# Nitrogen use efficiency and nitrogen balance in Australian farmlands

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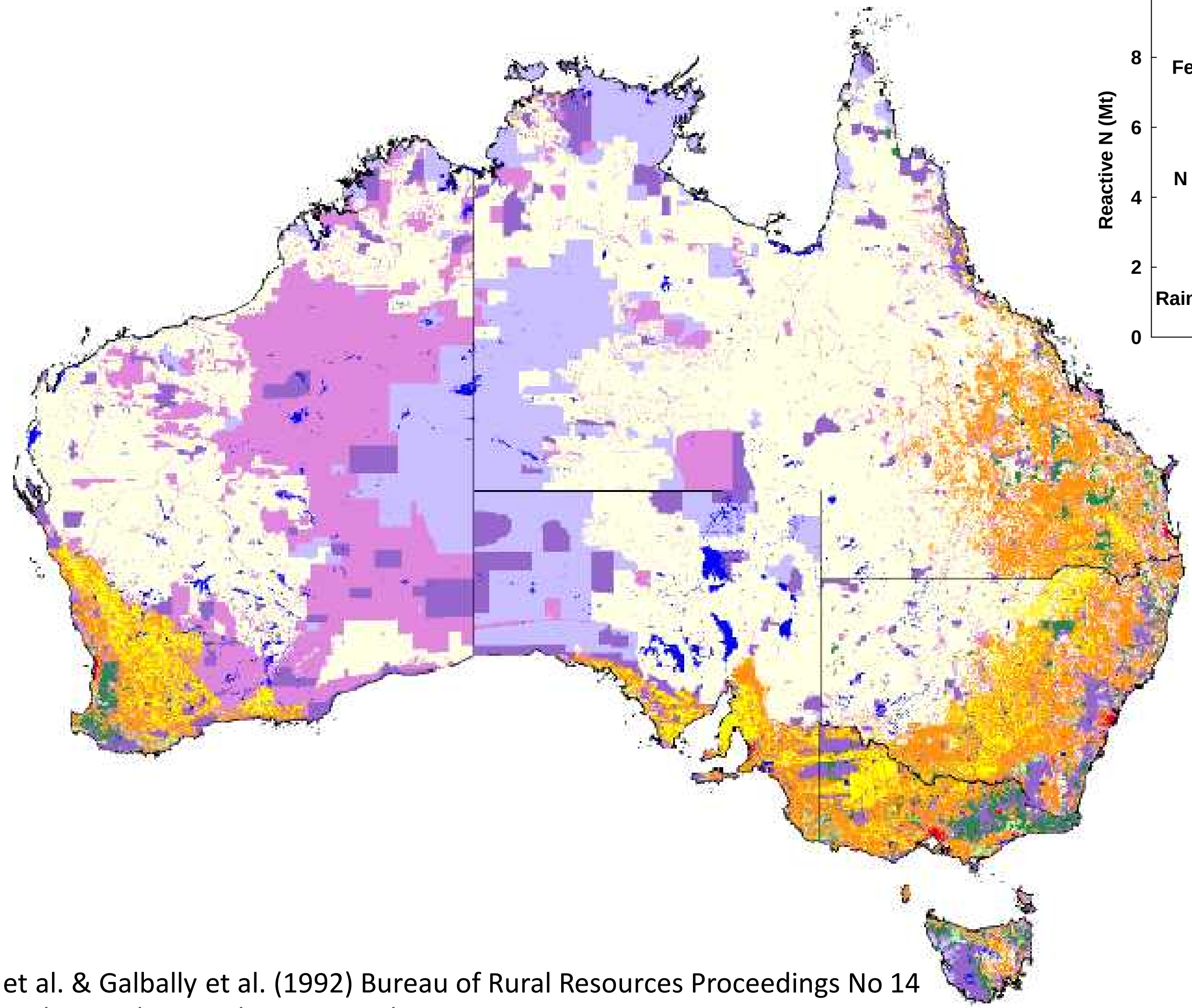
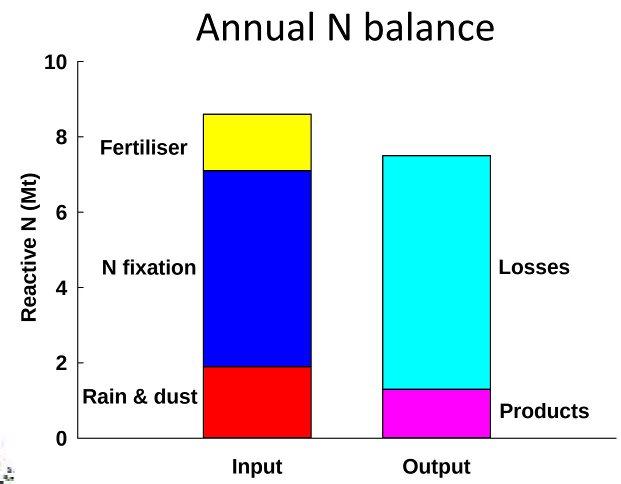
# Continental N balance

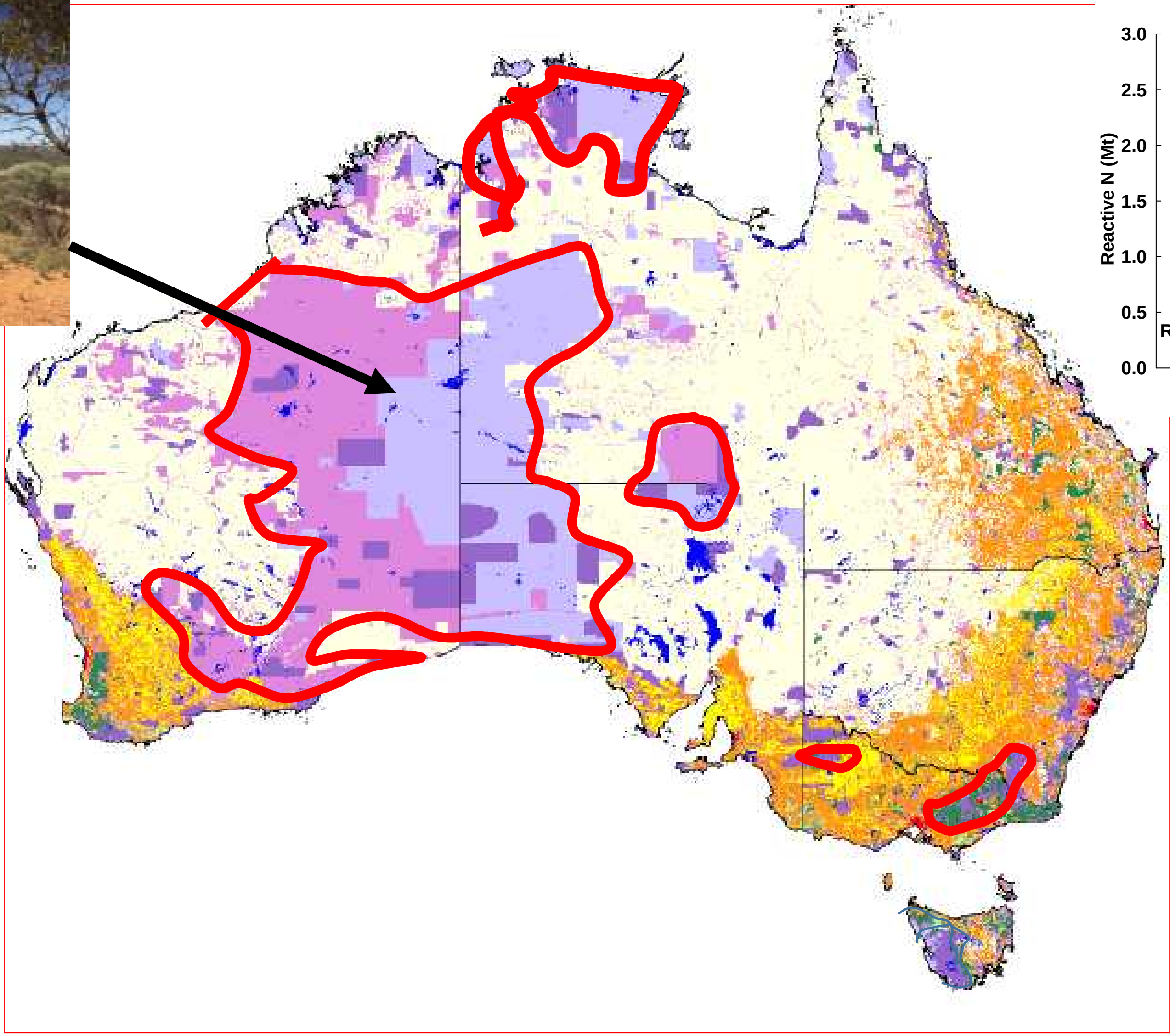


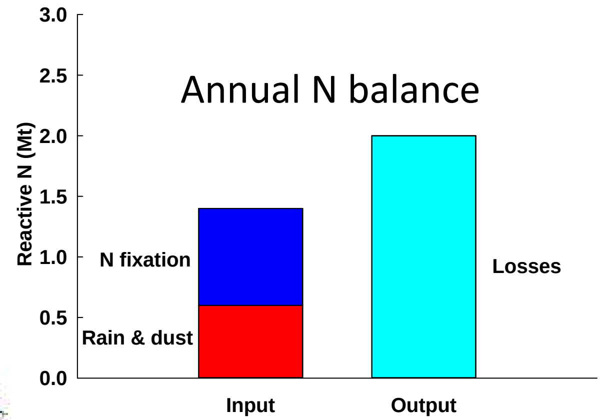



N-balance method: McLaughlin et al. & Galbally et al. (1992) Bureau of Rural Resources Proceedings No 14
Base map: www.agriculture.gov.au/abares/aclump/Documents/Land_use_in_Australia_at_a_glance_2006.pdf

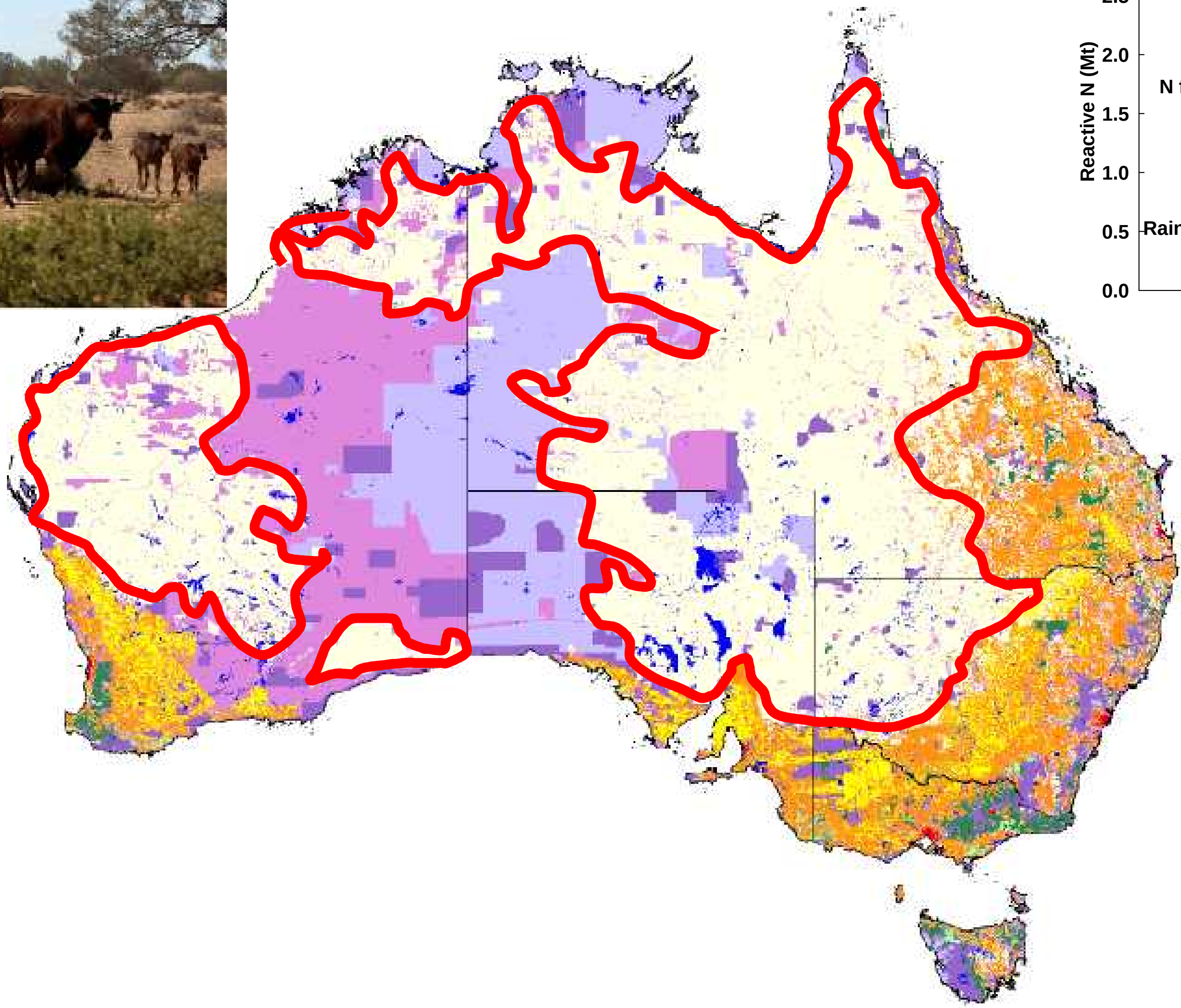
# No agricultural production – 309 m ha

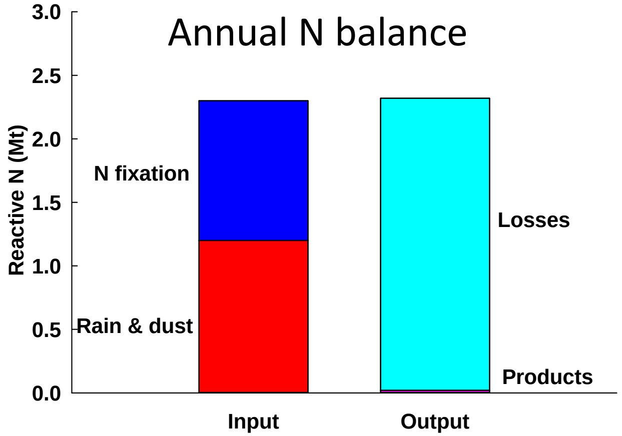
Canning stock route, July 2016



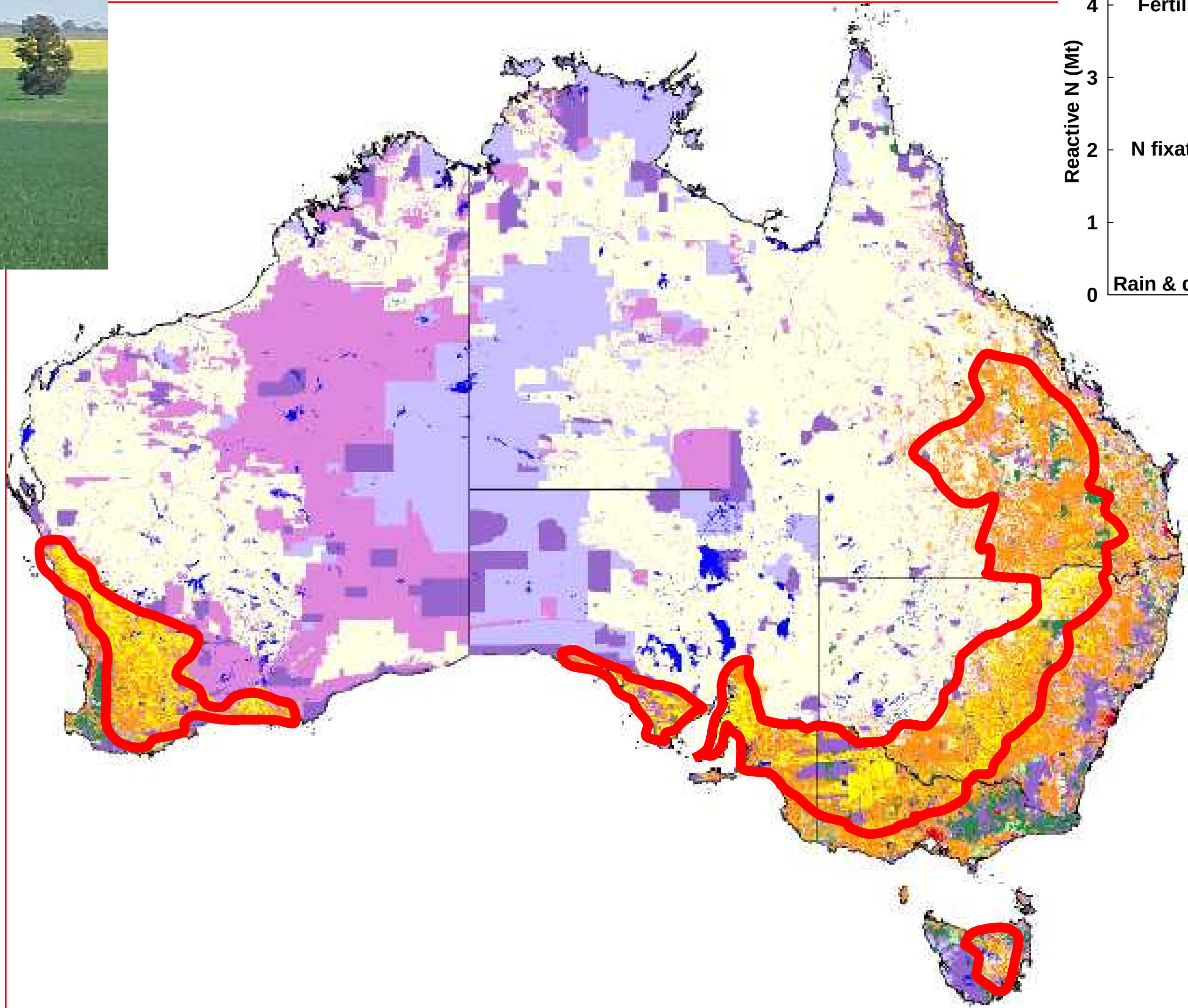


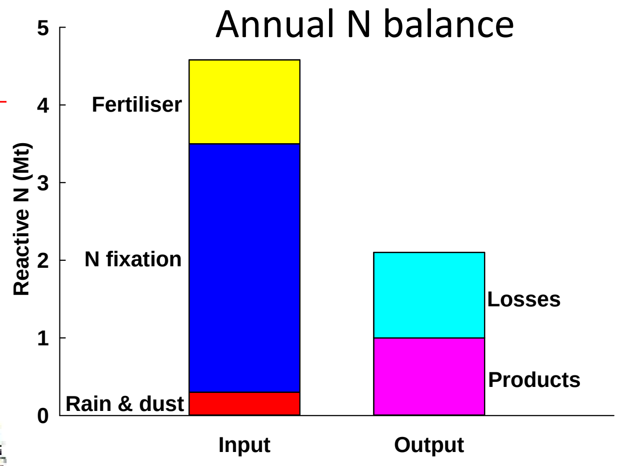
# Pastoral zone – 355 m ha



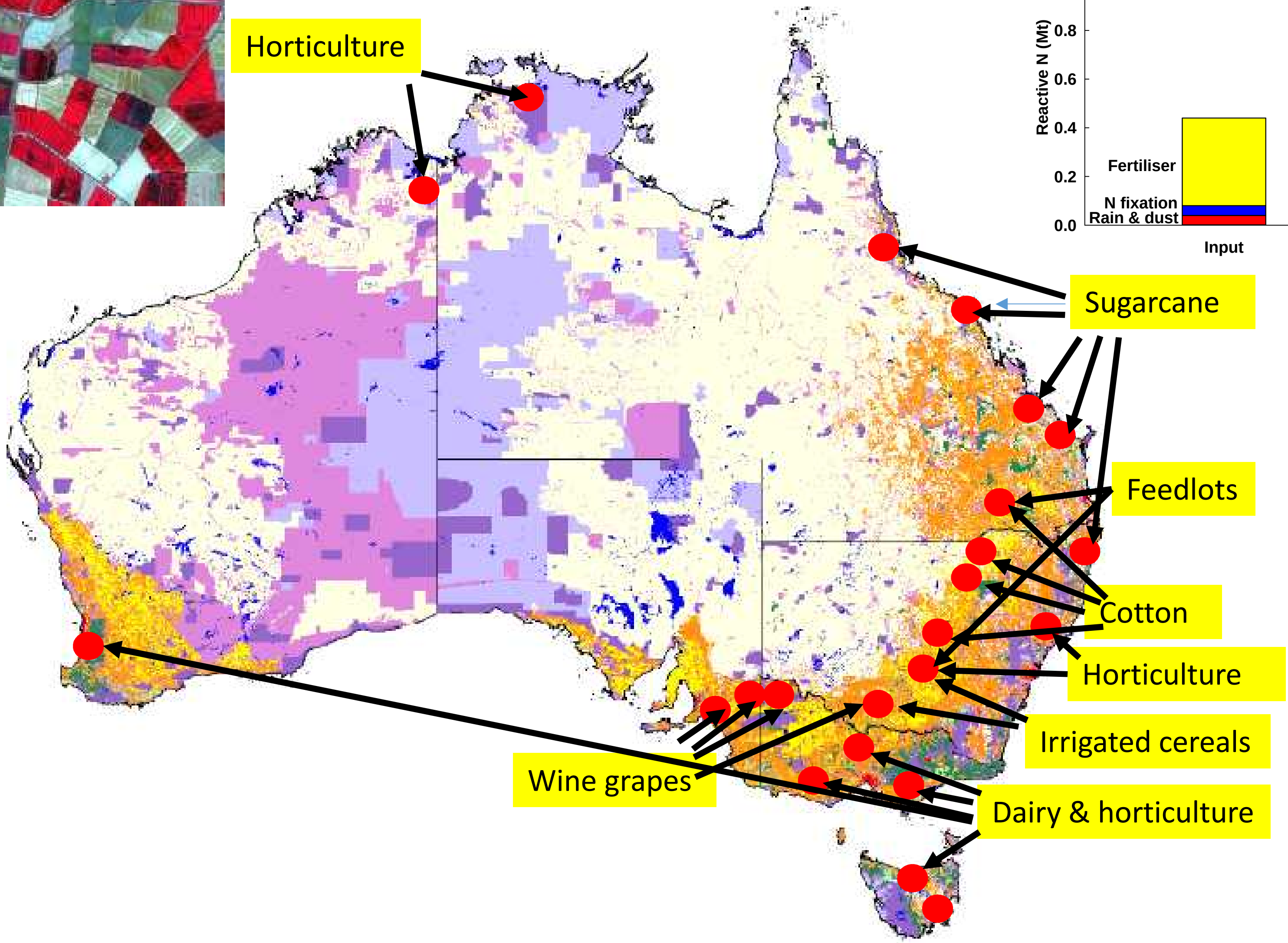


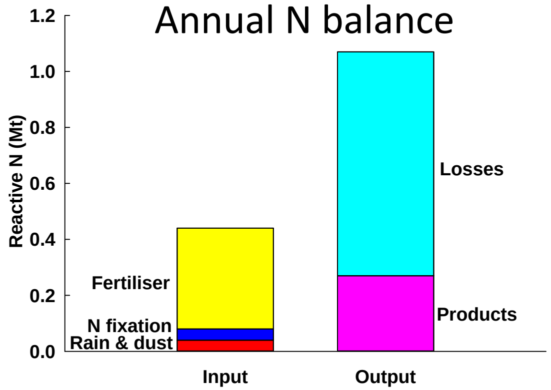
# Dryland farming – 97 m ha





# 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 $y^{-1}$ |

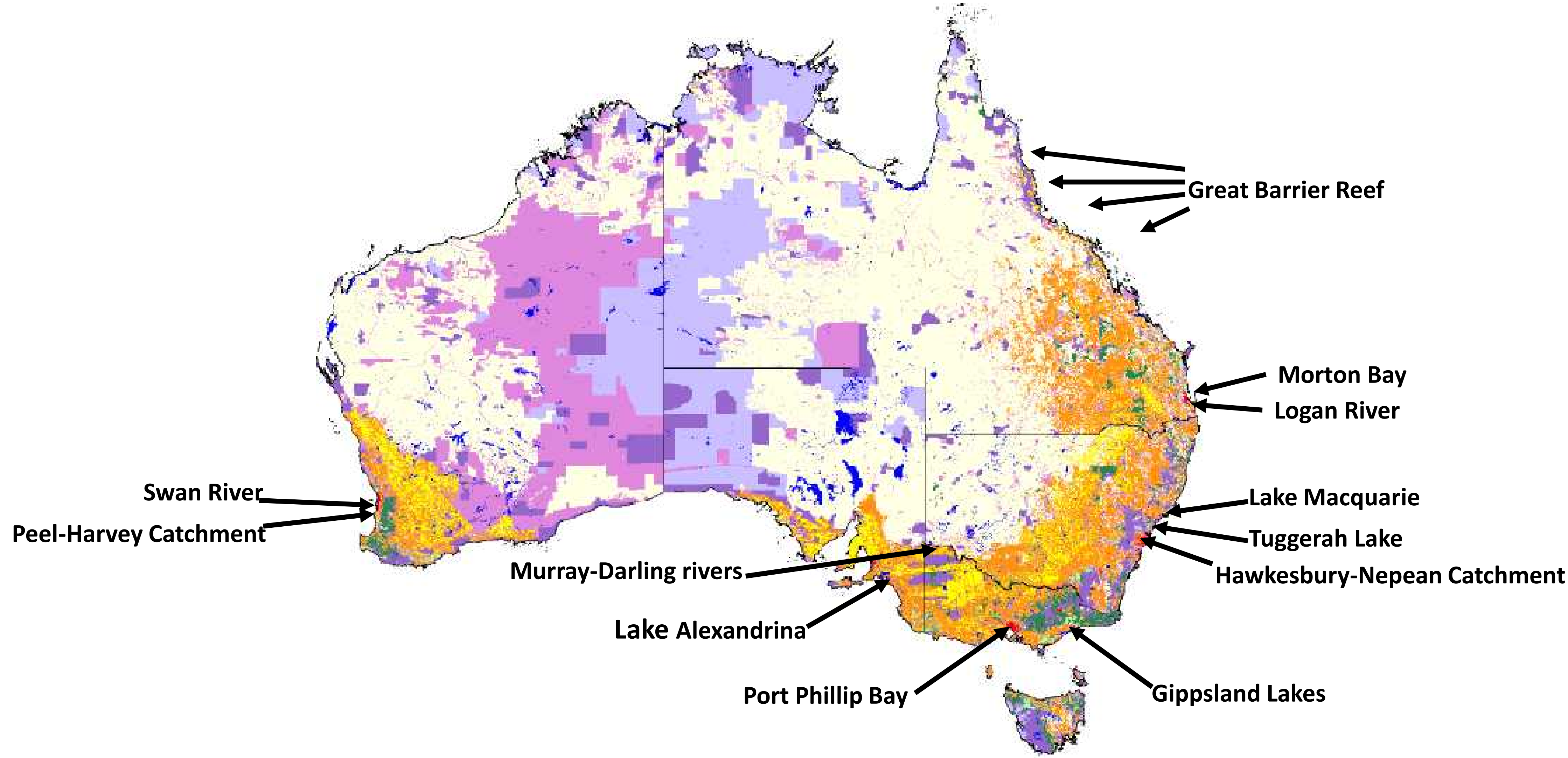
# Potential denitrification during 2010-11 flood

**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)**

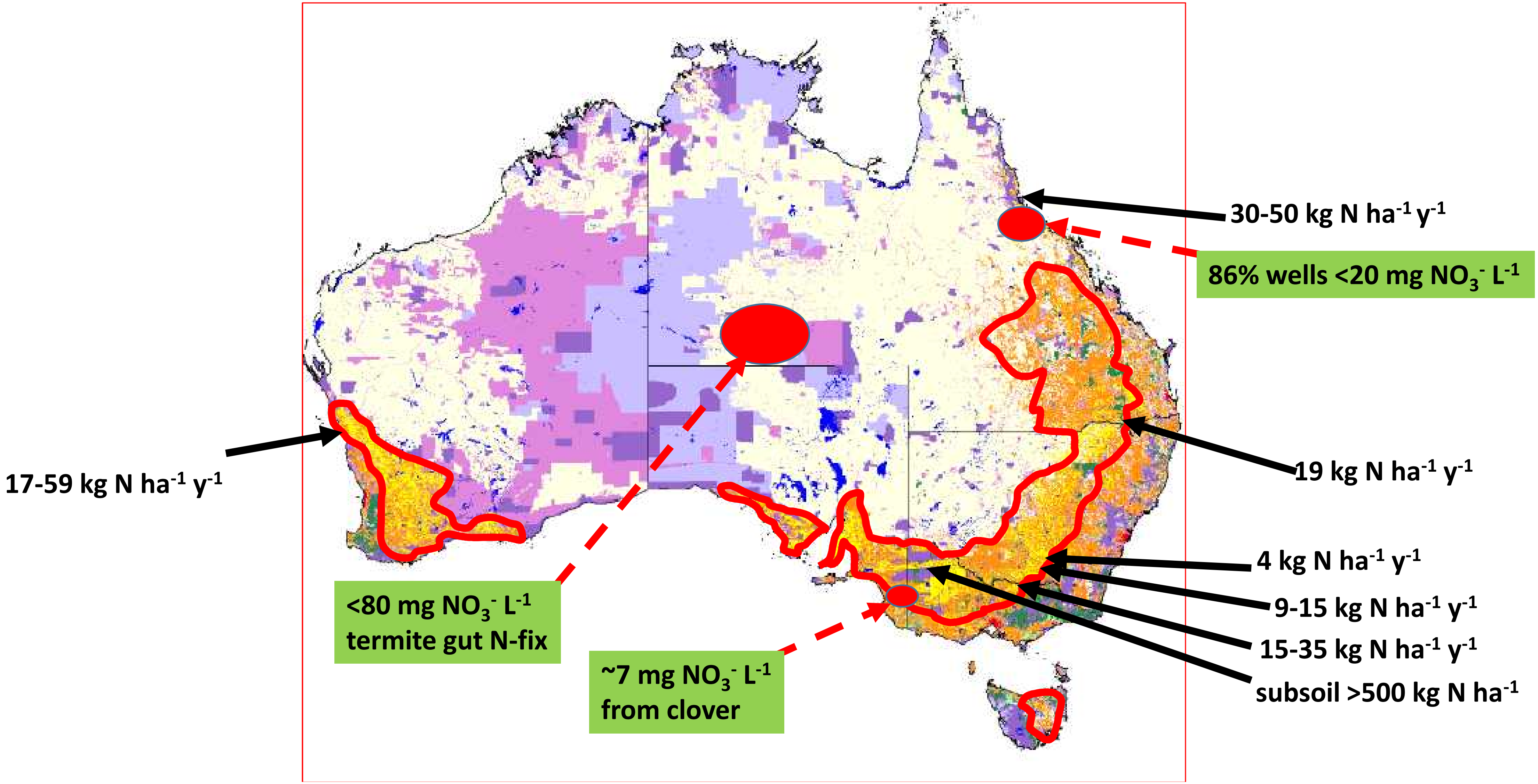
**Potential denitrification: 2.6 M t N**

# Contamination in rivers, estuaries and coastal lagoons




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

# Nitrate: deep drainage and groundwater contamination

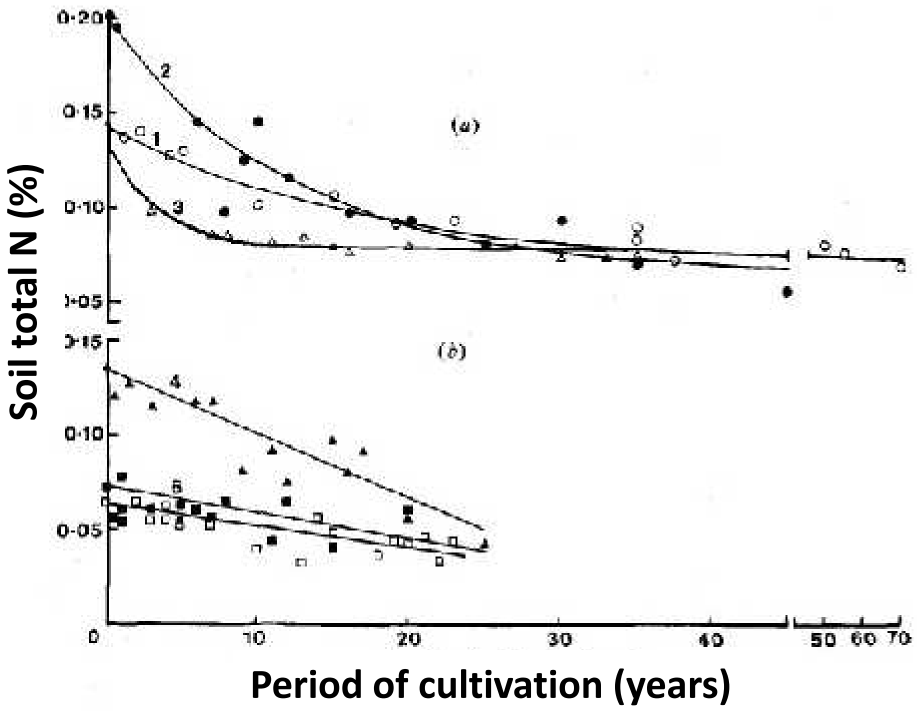


# Conventional wisdom

"…generally ancient and infertile soils……"

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

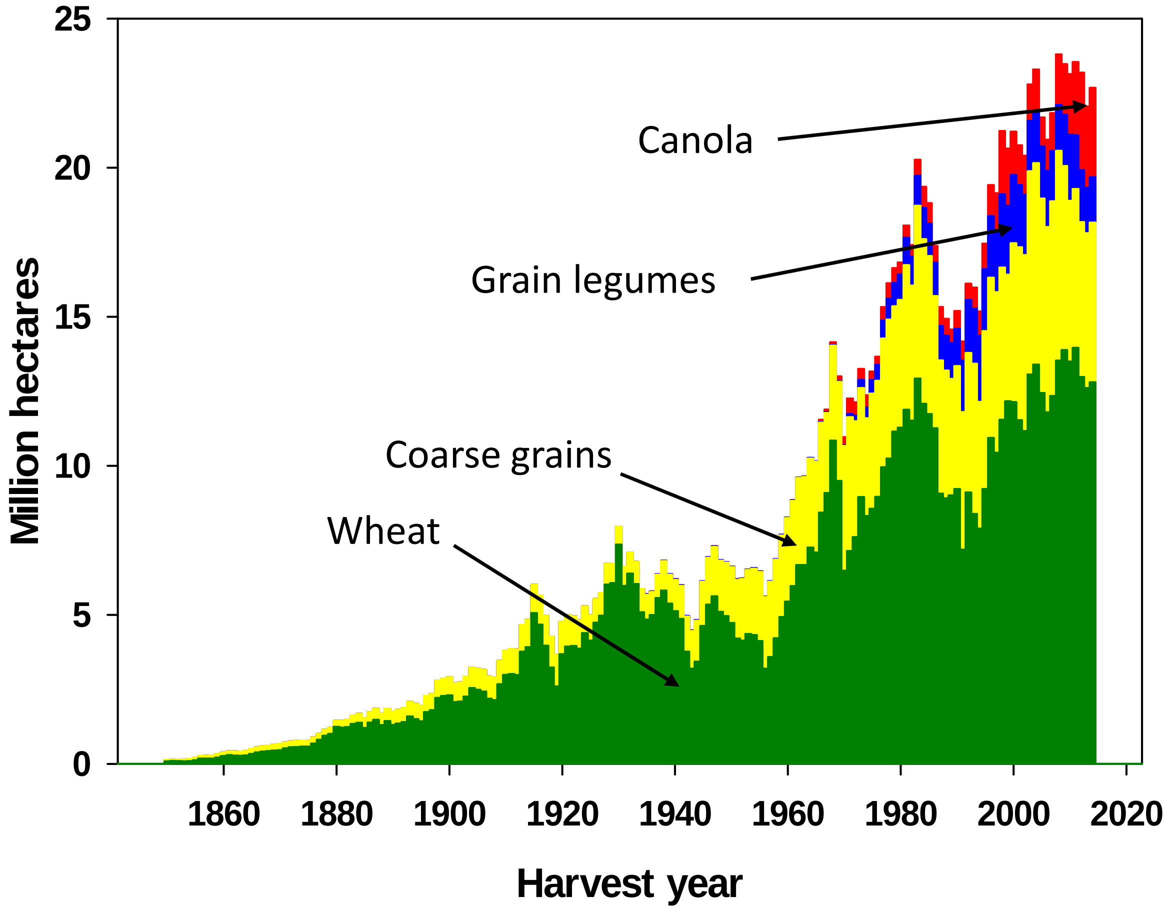
# Decrease in soil total N with continuous crops and crop-fallow




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

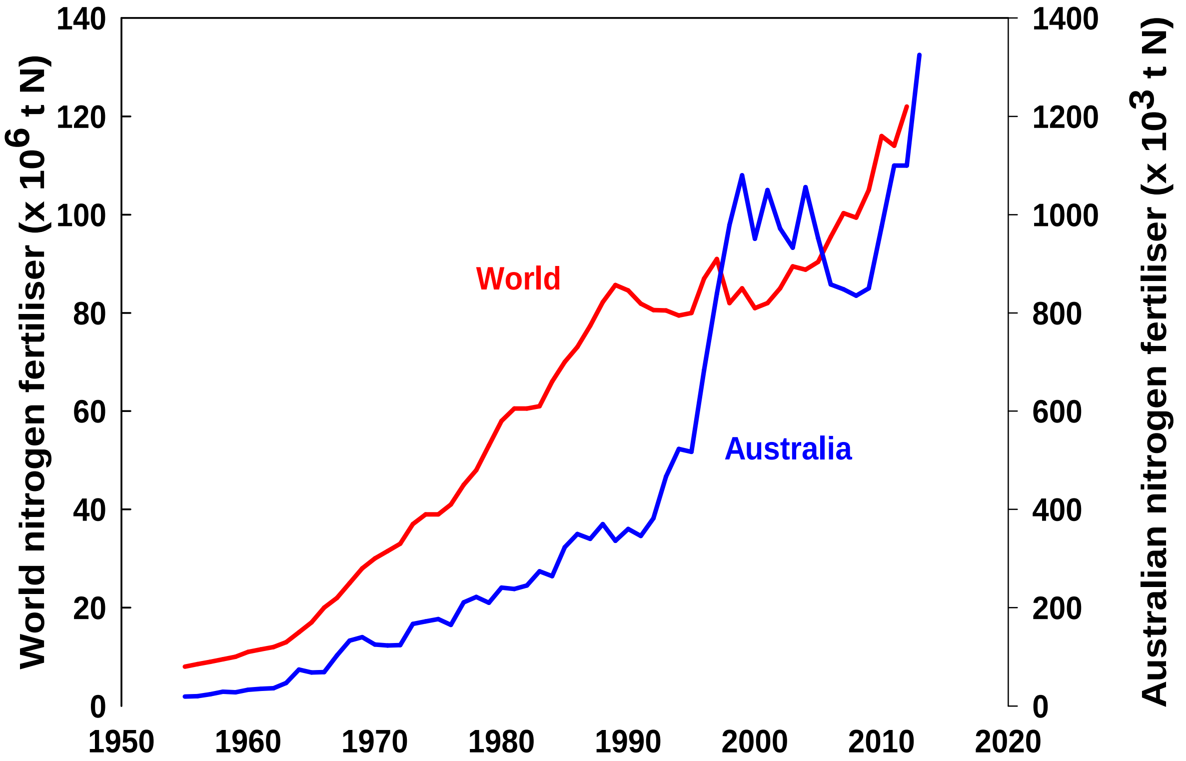



**Average increase in crop area : 3.2 % per year**

**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



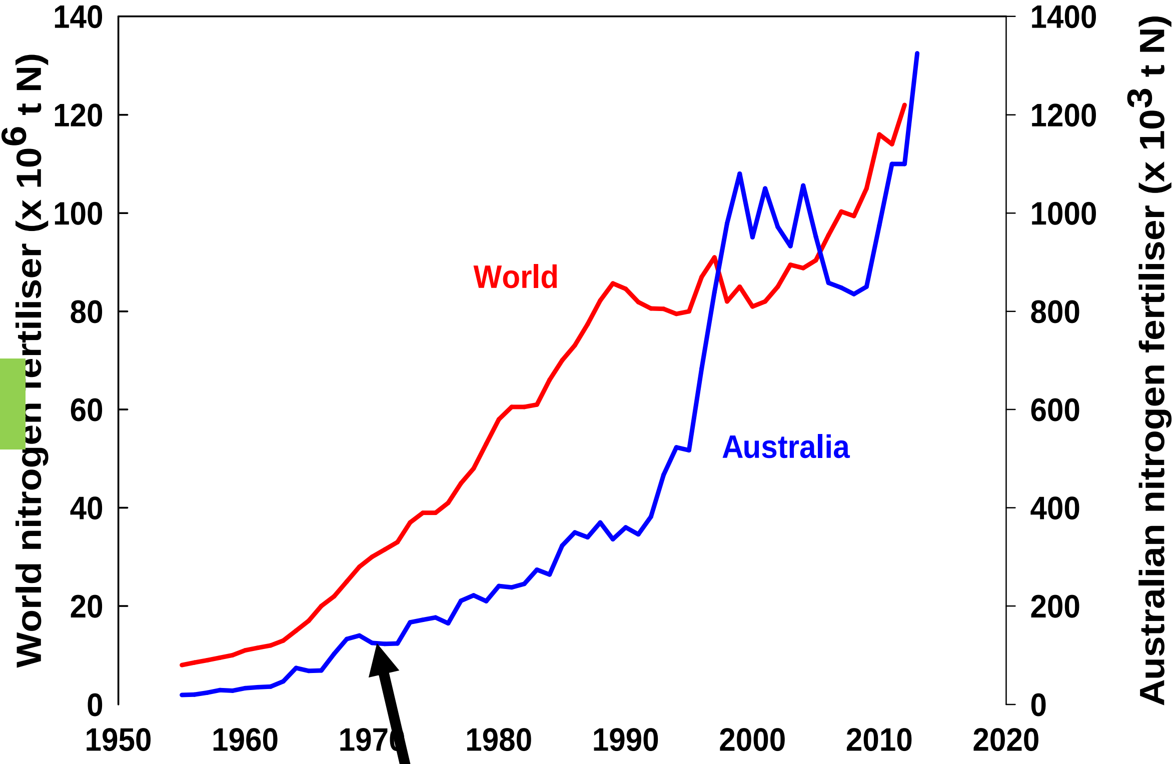

Sources: World: fao3stat.org; Australia: abs.gov.au & Fertiliser Australia

# 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

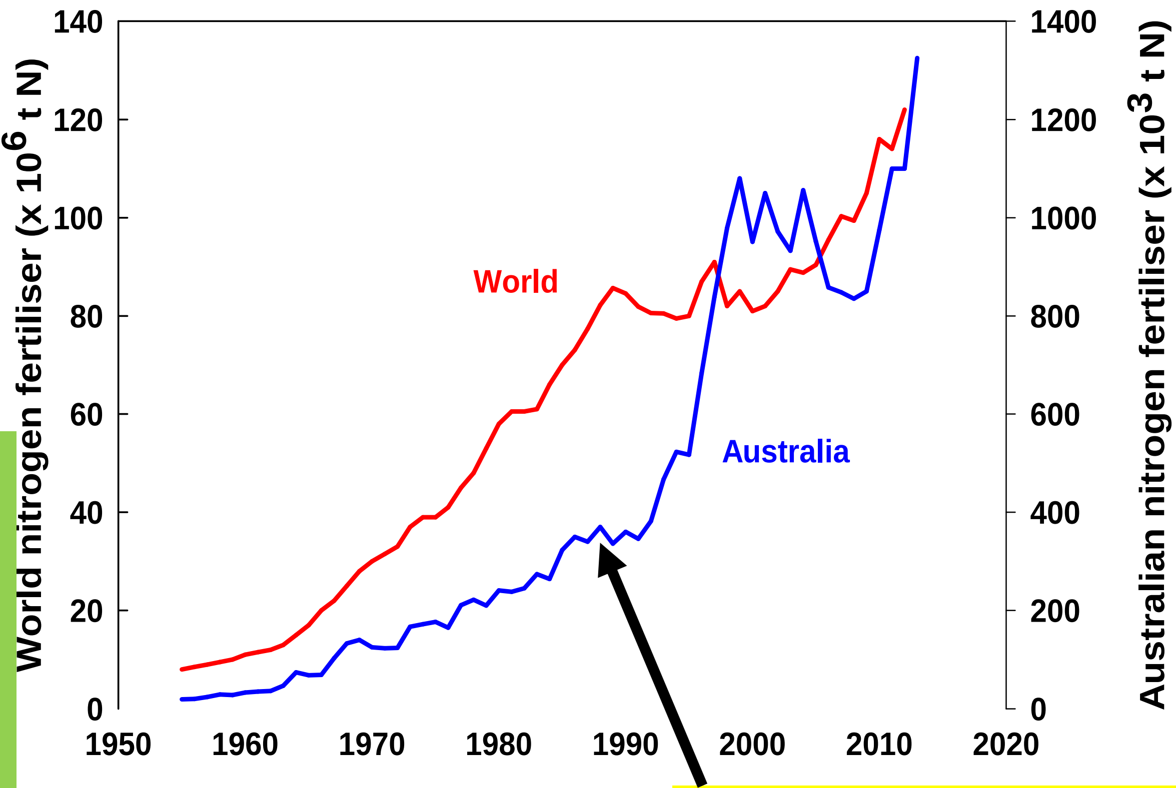
# Nitrogen supply and demand – which is more important?

"….. 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

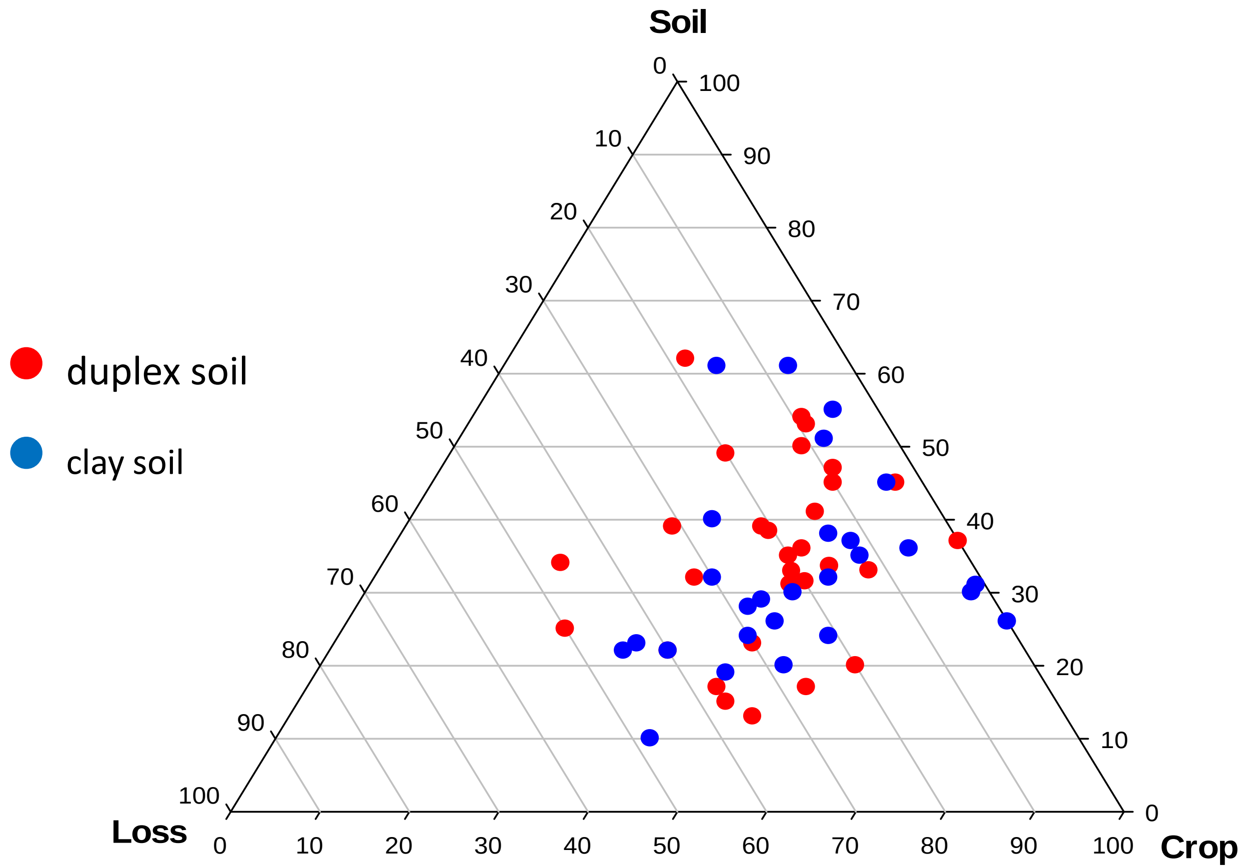
# International N:grain price ratios, most recent crop

| 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 |

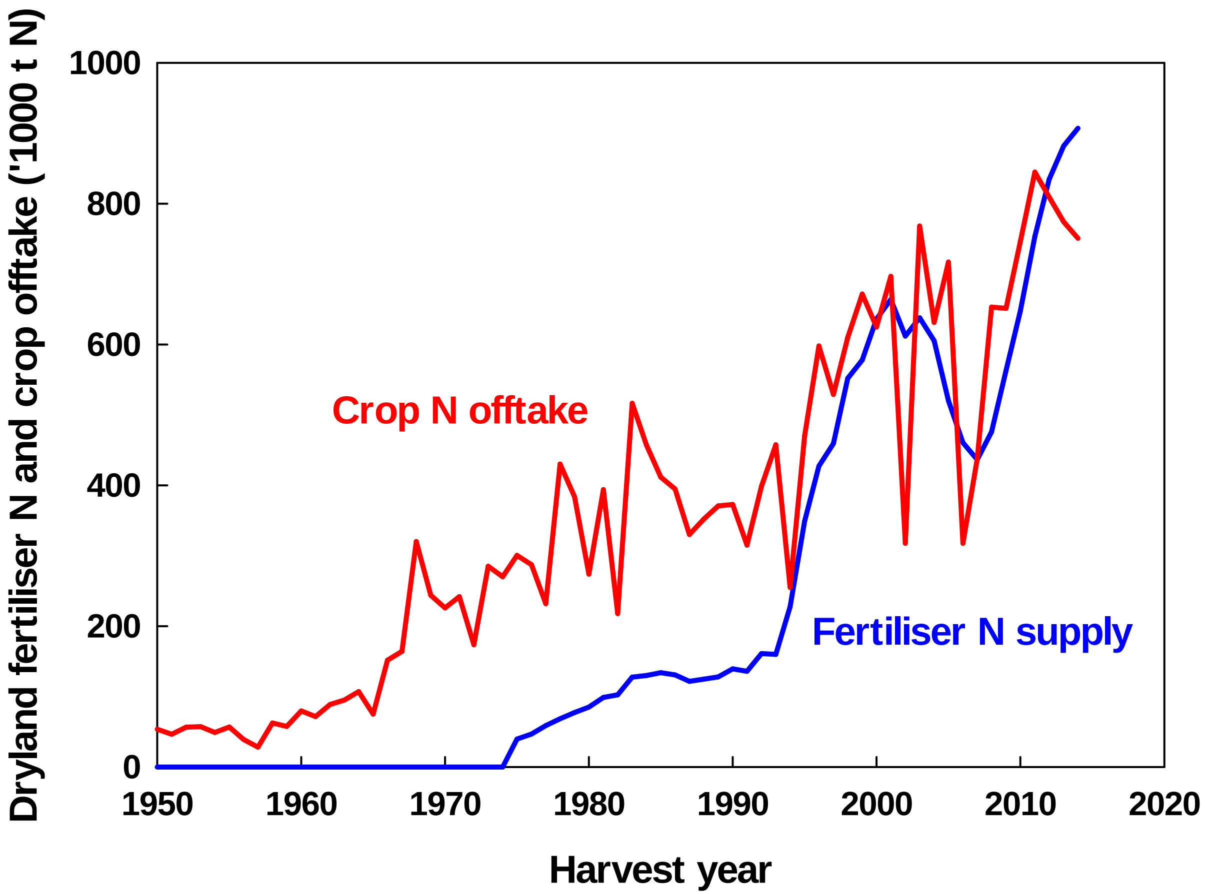
Elemental N and grain mass in metric tonnes, assuming 1 wheat bushel = 27.2 kg. N form urea

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

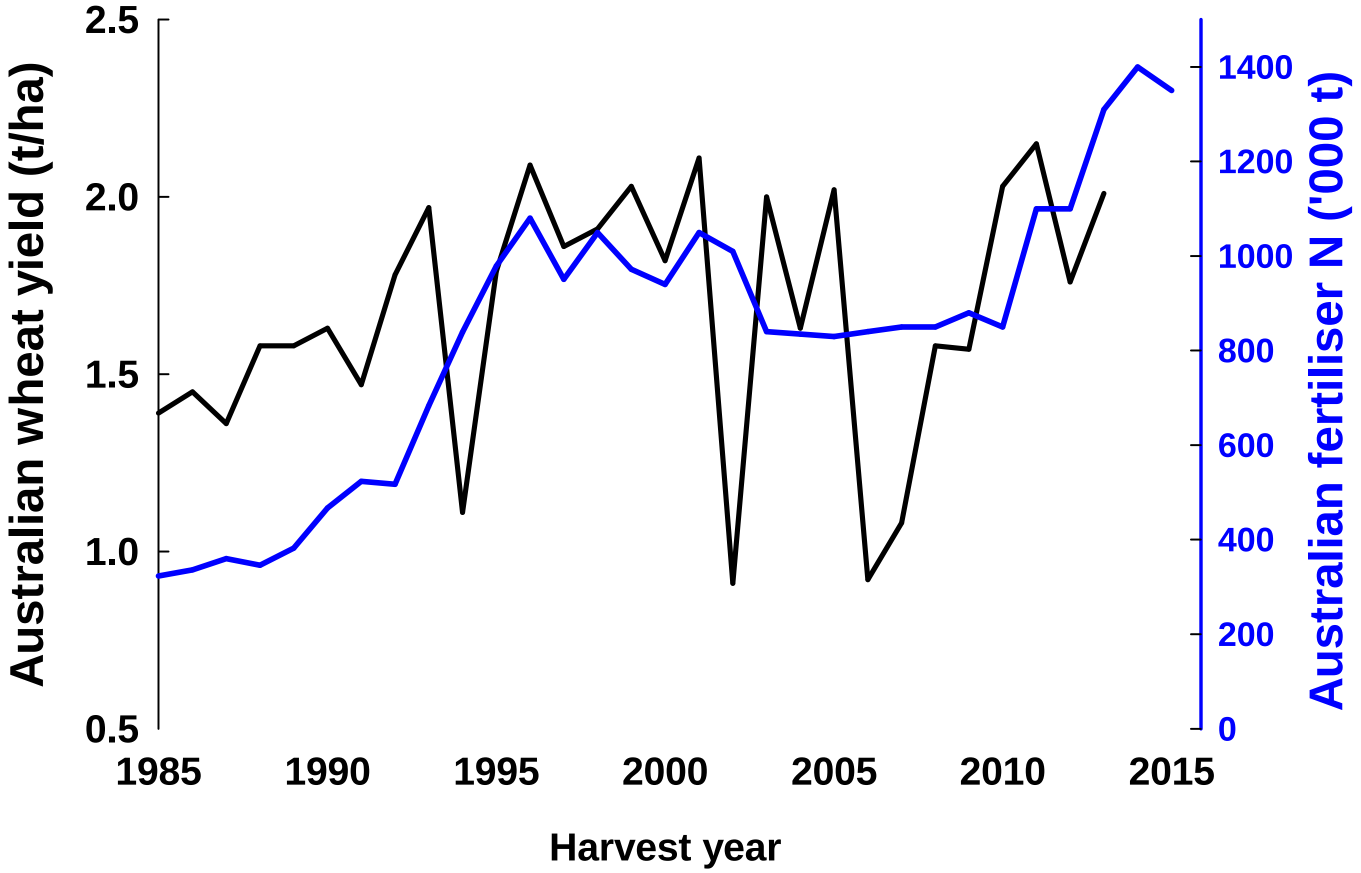
# $^{15}N$ fate in 57 Australian wheat experiments
# Averages: 44% crop, 34% soil, 22% loss



# 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**

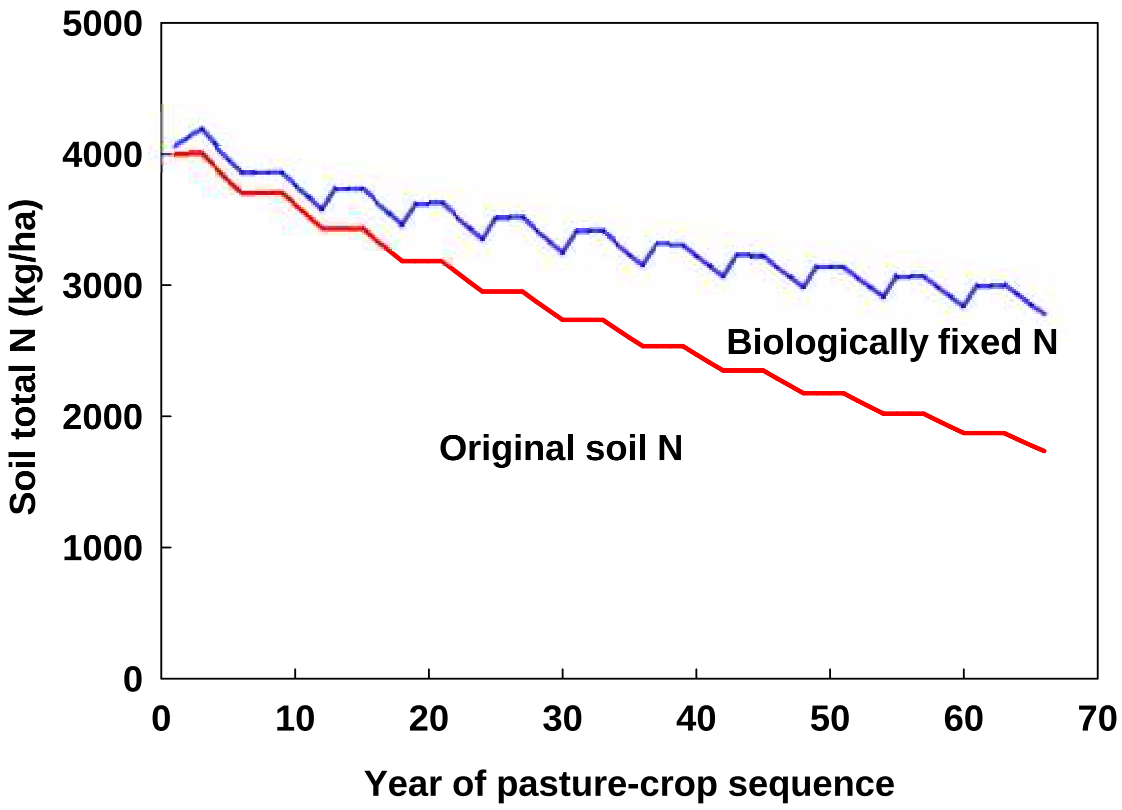
**AJ(BM1** Angus, John (Agriculture, Black Mountain), 04-Dec-16

# 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

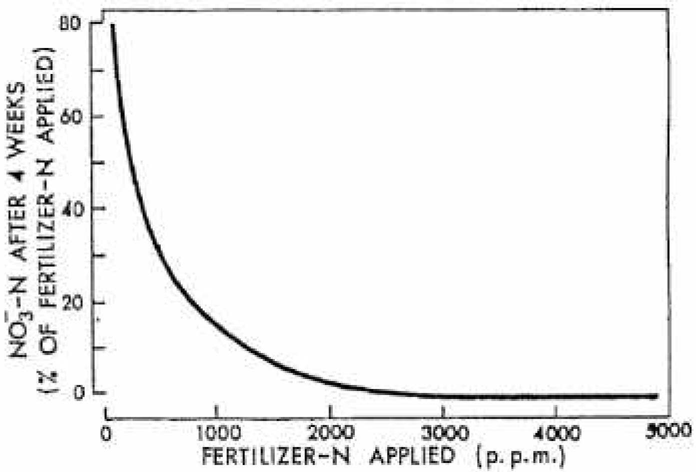
| | | kg N ha$^{-1}$ | Total (kgN ha$^{-1}$) |
|---|---|---|---|
| Crop N demand | Yield 2.1 t ha$^{-1}$ @ 10.5 % grain protein | 37 | |
| | Straw N (one-third of grain N) | 12 | |
| | Rhizodeposited N (34 % of total plant N) | 25 | 74 |
| | | | |
| N-supply | Fertiliser | 45 | |
| | Rain and dust | 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

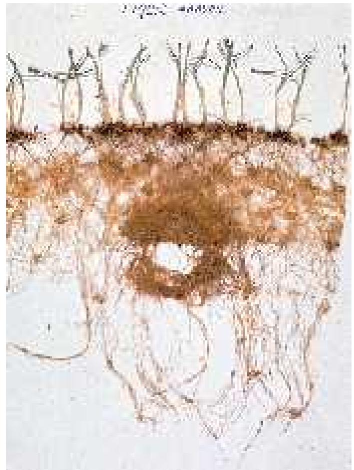
# What next for NUE research for dryland cropping?

- **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