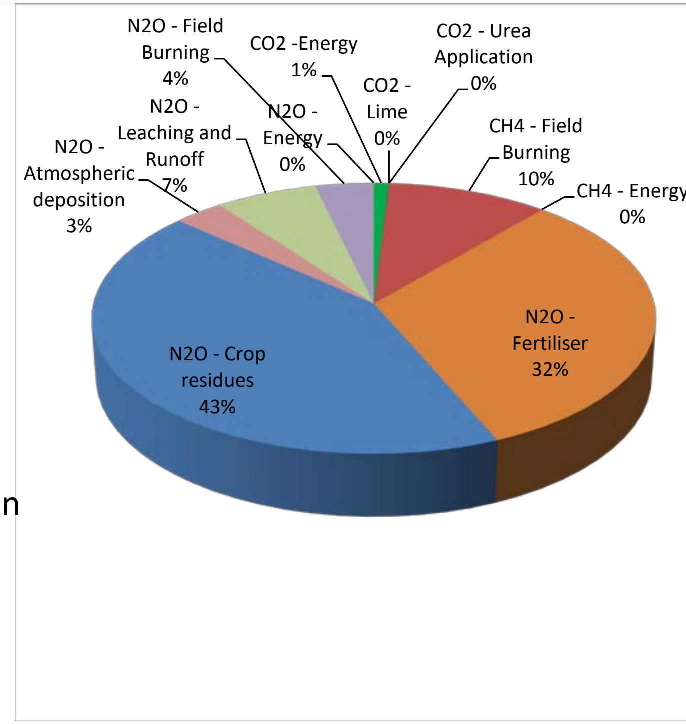
Marketing carbon neutral or carbon credits

- Fundamental difference between
  - Carbon sequestration offset = finite accumulating stock
    - Will need these stocks as an offset against future neutrality
  - Emissions avoidance offset = flux
    - Could sell these up to the day neutrality is required
- Future pricing
  - Soil carbon – less secure
  - Emissions avoidance – no permanence concerns
  - Value-added credits e.g. indigenous land, biodiversity etc.

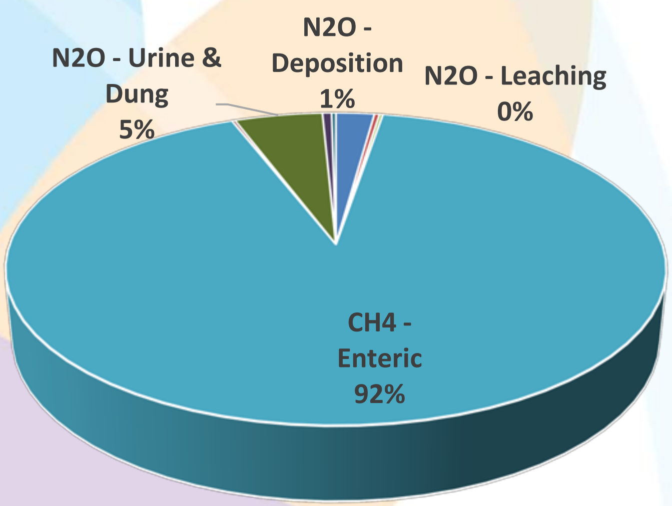
Why Carbon Neutral?
Typical Farm GHG profiles



Dairy
8 – 21 t CO_2 e/t MS



Grains / pulses
0.04 t/CO_2e/t grain



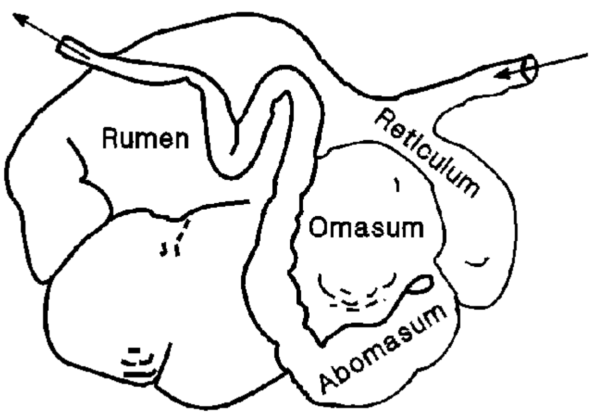
Rangeland Beef
14 t CO_2e/t LWT

Christie *et al.* 2016

What can be done on farm now?
Methane

Methane from animal production
Rumen digestion

- Ruminants evolved 4 stomachs about 50M years ago
  - We aim to change this in 30 years
  - Adaptation to mitigants is a challenge
- Rumen = Microbial fermentation
  - 40-60% bacteria & protozoa
    - 10^{11} & 10^{6} cells/ml over 200 species
  - 5-10% fungi
    - 10^{6} zoospores/ml
  - 3% Archaea (*methanogens*)
    - 10^{8} cells/ml



Hackmann & Spain (2010)

Methane from animal production

- Largest inefficiency in animal production
  - Methane energy content - 55.22 MJ/kg
  - 6 to 10% of GEI lost as CH_4

Animal Class	Methane (kg/year)	Methane (g/day)	MJ lost (CH_4 hd/day)	Potential km driven in 6-cylinder car
Mature ewe	6 – 10	16 – 27	1 - 1.5	54 – 90
Wether	7 – 11	19 – 30	1 – 2	63 – 100
Beef steer	40 – 60	110 – 164	6 – 9	360 – 540
Breeder cow	50 – 90	140 – 250	8 – 14	450 – 800
Dairy cow	90 – 146	250 - 450	14 – 25	800 – 1480

Eckard, Grainger & de Klein (2010)

Enteric Methane Abatement
Animal Productivity

- Reducing unproductive animal numbers
    - Animal management, health, nutrition
    - Reproduction, fertility, weaning %

- Animal Breeding
    - Residual methane production
        - Low heritability & slow gains (<1% /year)
        - Low weight in multi-trait index
        - Could be breeding for rumen passage rate
    - Feed Conversion Efficiency
        - Moderate heritability
        - Higher weight in multi-trait index

Richardson et al. 2021; Pickering et al. (2015); Pinares-Patiño et al. (2013); Cabezas-Garcia et al. (2017); J. Lassen (Viking Genetics); Beauchemin, Ungerfeld, Eckard and Wang (2020); Barwick et al. (2019)

Enteric Methane Abatement
Forage quality

- Forage digestibility
  - – Better pastures & grazing management
    - Finishing animals faster
    - Lower rumen retention time
- Plant Breeding
  - – More balanced energy to protein ratio
  - – Secondary compounds
    - Tannin, oils

Mitchell Grass

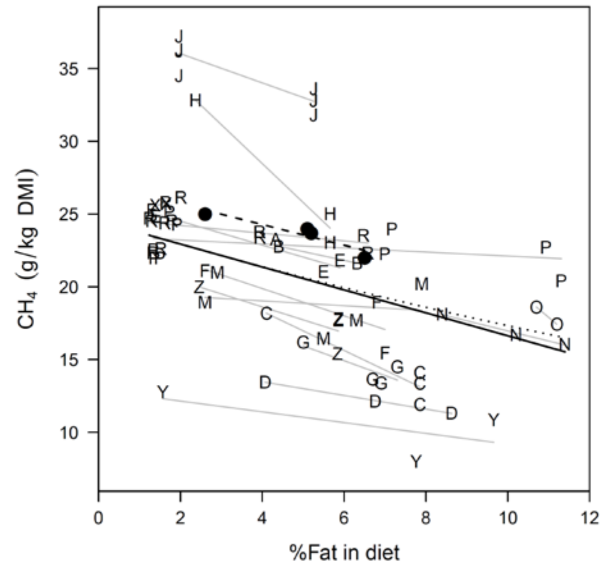
Eremophila

Lucerne

Sun et al. (2015); Jonker et al. (2017; 2018); Beauchemin, Ungerfeld, Eckard and Wang (2020); Charmley *et al.* (2015)

Enteric Methane Abatement
Dietary supplements

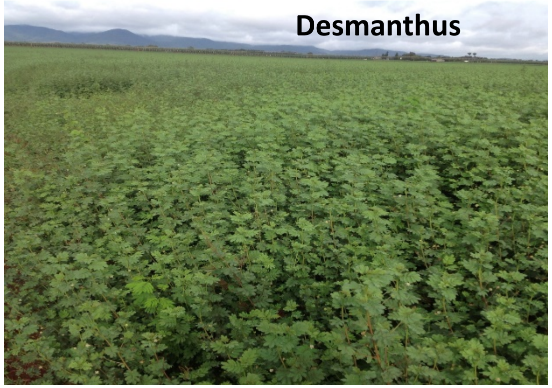
- Oils (~20%)
  - 1% added fat = 3.5% less CH_4
- Tannins (10-15%)
  - e.g. Forage legumes
- Tannin + Oil (~20%)
  - e.g. Grape marc
- Essential Oils
  - MOOTRAL (20-30%)
    - Garlic and citrus extract
  - AGOLIN (10-20%)



Moate *et al.* (2011)

Enteric Methane Abatement
Secondary plant compounds

- Legumes and novel forages
  - Tropical legumes
    - *e.g. Leucaena, Desmanthus, Desmodium*
  - Temperate legumes
    - e.g. Lotus, Sulla, Crown Vetch



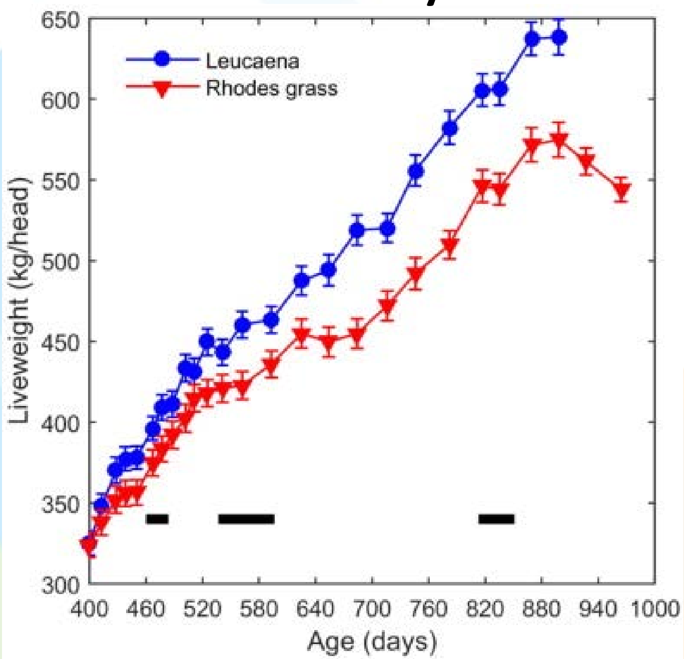
Crown vetch

Sulla

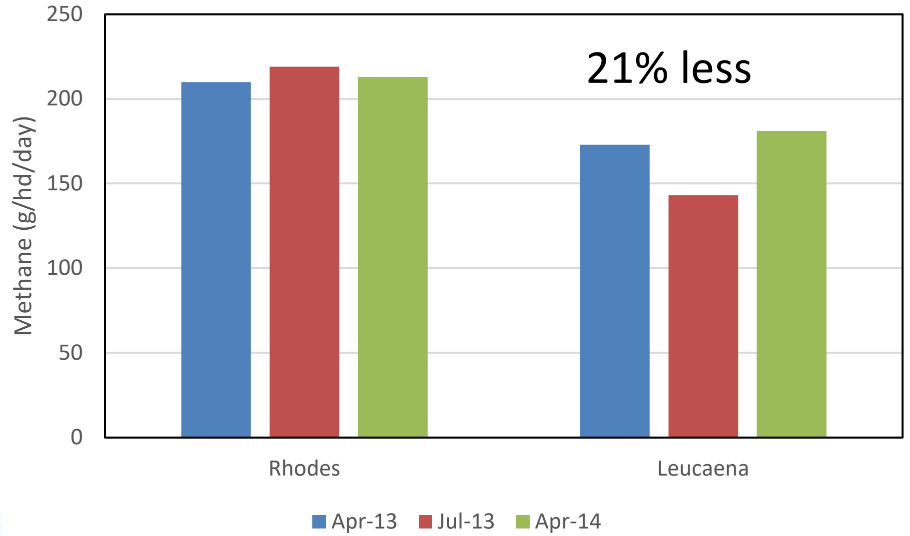
Li et al. (2014); Charmley et al. (2015); Doran-Browne et al. (2015); Eckard et al. (2010)

Enteric Methane Abatement
Leucaena example

Quality



Methane



Harrison, McSweeny, Tomkins, Eckard 2015

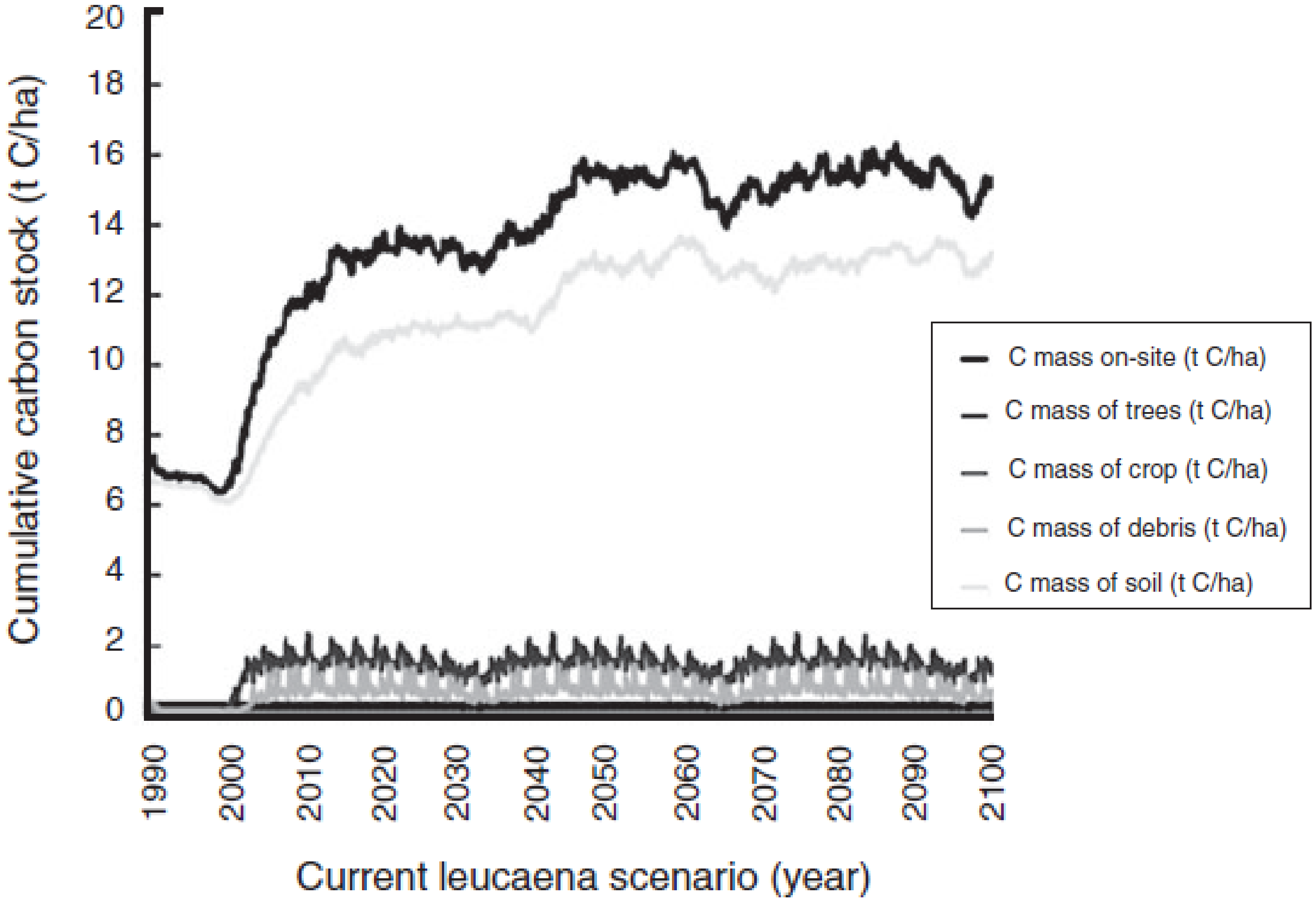
Enteric Methane Abatement
Irrigated Leucaena example

Pasture	Area (ha)		Steers	GHG	GHG/LW	Mths	ADG
	Grass	Legume	(hd)	(t CO2e)	(t CO2e/t LW)		(kg/hd/d)
Rhodes	9556	0	600	2739	8.4	36	0.36
Irrigated Leucaena	9170	386	1250	2677	3.9	18	1.03

Taylor et al. 2016

Irrigated Leucaena

Soil carbon increased 3.6 to 5.0 t C/ha (2000-2100)

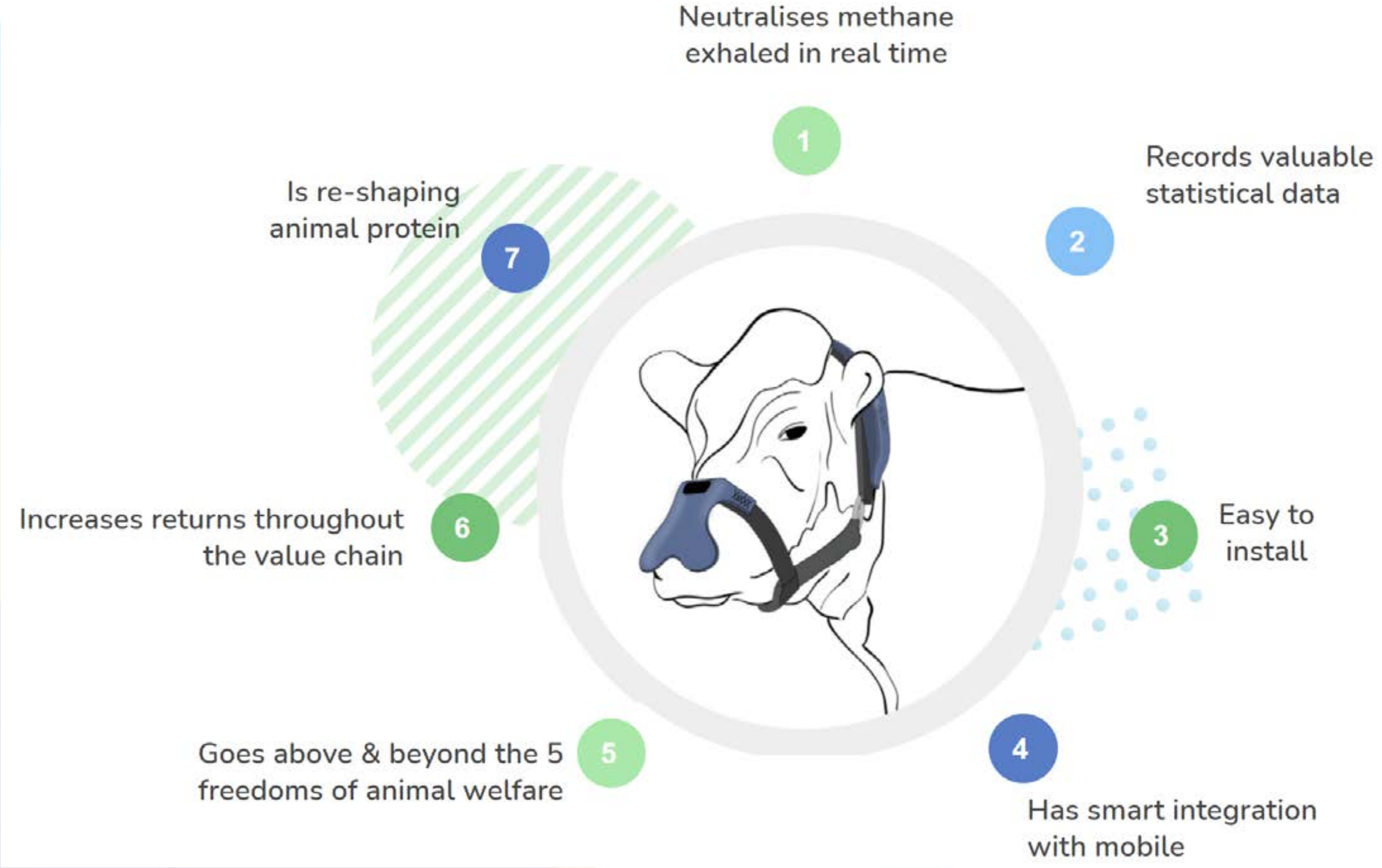


Radrizzani et al. 2010; Conrad 2014; Shelton and Dalzell 2007; Taylor et al. 2016

Enteric Methane Abatement

Zero Emissions Livestock Production (ZELP)

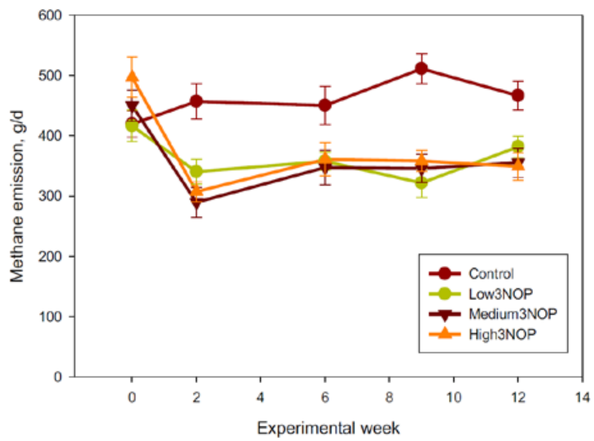
- Post emission catalytic technology for real-time oxidation of up to 53% enteric methane emission
- 4 years solar cell and a thermo-electric generator to allow it to re-charge automatically

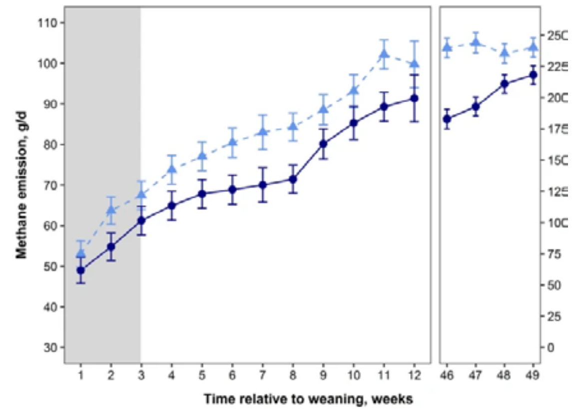


https://www.zelp.co/

Enteric Methane Abatement *Coming Soon!*

- Bovaer® (3-nitrooxypropanol - 3-NOP)
    - 20-40% (>70%)
  - Registration in Brazil, Chile, EU
- Seaweeds (e.g. *Asparagopsis*)
  - Red: **>80%** or 5.3 g CH_4 /kg DMI over 72 days
  - Due diligence issues still required
- Vaccine (20%?)
- Early life programming

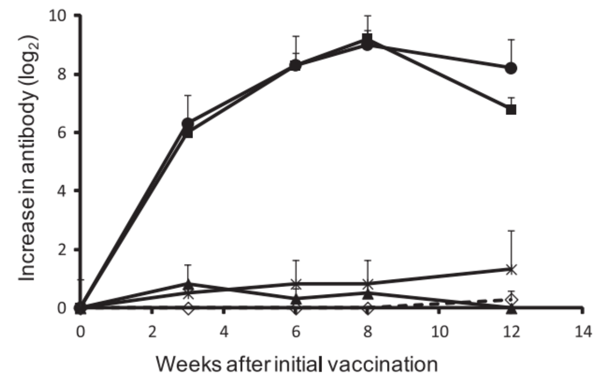




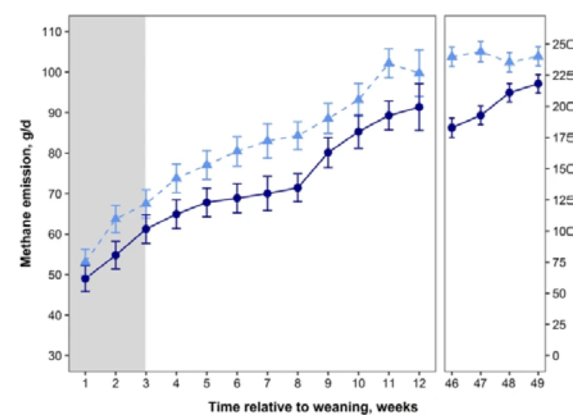
Muizelaar et al. (2021); Machado et al. (2014); Kinley et al. (2016), Li et al. (2018), Tomkins *et al.* (2015) Wedlock et al. (2013); Yánez-Ruiz et al. (2015); Eckard and Clark (2018); Meale *et al.* (2021)
Ungerfeld 2018, Roque *et al.* 2019; Van Nevel and Demeyer 1996; Hristov et al. 2015; Dijkstra et al. 2018; Vyas et al. 2018; Romero-Perez et al. 2014; McGinn et al. 2019; Thiel et al. 2019a & b

Enteric Methane Abatement
Rumen manipulation

- Vaccine (20%?)
  - Antibodies in saliva
  - Suited to more extensive grazing



- Early life programming
  - Programming the rumen early in the animal's life
    - Using 3-NOP
  - Early evidence, persistence?
  - Most suited to extensive grazing



Wedlock et al. (2013); Yánez-Ruiz et al. (2015); Eckard and Clark (2018); Meale *et al.* (2021)

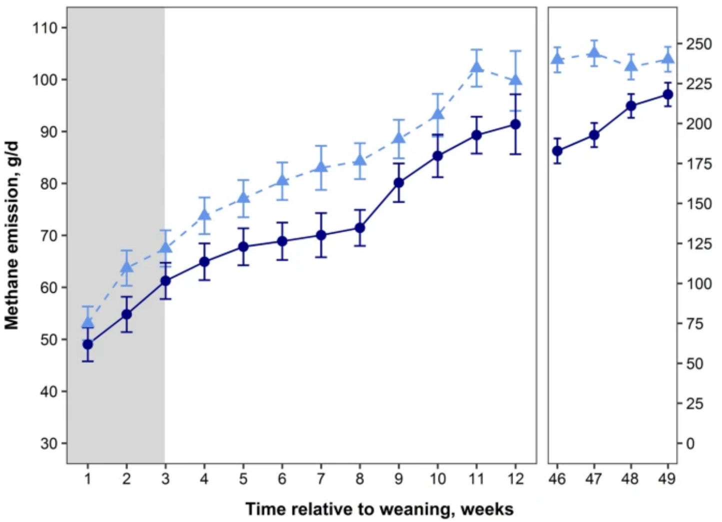
Summary of options for reducing Enteric Methane

Do Now

- Management (10%)
  - Efficiency, health, fertility
- Legumes (10-15%)
  - Leucaena, Lucerne, Vetch, Lotus
- Supplements (10-20%)
  - Oils, tannins e.g. grape marc
- Breeding (1%/yr)
  - Plants
  - Animals
- Wearable device (ZELP – 50%?)

Do in 5-10 years

- Vaccine (20%)
- Inhibitors (>80%)
  - Seaweed
  - 3-NOP
- Early life programming



Charmley *et al.* 2016; Grainger et al. (2009); Moate et al. (2011; 2014; 2016); Williams et al. (2019); Van Nevel and Demeyer (1996); Machado et al. (2014); Li et al. (2018); Eckard and Clark (2018); Li et al. (2018), Meale *et al.* (2021)

What can be done on farm now?

Nitrous oxide

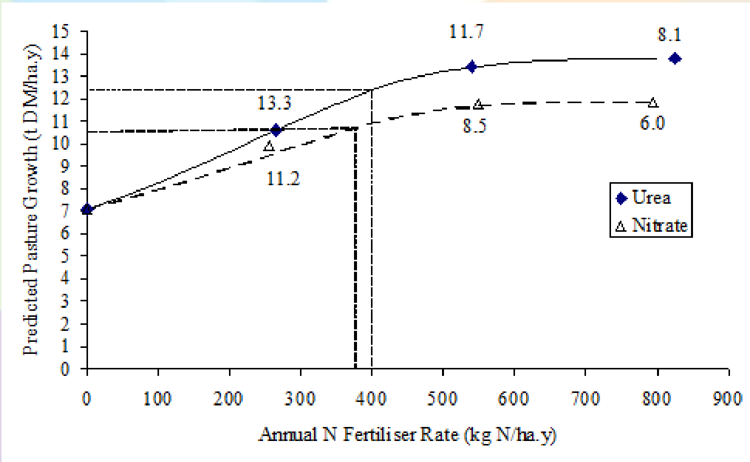
Options for reducing nitrous oxide loss

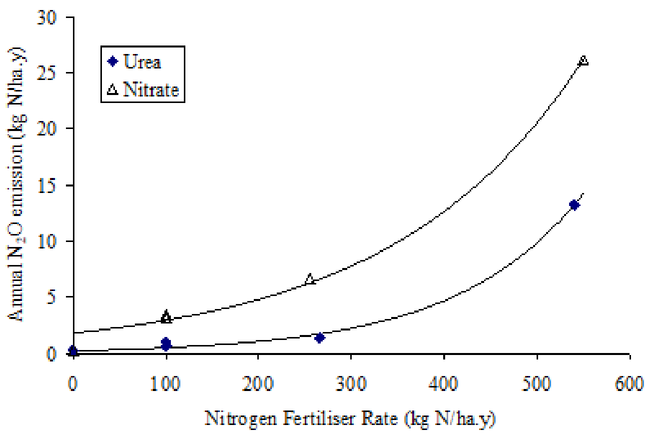
Input management

- N fertiliser
- Legumes
- Animals

Soil management

- More efficient use of soil N
- Less saturation & compaction
- Less soil disturbance
- Irrigation management





De Klein & Eckard 2008; Eckard R.J. et al. (2006); Christie et al. (2018); Smith et al. (2018)

Nitrous Oxide Abatement
Livestock Urine

- Ruminants excrete 75 to 95% of N intake
  - Urine: Dung
    - 50:50 when N limited
    - Increasing in urine above sufficiency
  - Urine N mainly urea
    - <30% utilised for production but >60% lost
  - N content of urine
    - Dairy: 800 - 1300 kg N/ha in a patch
    - Beef: 200 - 400 kg N/ha in a patch

Whitehead 1995; Eckard et al 2007; de Klein & Eckard 2008

Nitrous Oxide Abatement
Livestock Urine

- Tannin (some legumes)
  - Redirect surplus N from urine into faeces
    - Ok - if CP is high
    - Could induce N deficiency if CP is low
  - Tannin-protein complex
    - Digested in abomasum
    - Excreted in less volatile form than urine
    - More recalcitrant in the soil

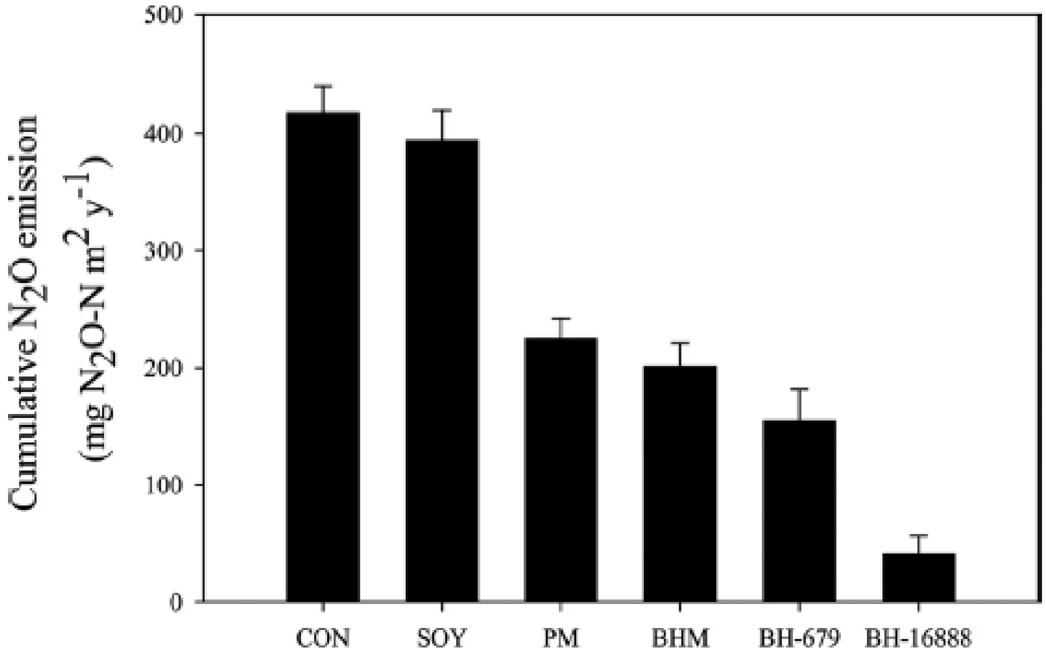
Crown vetch

Leucaena

Grainger, Eckard et al. 2009

Nitrous Oxide Abatement
Biological Nitrification Inhibitors

- Brachiaria species
  - Root exudate
  - Brachialactone



  - Blocks
    - Ammonia monooxygenase (AMO) and hydroxylamine oxidoreductase enzymatic pathways in *Nitrosomonas*

Subbarao et al. (2006)

What can be done on farm now?
Soil Carbon

Loss of Soil Organic Matter

Source: Peter Grace

Sequestration - Soil Carbon
What determines SOC content?

$$\text{Soil organic carbon content} = f\left(\text{Inputs of organic carbon}, \text{Losses of organic carbon}\right)$$

Inputs

- Plant Growth
- Imported C

High rainfall = high

Drought = lower

Outputs

- Microbial turnover

High rainfall = high

Drought = **still high**

In Australia rainfall has a dominant impact

Perhaps think of SOC in decadal time-steps

Source: Jeff Baldock

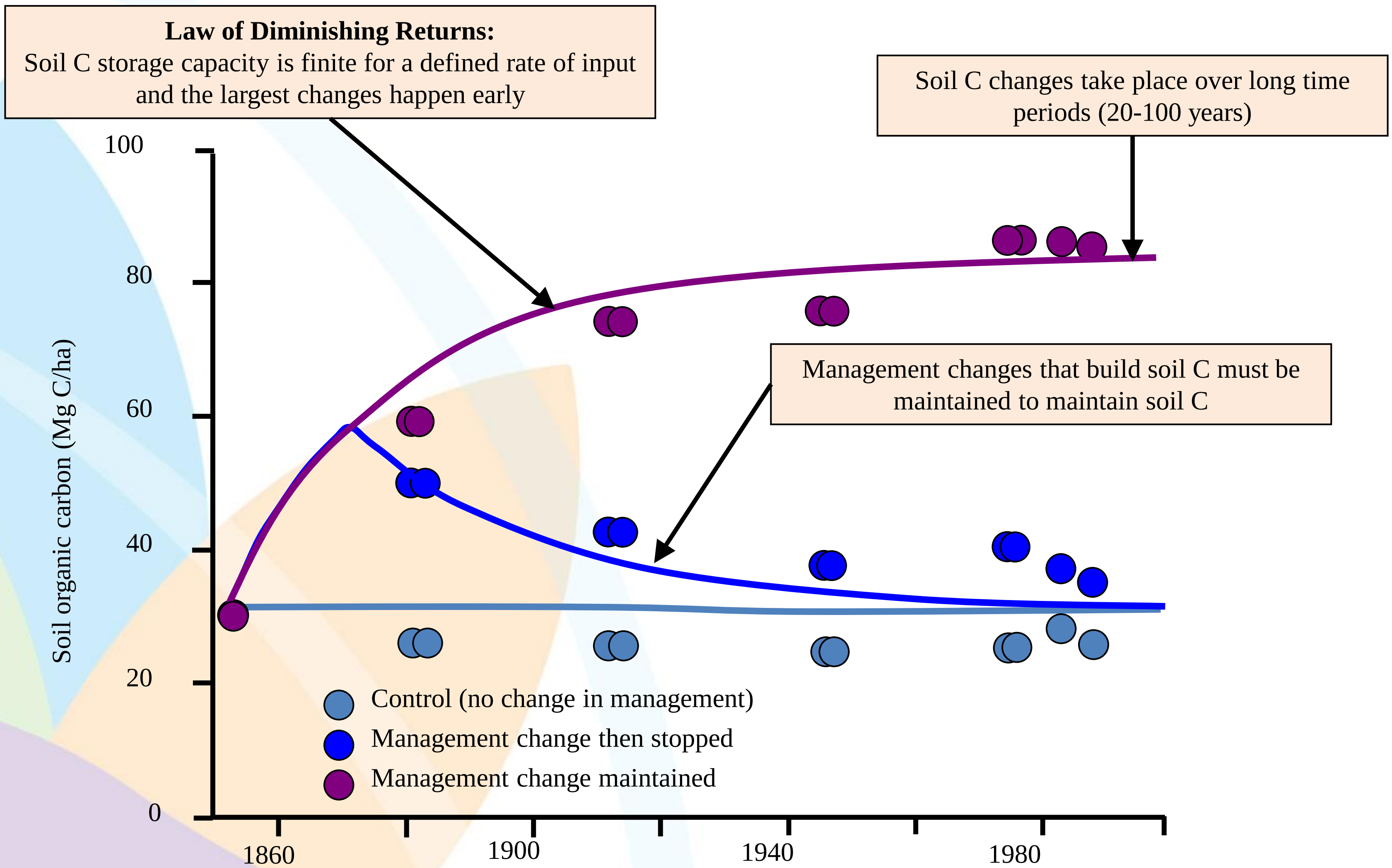
Sequestration - Soil Carbon
Soil Organic Matter - Benefits

- Building SOM is good just good practice
  - Healthy, more productive and resilient soils
  - Adaptation to climate change
  - Payment is there already?

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

Source: Jeff Baldock

Sequestration - Soil Carbon
Soil organic carbon – challenges

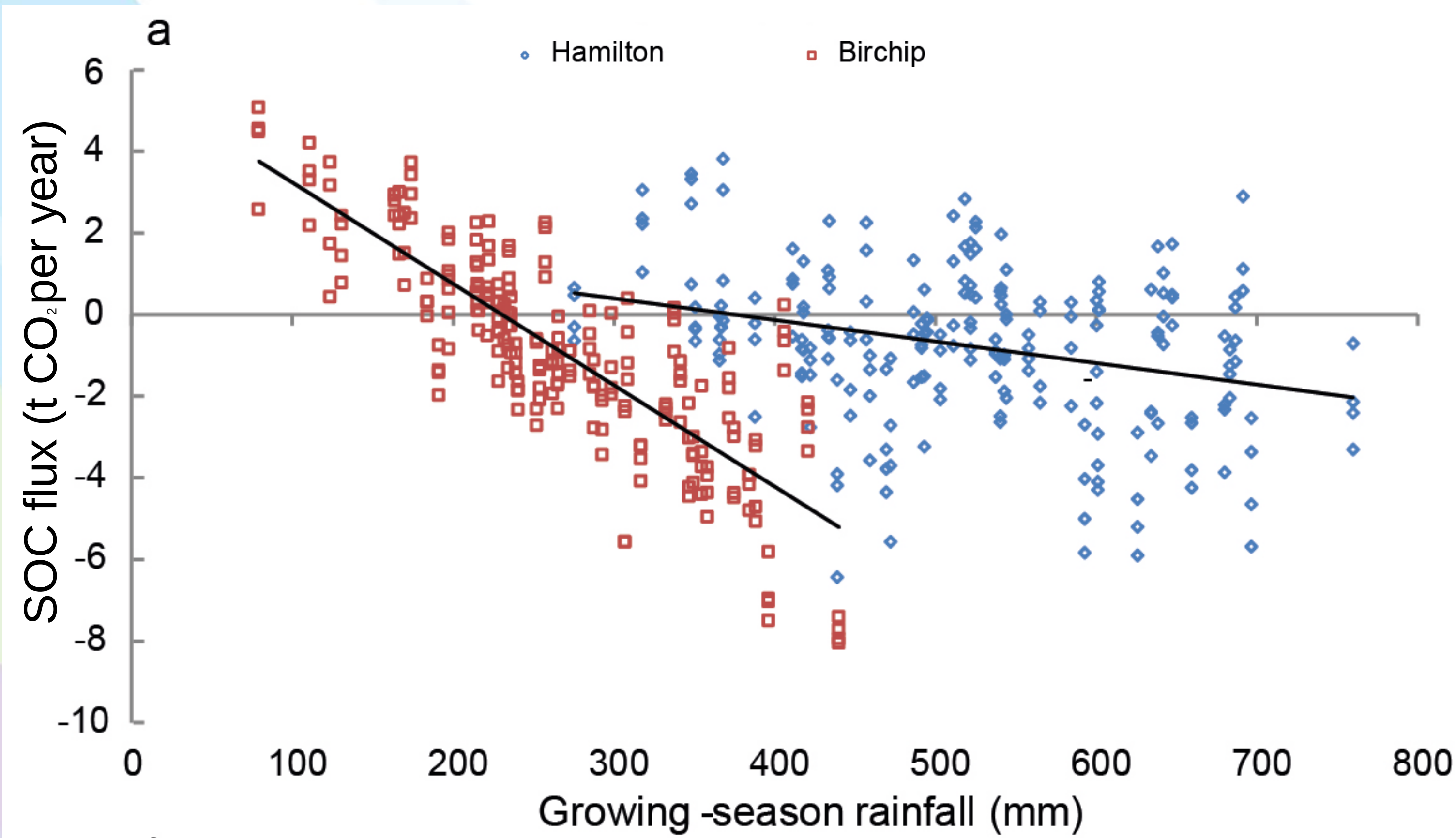


10–25 years for the SOC changes to become measurable

Petersen et al. (2005)

Sequestration - Soil Carbon
Rainfall a key driver

- Growing-season rainfall explains **most** of the variation in SOM
- Particularly in lower rainfall regions



Meyer, Cullen, Eckard (2016)

Sequestration - Soil Carbon
What are reasonable rates of change?

ERF Offset method: *Estimating Sequestration of Carbon in Soil Using Default Values, Methodology Determination 2015*

	Categories of sequestration potential (t C/ha/yr)		
Project management activity	Marginal benefit	Some benefit	More benefit
Sustainable intensification	0.03	0.16	0.45
Stubble retention	0.02	0.08	0.20
Conversion to pasture	0.06	0.12	0.23

Potential for soil organic carbon sequestration by pasture land use and rainfall zone in Australia

Rainfall (mm)	**t C/ha/y**
300 – 600	0.41
600 – 900	0.68
900 – 1200	0.90
1200 – 1500	1.17
>1500	1.23

AUSTRALIA'S LONG-TERM EMISSIONS REDUCTION PLAN

Cropping to long-term pasture (t C/ha/yr):

- 0.34 to 0.97 (Badgery et al., 2014)
- 0.26 to 0.70 (Chan et al., 2011) *(Long term data)*
- 0.30 to 0.90 (Robertson & Nash, 2013)
- 0.50 to 0.84 (USDA 2014)

Sequestration - Soil Carbon
A new view

- Spatial
  - – Focus on areas with potential
    - Granite ridges vs clay soils
- Temporal
  - – Managing rainfall variability
  - – We build more SOM in La Niña years than El Niño
    - Maximise SOM in good years
    - Minimise SOM loss in bad years
- National and Industry good
  - – Agriculture will need its own offsets to be carbon neutral
  - – Should we be selling our offsets outside of the land sector?

piccc.org.au

www.piccc.org.au/education/carbonneutraltraining

On-farm Carbon Accounting

THE UNIVERSITY OF MELBOURNE

Carbon Accounting

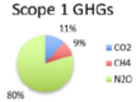
- Greenhouse Gas emissions
  - – Sheep & Beef (SB-GAF)
  - – Cropping (G-GAF)
  - – Dairy (ADCC)
  - – Feedlot, Cotton, Sugar, Hort etc

Grains Greenhouse Accounting Tool

Crop	Wheat	Barley	Pulses	Oilseeds	
Outputs	t CO_2e/farm	t CO_2e/farm	t CO_2e/farm	t CO_2e/farm	total t CO2e/farm
Scope 1 Emissions (on-farm)					
CO_2 - Fuel					7.63
CO_2 - Lime	0.20	0.00	0.20	0.00	0.40
CO_2 - Urea	36.67	0.00	0.00	0.00	36.67
CH_4 - Field burning	99.35	0.00	0.00	0.00	99.35
CH_4 - Fuel					0.02
N_2O - Fertiliser	49.97	35.40	0.00	226.54	311.91
N_2O - Atmospheric Deposition	5.50	3.89	0.00	24.92	34.31
N_2O - Field Burning	36.09	0.00	0.00	0.00	36.09
N_2O - Crop Residues	120.05	18.88	57.92	196.97	393.83
N_2O - Leaching and Runoff	0.00	7.10	15.29	122.36	144.75
N_2O - Fuel					0.05
Scope 1 Total	**348**	**65**	**73**	**571**	**1,065**
Scope 2 Emissions (off-farm)					
Electricity					3.24
Scope 2 Total					**3.24**
Scope 3 Emissions (pre-farm)					
Fertiliser (urea + Superphosphate)					90.83
Herbicides/pesticides					0.29
Electricity					0.36
Fuel					0.40
Lime					0.01
Scope 3 Total					**92**
Carbon Sequestration					
Carbon sequestration in trees	-16.40	-6.84	-1.37	-2.73	-27.34
Net Farm Emissions	**335**	**58**	**72**	**568**	**1,133**
Emissions intensity	**0.11**	**0.02**	**0.04**	**0.19 t CO2-e/t crop**	

Summary	t CO2e/farm
CO_2	132
CH_4	103
N_2O	921

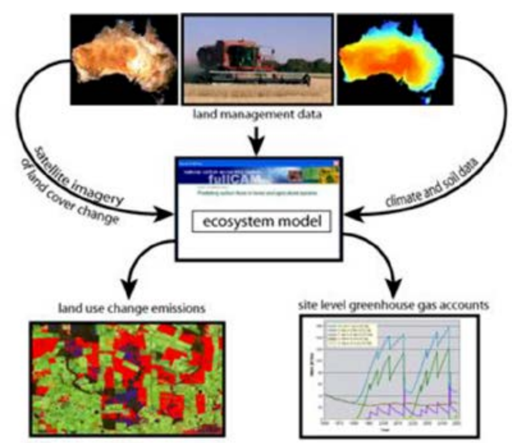
Breakdown of Scope 1 GHGs



www.piccc.org.au/Tools

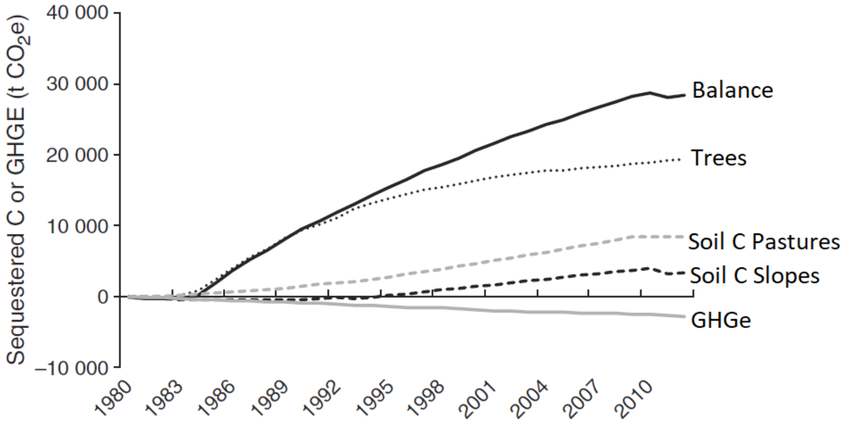
- Carbon stocks and fluxes
  - – Direct measurement

    or
  - – FullCam model
    - Soil carbon
    - Vegetation carbon

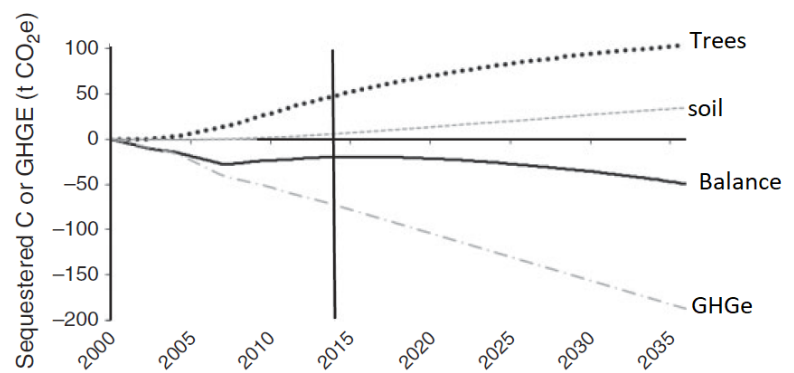


Carbon Neutral Accounting
Dynamic accounting

- Talaheni - Yass
  - Low stocked wool
    - Lower methane
  - Significant land restoration
    - Tree planting, natural regeneration, erosion control



- Jigsaw Farms - Hamilton
  - High stocked beef and sheep
  - Significant tree planting
    - Salinity control
    - Carbon offset planting
    - Biodiversity



Doran-Bowne *et al.* 2016, 2017