Nitrogen use efficiency and nitrogen balance in Australian farmlands

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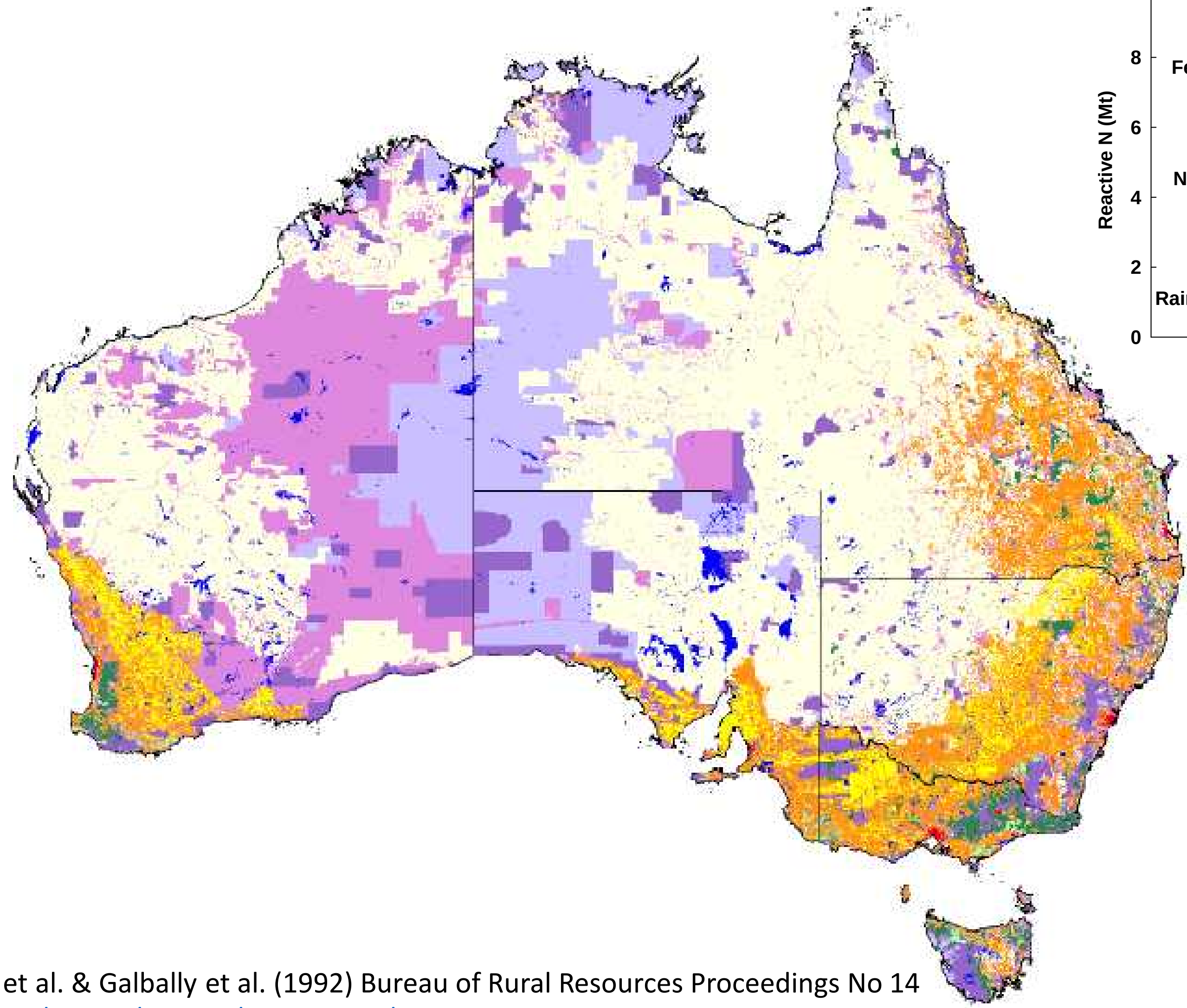
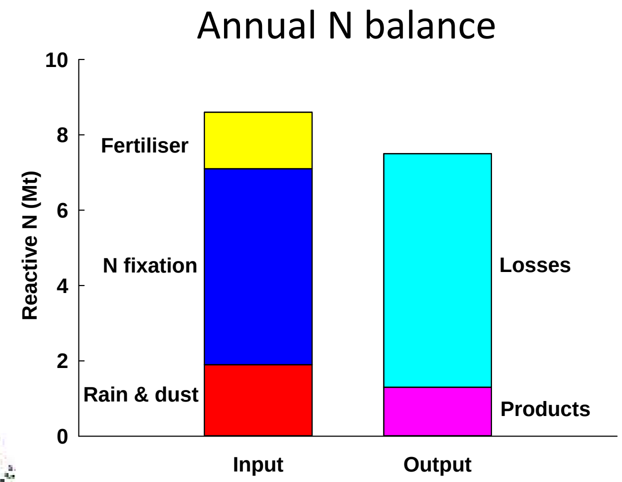
Continental N balance

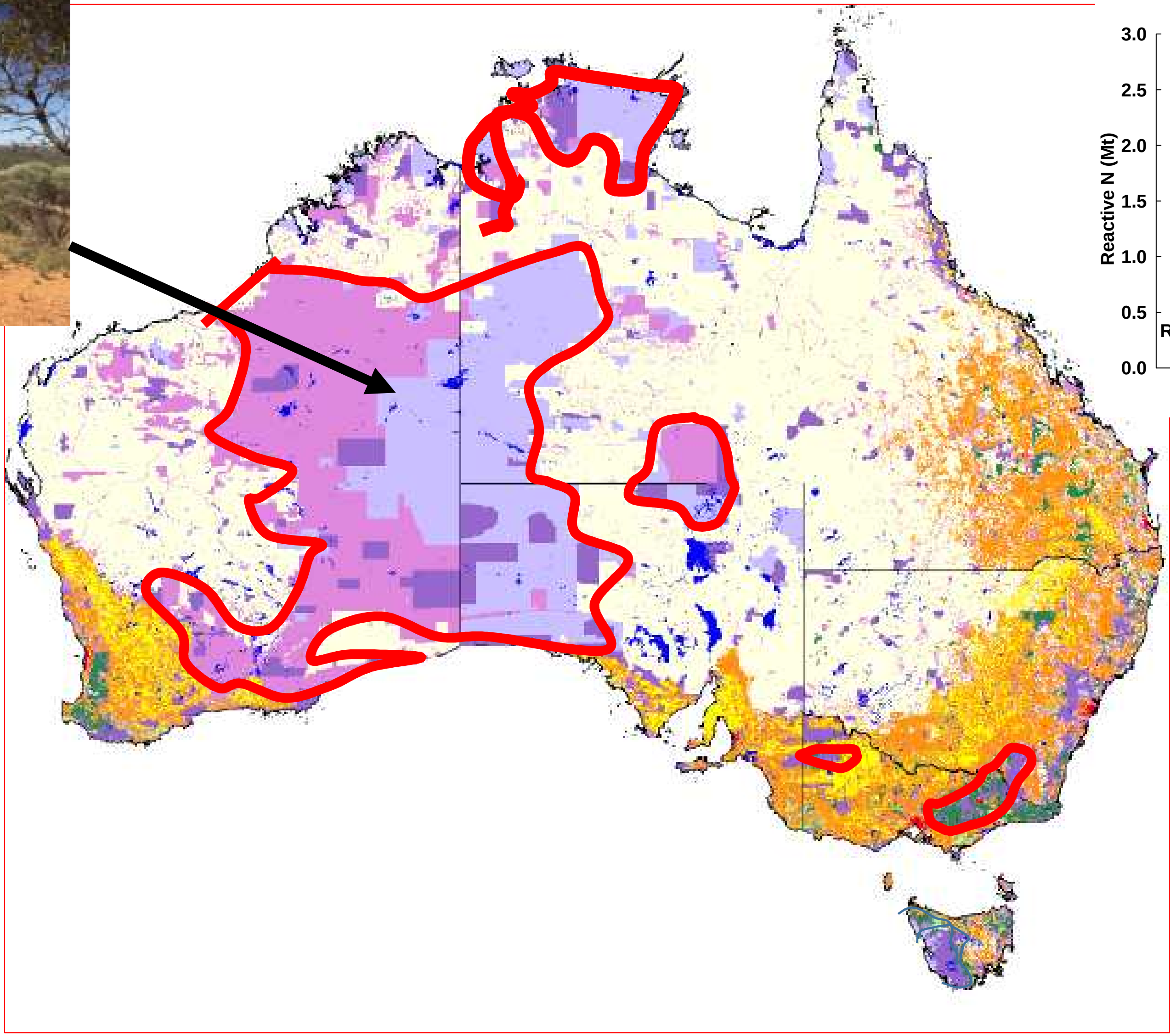


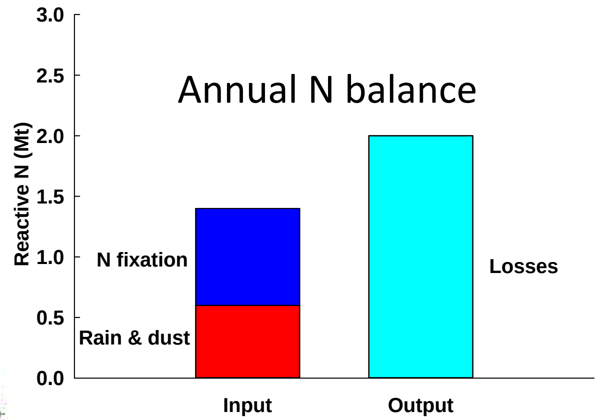


N-balance method: McLaughlin et al. & Galbally et al. (1992) Bureau of Rural Resources Proceedings No 14
Base map: www.agriculture.gov.au/abares/aclump/Documents/Land_use_in_Australia_at_a_glance_2006.pdf

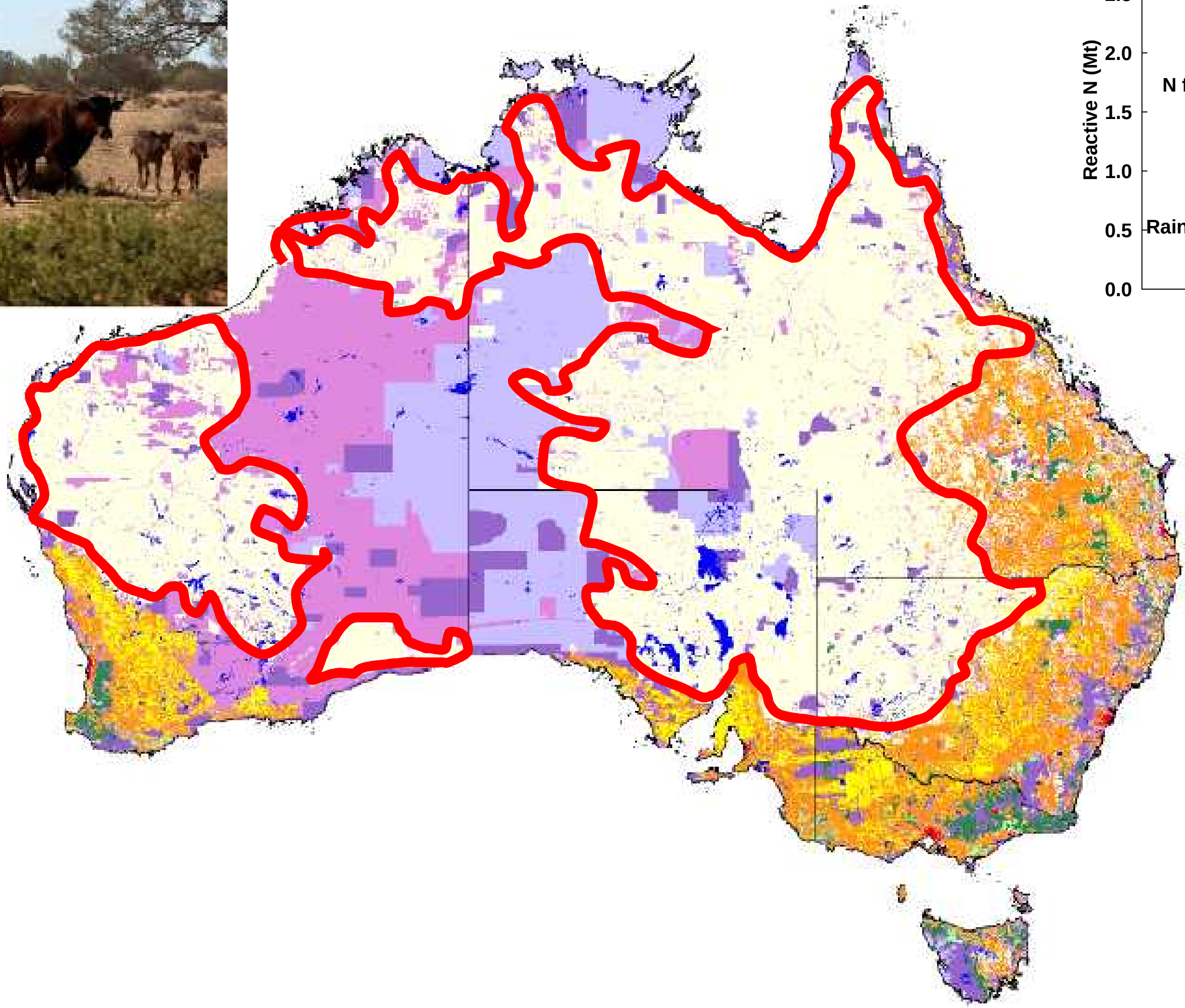
No agricultural production – 309 m ha

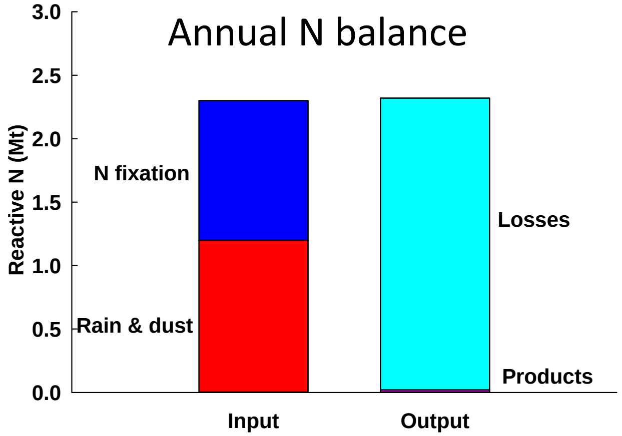
Canning stock route, July 2016



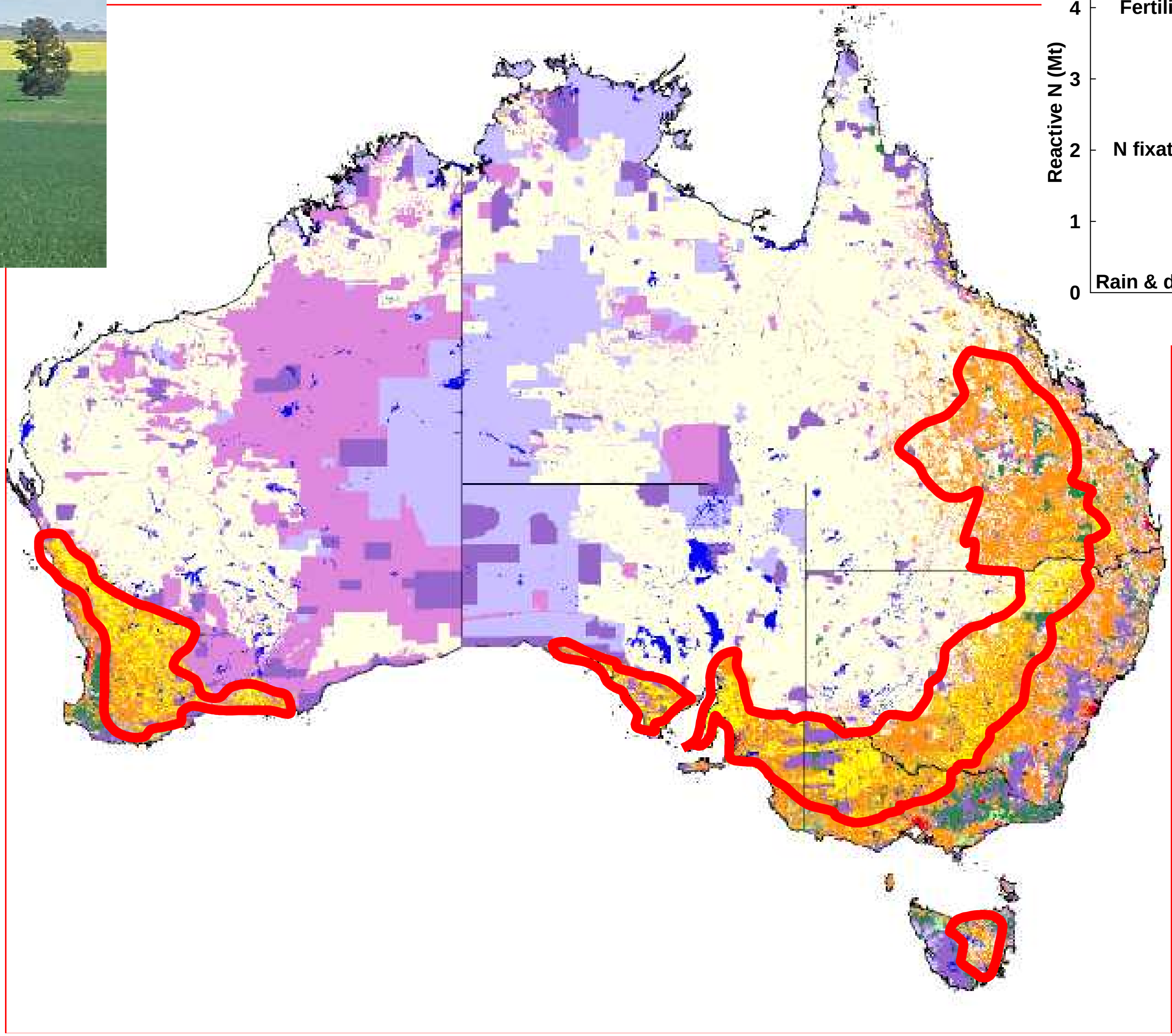


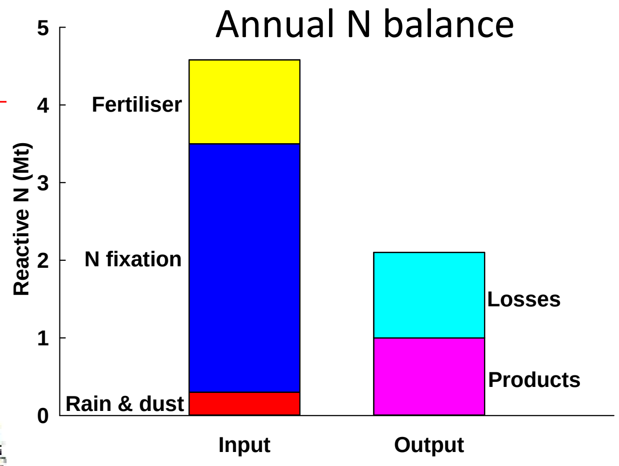
Pastoral zone – 355 m ha



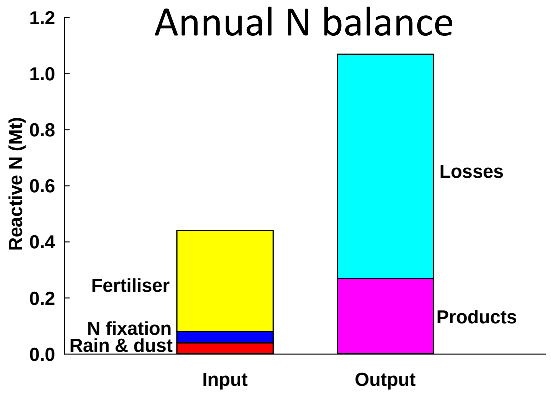


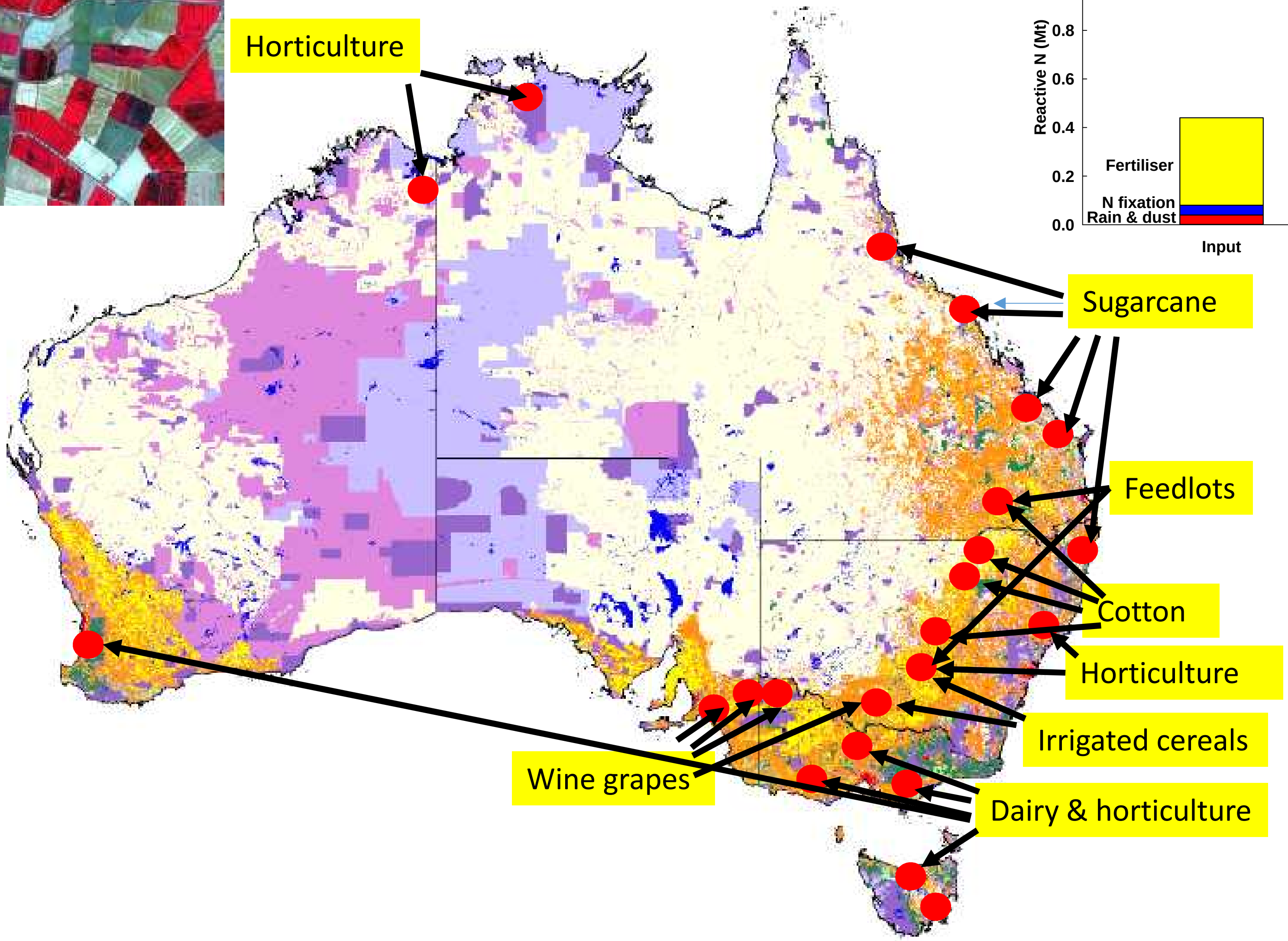
Dryland farming – 97 m ha





Intensive farming – 4 m ha





Reactive N carried in Australian dust storms

Average number of dust storms per year:	62
Particulate content of a large dust storm (assume 2 Mt average)	3-5 Mt
Organic matter content of dust	10.6%
N content of organic matter	4%
N amount redistributed in dust:	0.5 Mt y^{-1}

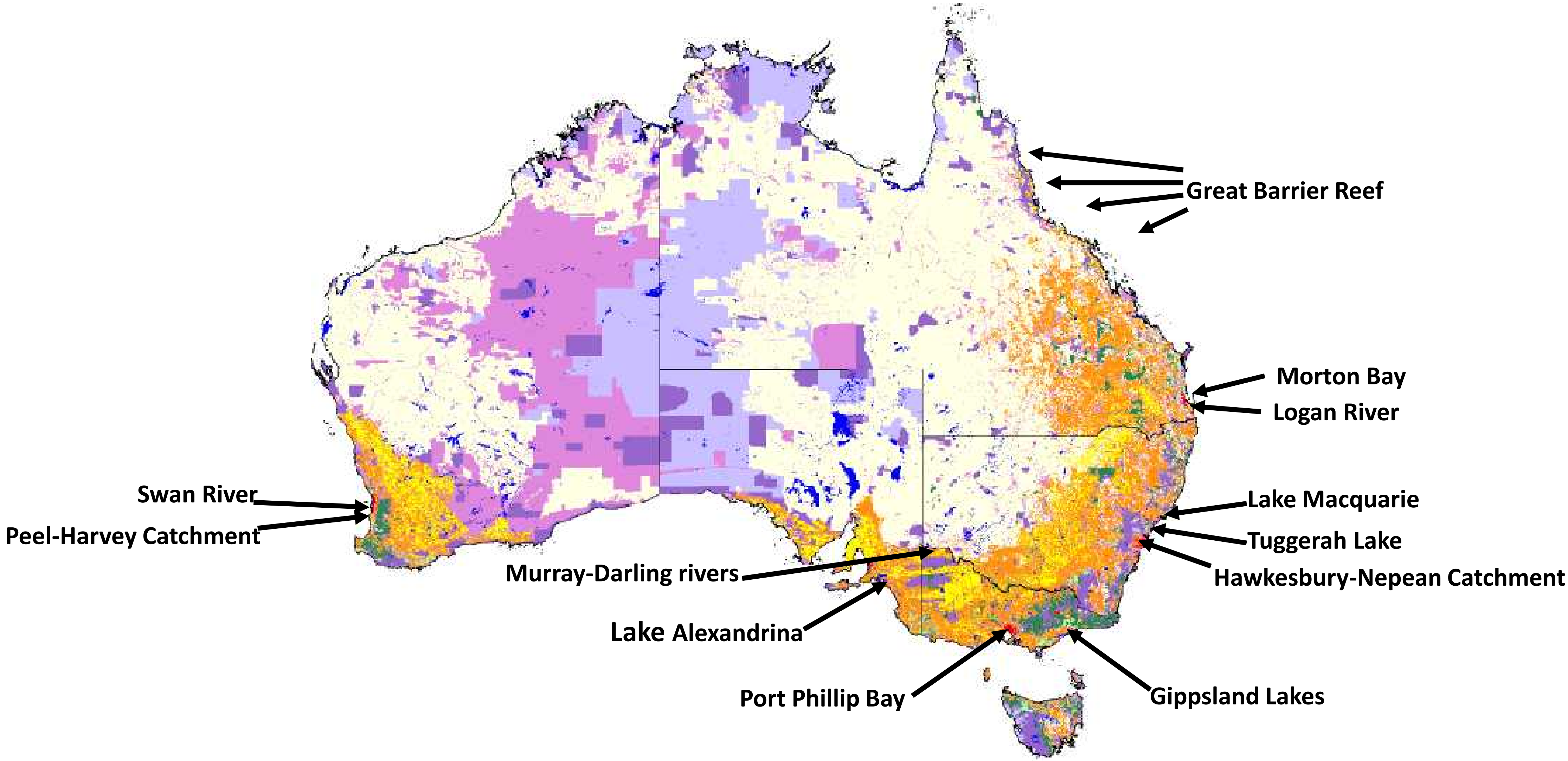
Potential denitrification during 2010-11 flood

Area flooded: 130 M ha
(area of France + Germany + Netherlands +Belgium + Denmark + Norway)

Assumed soil NO_3^- content: 20 kg N ha^{-1}
(lowest value for 60 cm regional soil tests)

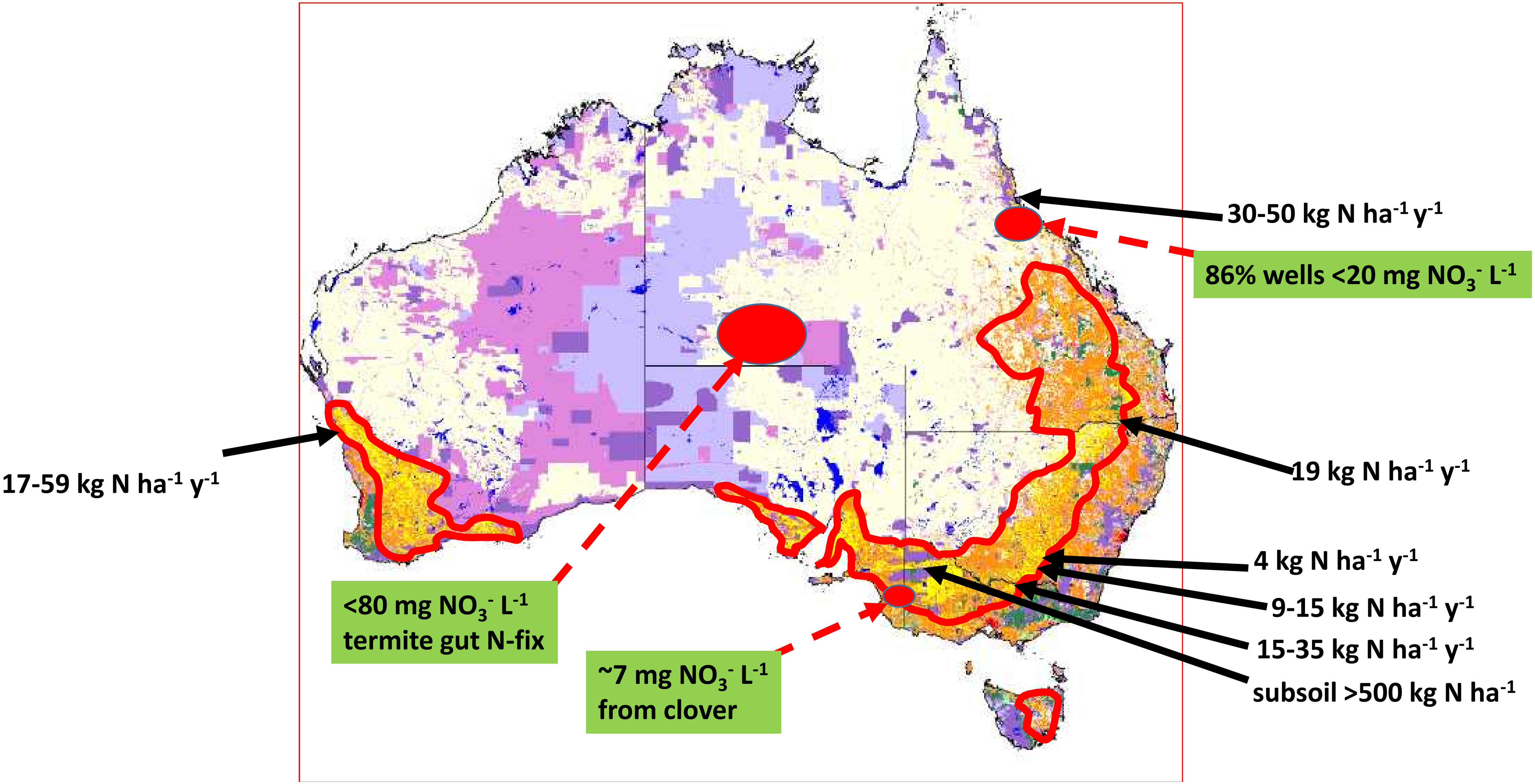
Potential denitrification: 2.6 M t N

Contamination in rivers, estuaries and coastal lagoons



Harris GP (2001) Marine & Freshwater Research 52, 139-149

Nitrate: deep drainage and groundwater contamination

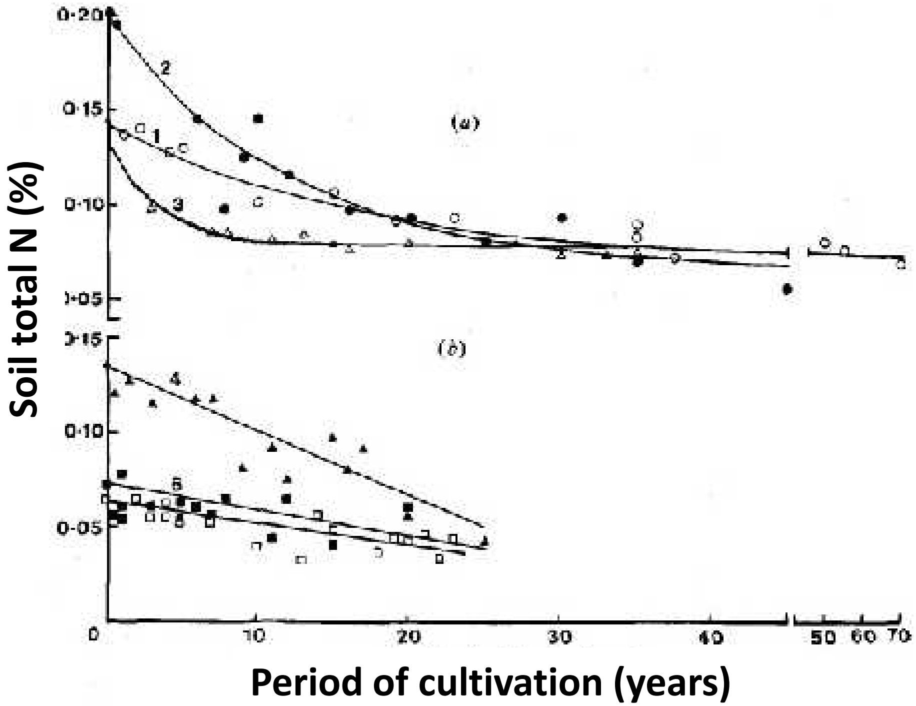


Conventional wisdom

“…generally ancient and infertile soils……”

Prime Minister’s Science, Engineering and Innovation Council, 2010

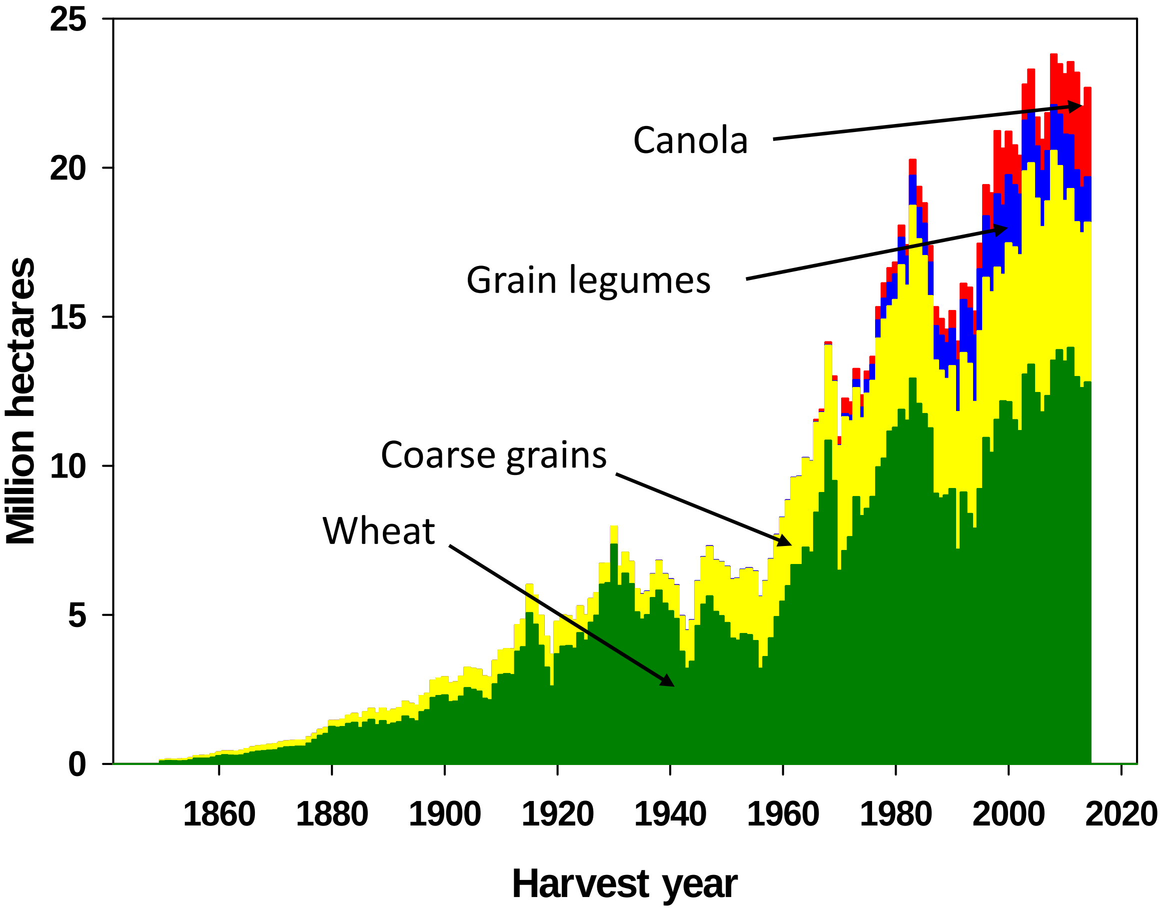
Decrease in soil total N with continuous crops and crop-fallow



Dalal & Mayer (1986) Aust. J. Soil Res. 24, 493-504

- Reviewed 10 long-term Australian experiments
- Average half-life of soil total N ≈ 30 years,
- Equivalent to an annual reduction of 2.3%
- N fertiliser alone does not arrest the decline
- Additional N, P & S arrest the decline, at high cost

Dryland crop area 1850-2015

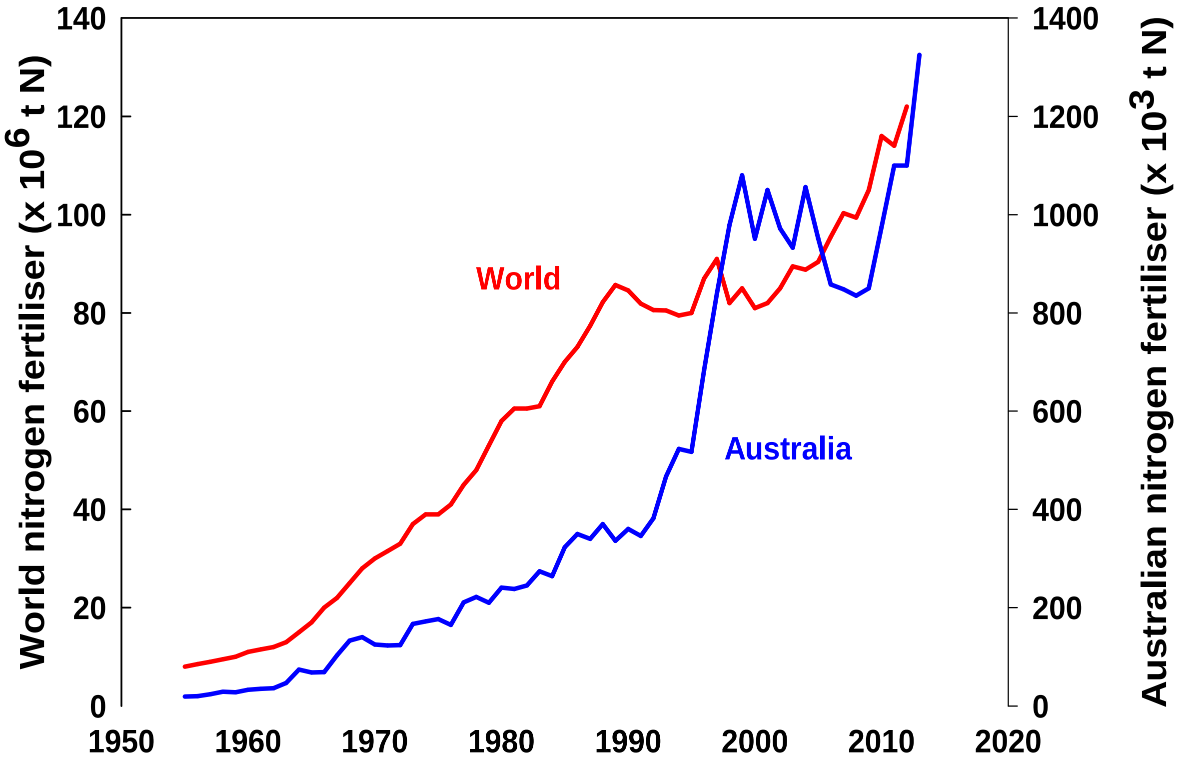


Average increase in crop area : 3.2 % per year

Average number of crops harvested per field by 2014 : 20 – 30

Proportion of total soil N mined : About half the pre-farming soil N removed

World and Australian use of N fertiliser

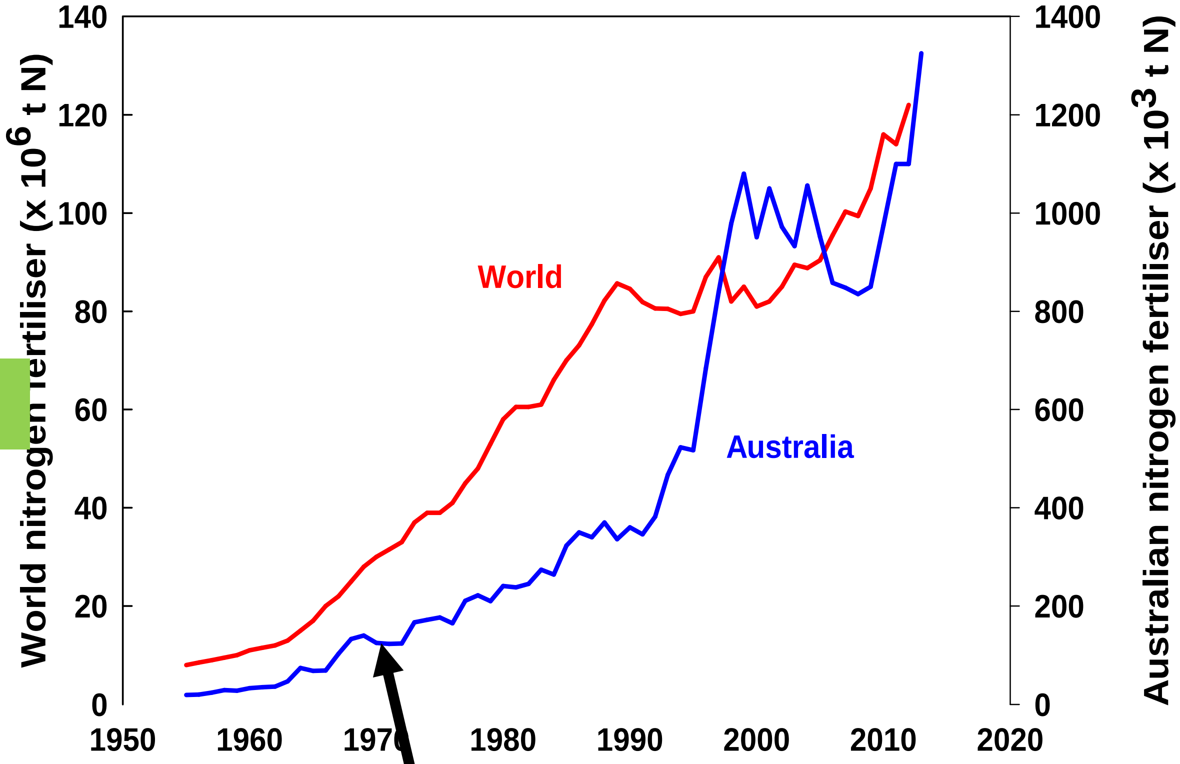


Sources: World: fao3stat.org; Australia: abs.gov.au & Fertiliser Australia

Australian usage of N fertiliser, 2014

	Area (M ha)	Rate (kg N ha^{-1})	N amount (M t)
Dryland crops	**26**	**45**	**1.17**
Intensive crops and pastures	**3.5**	**110**	**0.39**
Other			**0.04**
Total			**1.60**

National Soil Fertility Project 1970s– little adoption



Ammonium sulfate drilled at sowing
Soil tests

Focus on N-supply
Agronomic efficiency: 3 kg grain / kg N

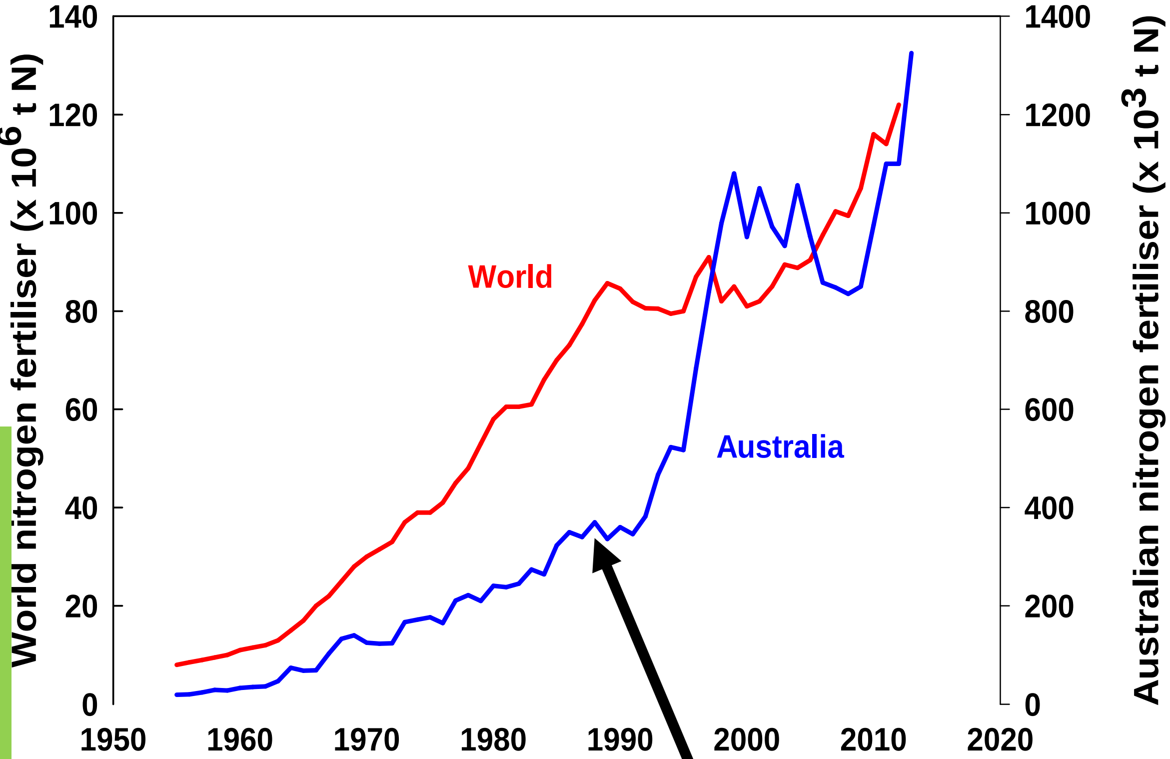
Nitrogen supply and demand – which is more important?

"….. this simple-minded view of the plant, as a kind of hapless sponge passively taking on board nutrients at rates determined by soil chemistry, neglects evidence that the **demand for nutrients in the growing plant is the actual pacemaker for nutrient uptake by the roots**"

David Clarkson (1981)

pp 1-14 in ADAS Conf. Proc. HMSO, London

Bob Myers and N supply-demand



“Tactical” N fertiliser
Topdressed urea at DC30
Adequate water
Wheat after a break crop
Early sowing
No soil constraints
Low N status (shoot counts)

Crop N demand and soil N supply
Average agronomic efficiency : 14 kg grain kg N fertiliser
on-farm experiments : Average NUE: 36%

“…. overall R&D … lags in the range of 35-50 years are certainly plausible” Alston et al. (2009). Persistence pays. Springer

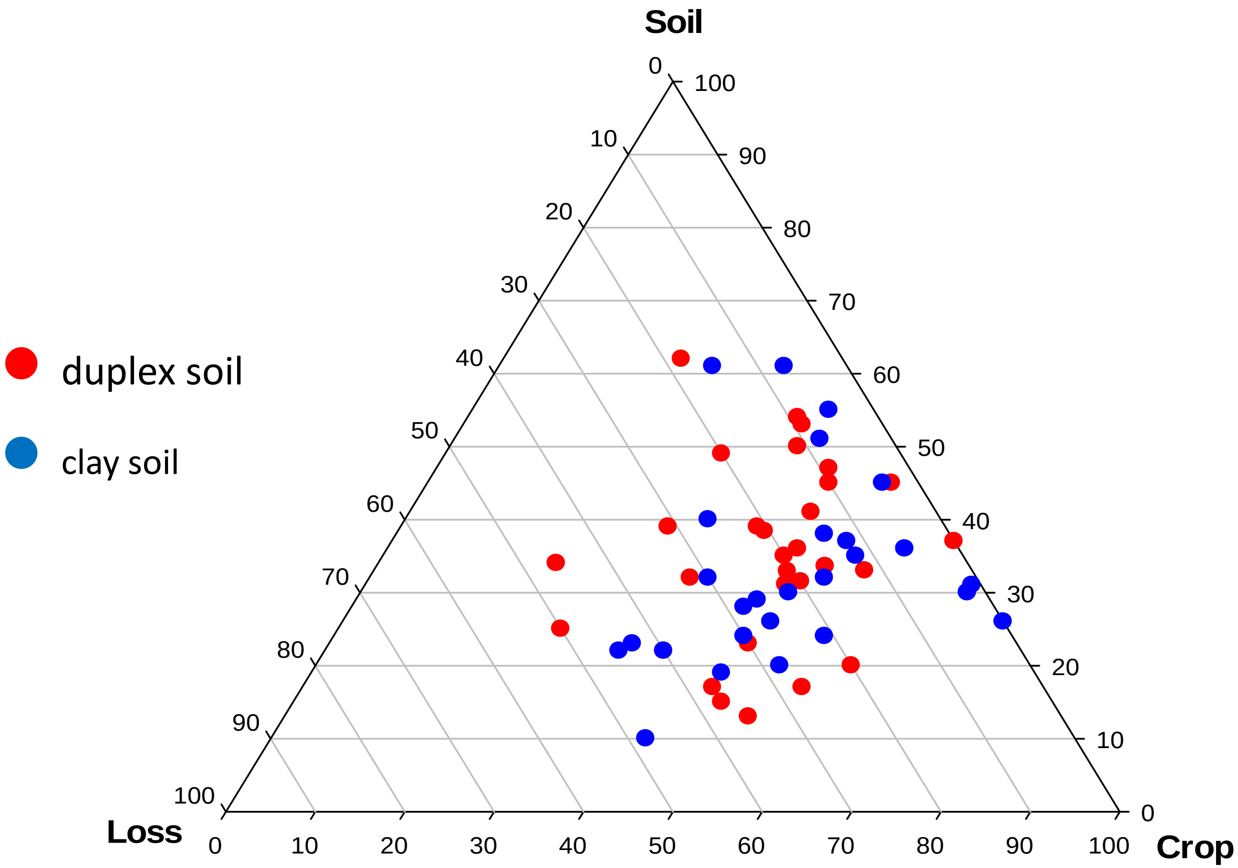
International N:grain price ratios, most recent crop

Region	Farm-gate N price / t	Farm-gate grain price / t	N:grain price ratio
Ethiopia	ET Birr 24347.83	ET Birr 4150 maize	5.9
Ghana	Cedi 3478	Cedi 900 maize	3.9
Kenya	Ksh139,130	Ksh 33333 maize	4.2
Australia (Stockinbingal)	$A 935	$A 180 wheat (APW)	5.2
China (6 counties in Jiangsu)	$US 526	$US 330 wheat	1.6
Europe (southern Sweden)	SEK 2782	SEK 1280 milling wheat	2.2
India (Andra Pradesh)	Rupee 11950	Rupee 13250 rice	0.9
USA (Illinois)	$US 729	$US 135 wheat	5.4
USA (Montana)	$US 748	$US 170 hard red spring (14%)	4.4

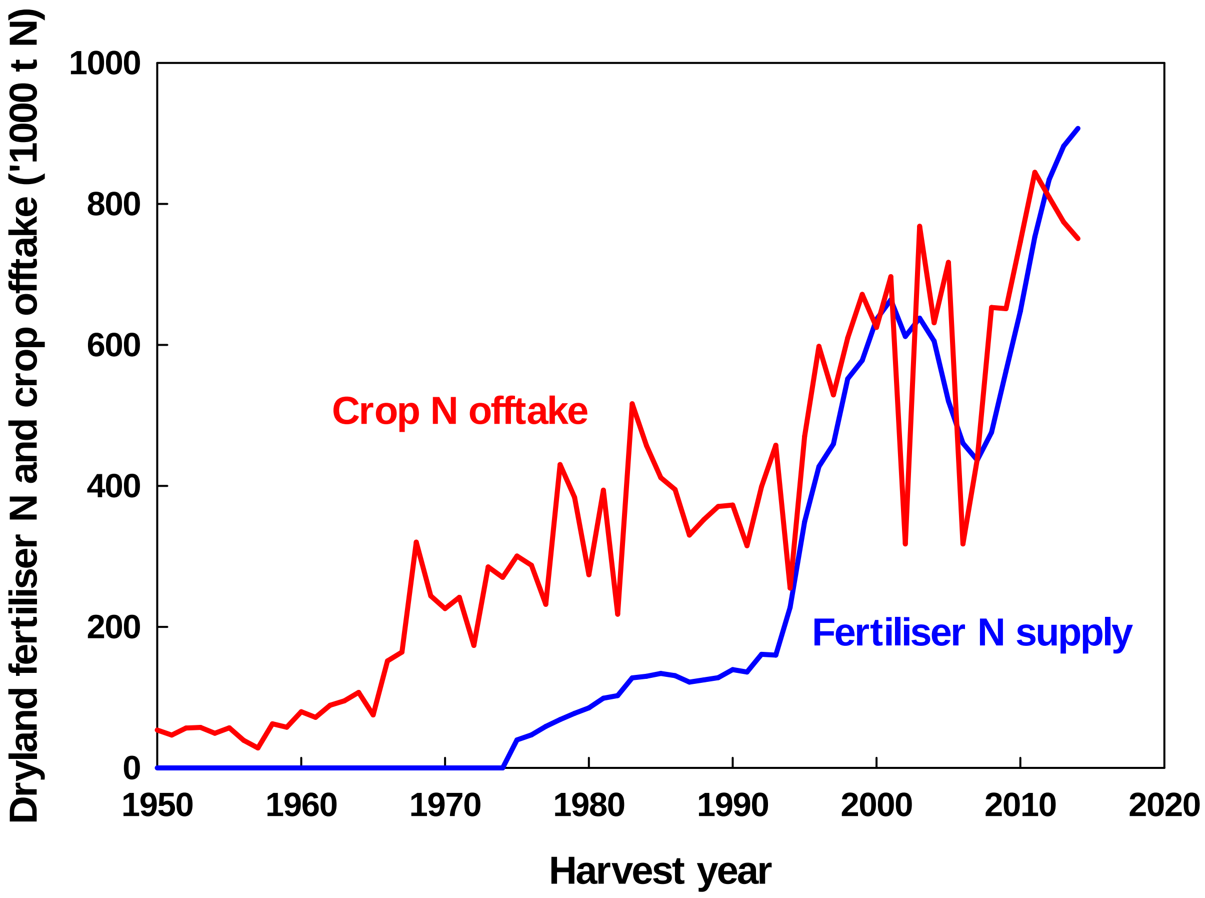
Elemental N and grain mass in metric tonnes, assuming 1 wheat bushel = 27.2 kg. N form urea

Thanks: Cargele Masso, Dejian Wang, Gupta Vadakattu, Göran Bergkvist, Cliff Snyder, Perry Miller, Anton Bekkerman, Daniel Chalmers

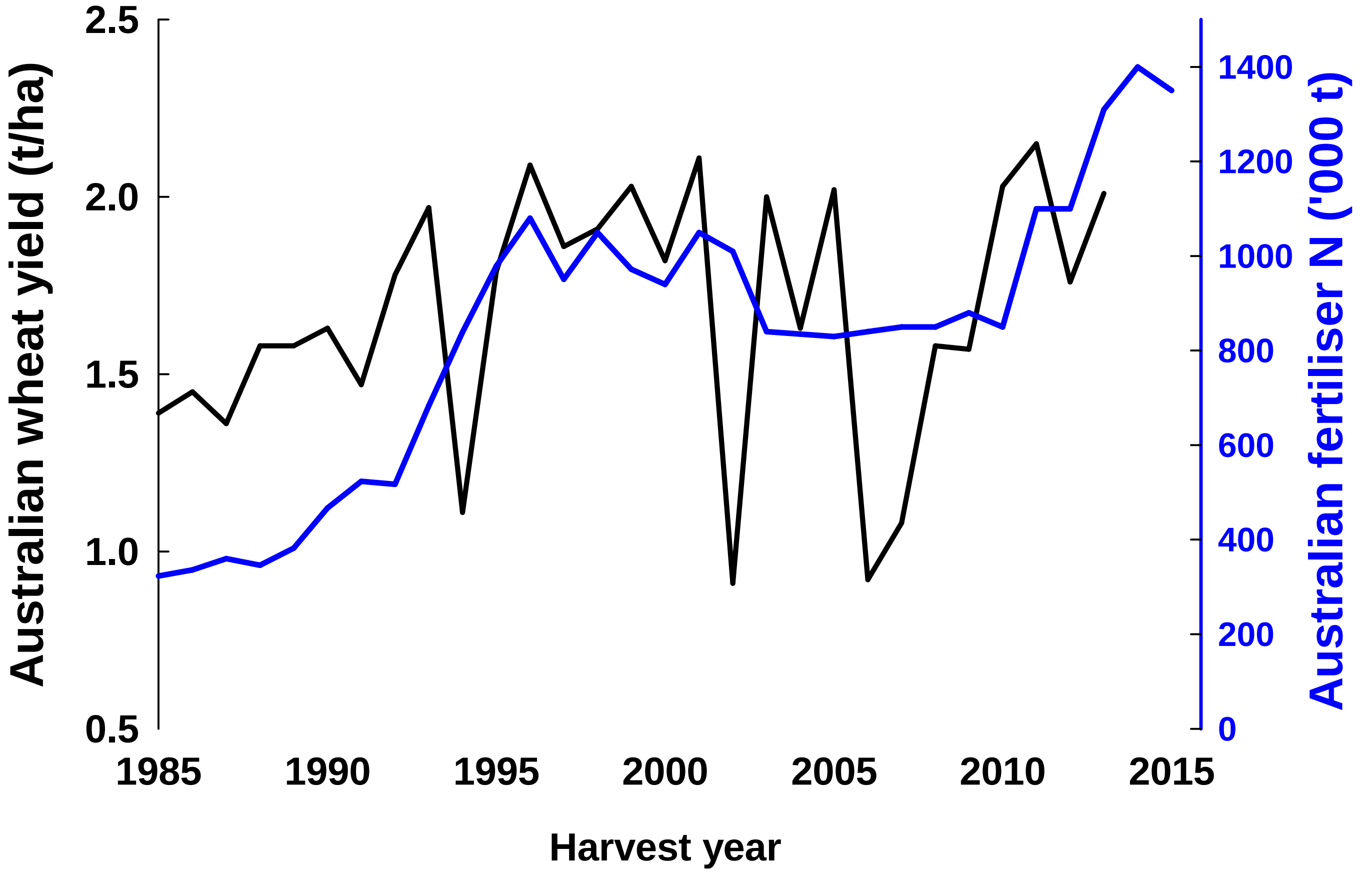
^{15}N fate in 57 Australian wheat experiments
Averages: 44% crop, 34% soil, 22% loss



Dryland fertiliser N supply and crop N offtake in Australia



N fertiliser and wheat yield – efficient during the 1990s, inefficient after 2010?



Additions needed in a crop-N budget

- **Immobilisation rates and duration**
- **Mineralisation from soil-N mining vs N-fixation**

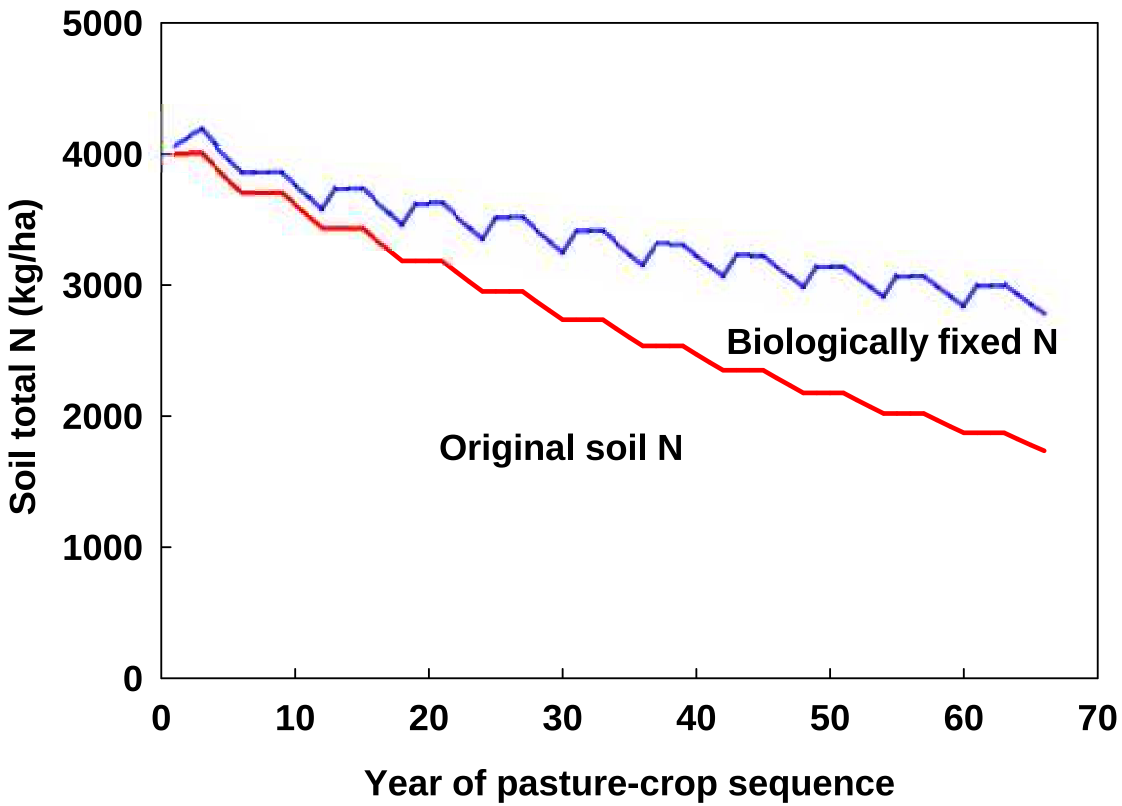
Slide 23

AJ(BM1 Angus, John (Agriculture, Black Mountain), 04-Dec-16

Simulating soil total N in a crop-pasture sequence

3 years pasture – 3 years crop

Pasture N-fix = 60 kg/ha/yr
Soil N mineralisation: 2.3%/yr
Fixed-N mineralisation
year 1: 17%/yr
year 2: 7%/yr
year ≥3: 2.3%/yr



Nitrogen budget for an average hectare of Australian wheat

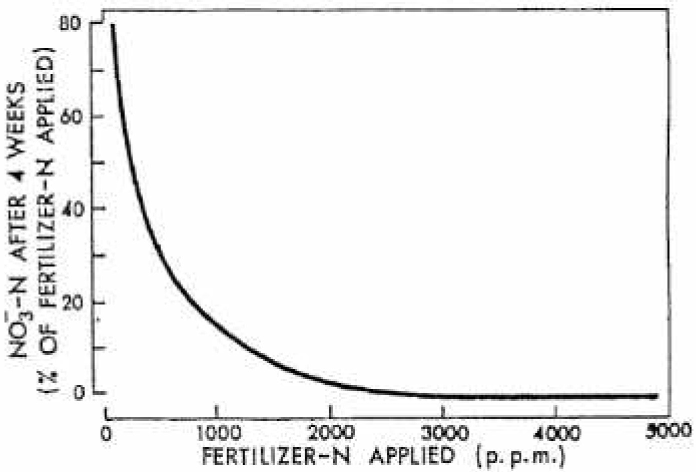
		kg N ha^{-1}	Total (kgN ha^{-1})
Crop N demand	Yield 2.1 t ha^{-1} @ 10.5 % grain protein	37	
	Straw N (one-third of grain N)	12	
	Rhizodeposited N (34 % of total plant N)	25	74
N-supply	Fertiliser	45	
	Rain and dust	5	
	Mineralisation		
	mining soil N	31	
	N-fixed from previous pastures	31	112
N 'losses'			
	Soil-N retention	24	
	Losses*	14	38

*leaching, ammonia volatilisation and denitrification of fertiliser and other N

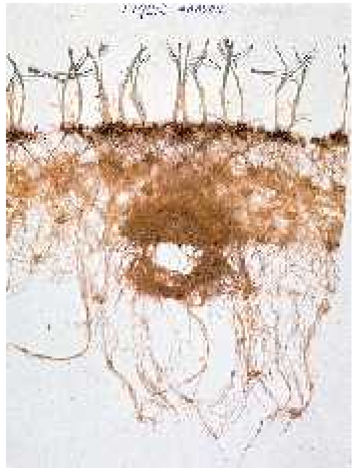
What next for NUE research for dryland cropping?

- **Unscramble N rhizodeposition from immobilisation**
- **How long before remineralisation of immobilised fertiliser N?**
- **More N-fix from rotational pastures (profitable grazing industries)**
- **Can we separate N fertiliser from immobilising and denitrifying microbes**

Rob Wetselaar and N fertiliser banding



Wetselaar et al. (1973). *Chimie & Industrie: Genie Chimique* 106, 567-572



Roots avoiding but clustered around NH_4^+-band

pH marker showing NH_4^+ band 8 weeks after injection in mid-row bands

Conclusions

- N fertiliser provides a small but increasing part of N supply to Australian agriculture
- Dryland cropping is still mining soil N. Fertiliser efficiency is exceedingly low and new methods are badly needed.
- Natural soil N, rather than fertiliser N, is responsible for many environmental problems
- Permanent pastures may be accumulating excess N and will lead to more off-site problems. Excess N can be removed by introducing crops into the system.
- Many N-related problems (losses, soil acidification, algal blooms) are found in extensive systems and can be solved by more intensive management