Sustainable intensification of grains in SE Australia

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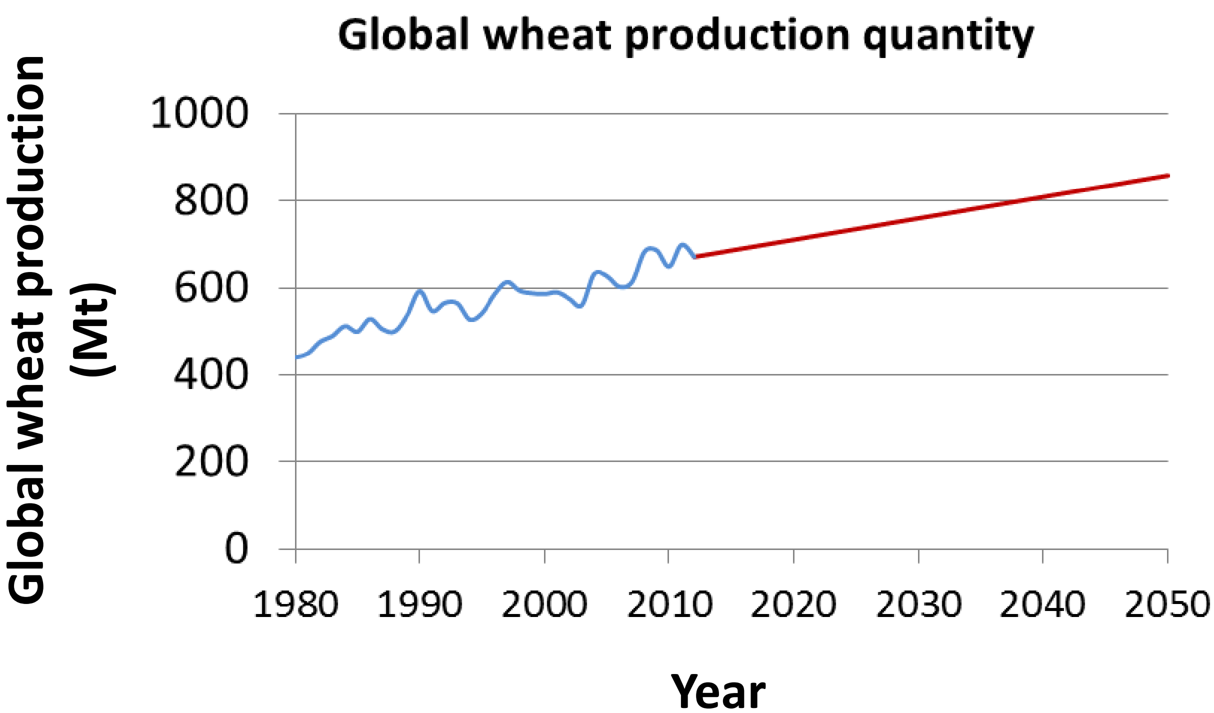
Global wheat production

FAO: Projected world wheat demand 2050



Fischer et al. 2014:

Year	Production (Mt)
2050	858

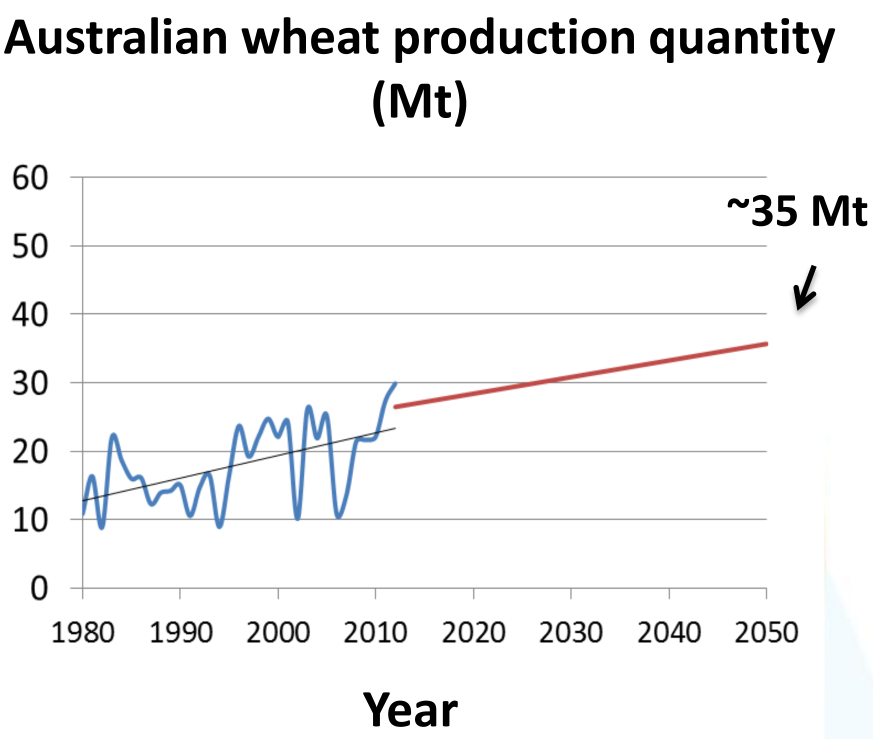
= ~ 40% increase from current

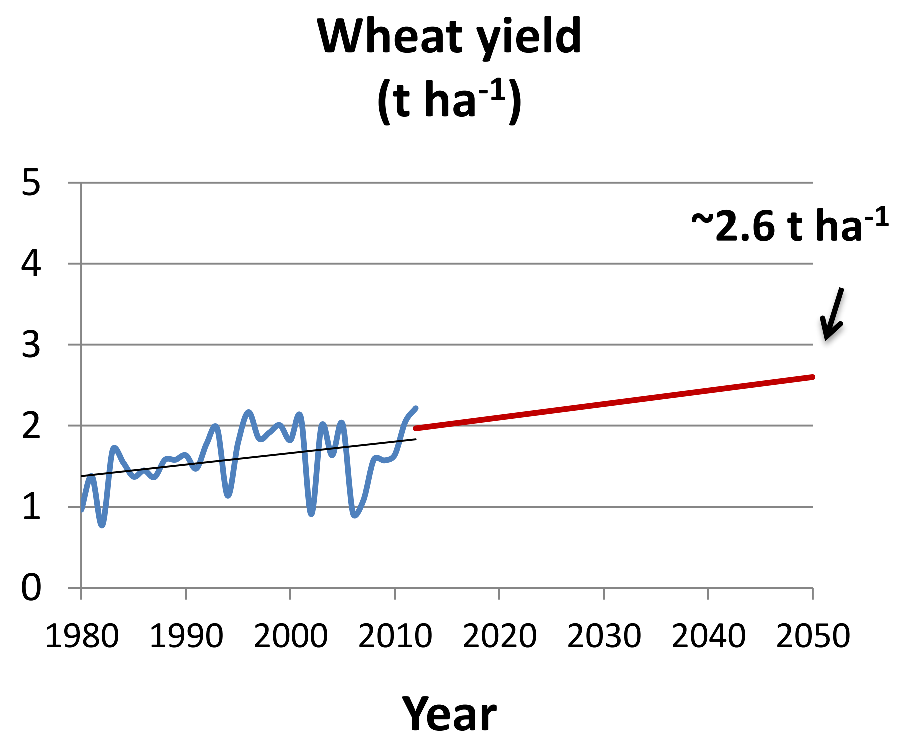
= ~ 1% per year*

* approximately same increase as in the past (~1% p.a.)

Source: FAOSTAT 2014

Wheat production - Australia





- Growth from current to 2050: approximately 1% per annum
- Previous growth: approximately 1% per annum

Source: FAOSTAT 2014

Productivity gains

Where does the 1% per annum increase come from?

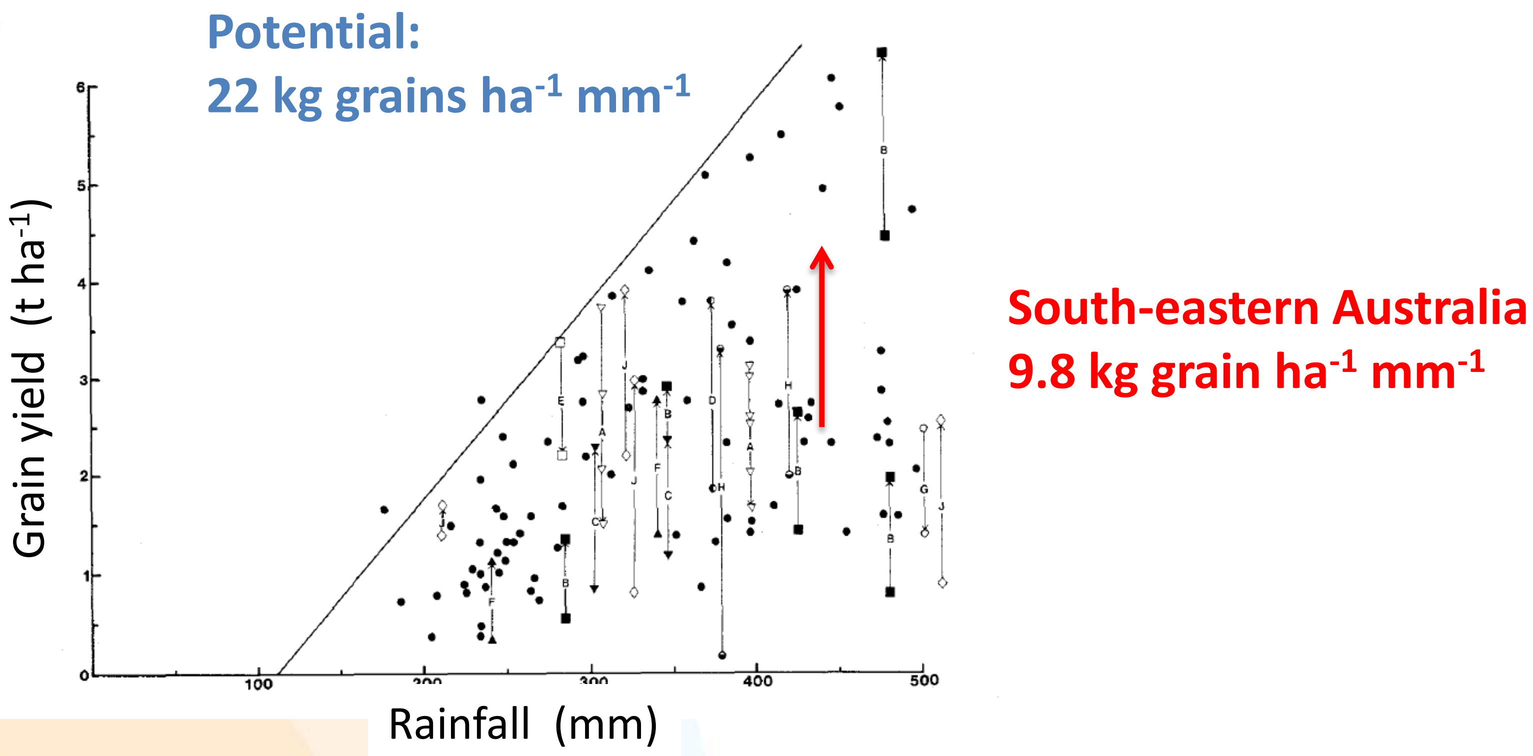
A combination of:

G x E x M

= **G**enetics x **E**nvironment x **M**anagement

Water

Sources: French and Schultz 1984, Sadras and Angus 2006



- ❑ Can we use genetics and management to reducing this gap?
- ❑ Which traits would we need to target?

Water

3. Trait: TRANSPIRATION EFFICIENCY

Increasing crops yields by,

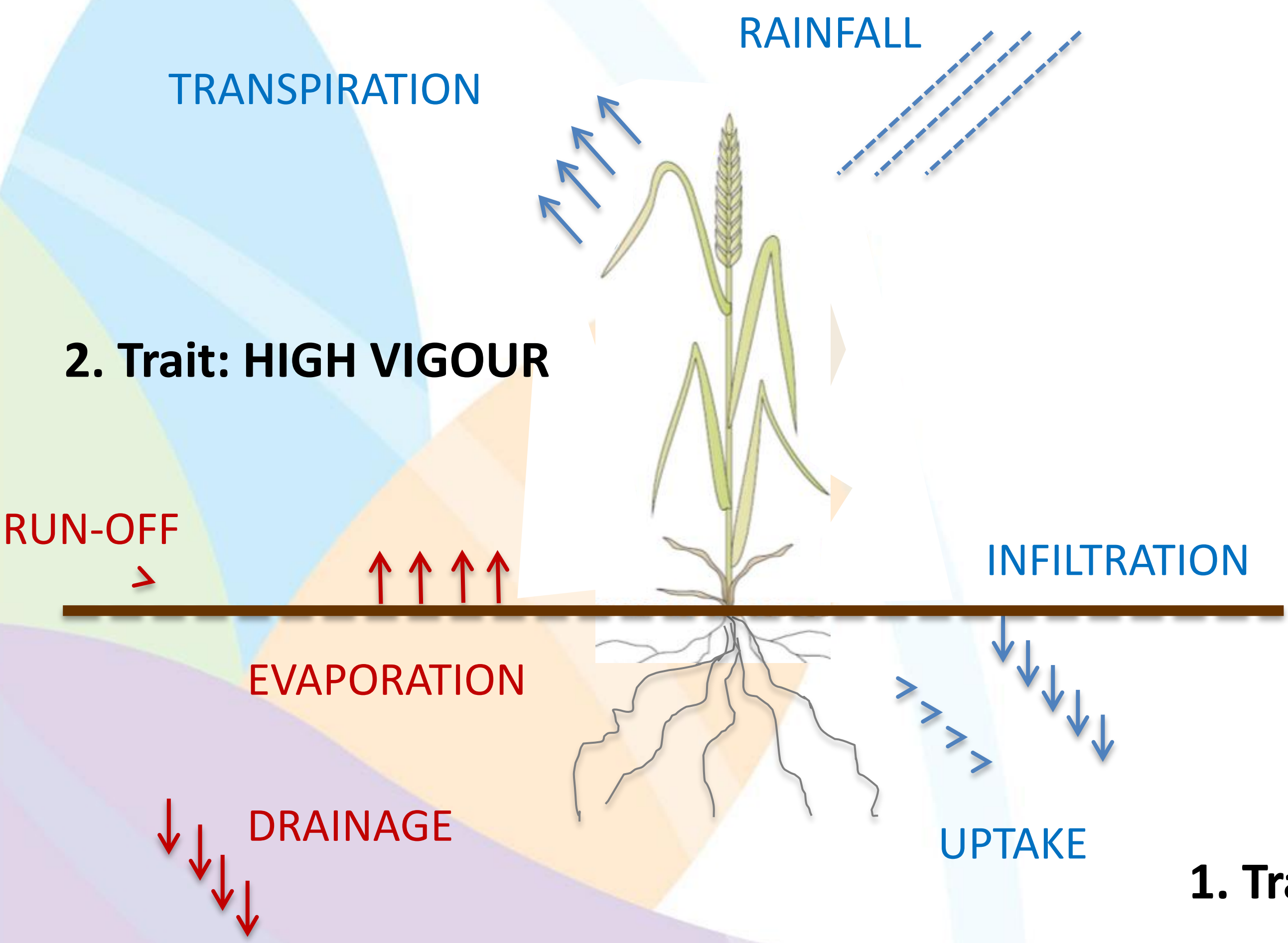
e.g:

(1) Increasing the capture of rainfall

(2) Increasing the proportion of water available for crop production

(3) Increasing the efficiency of water to usable product

(O'Leary et al. 2011)



1. Trait: ROOTS

Water

Roots:

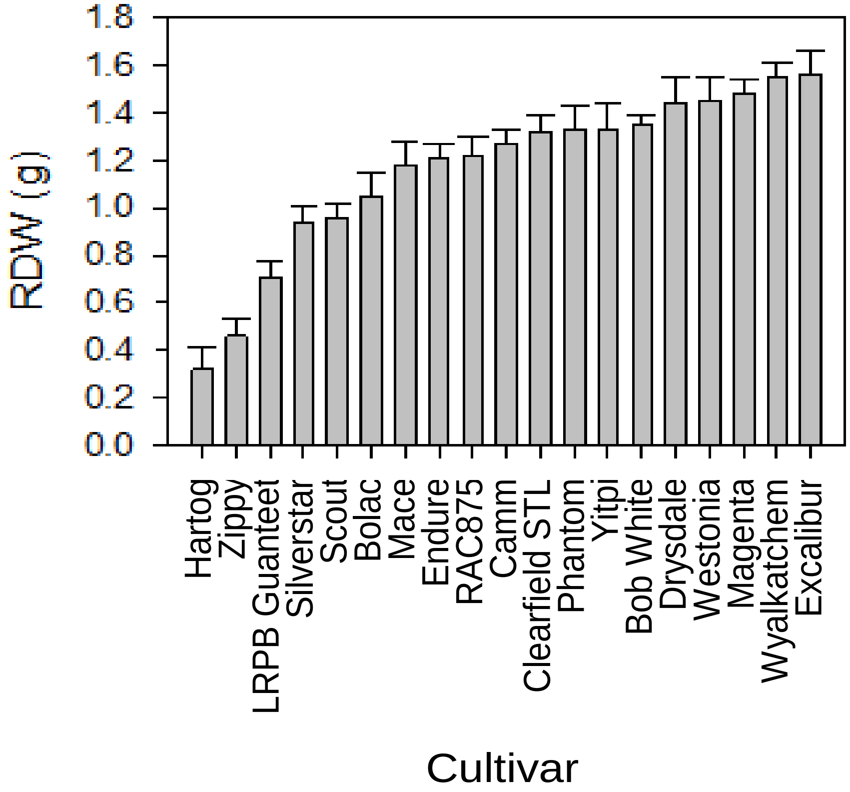
CSIRO PUBLISHING
www.publish.csiro.au/journals/ajar *Australian Journal of Agricultural Research*, 2007, **58**, 303–315

Source: Bahrami et al.

Impact of subsoil water use on wheat yield

J. A. Kirkegaard[A,B], J. M. Lilley[A], G. N. Howe[A], and J. M. Grah

- 10.5mm of additional subsoil water used after anthesis
- Increased grain yield by 0.62 t/ha
- Water-use efficiency up to 3 times greater
- **=relatively small amounts of subsoil water can be highly valuable to grain yield**



Water

High-vigour:

- Fast-growing
- Evaporation reduced
- Weeds outcompeted

Picture: CSIRO

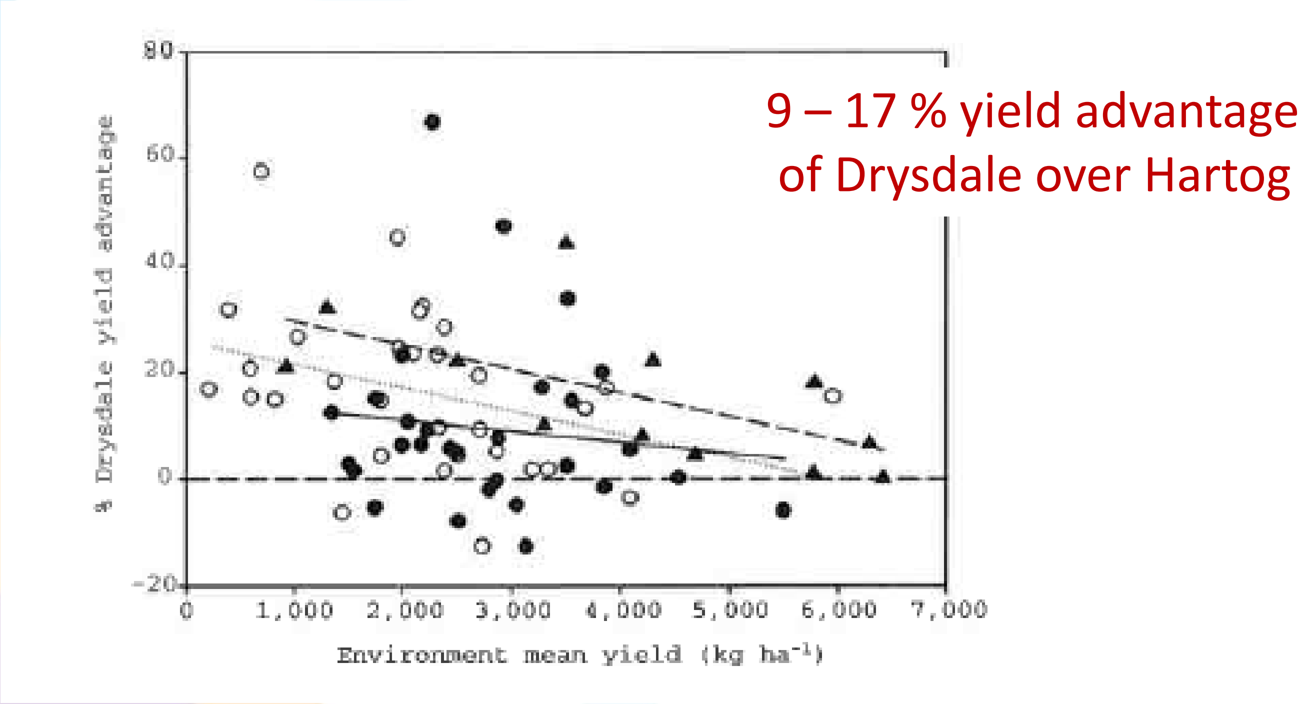
Botwright et al. 2002

Location	Vigour class	Leaf area index 50 DAS[a]	Anthesis biomass (g m^{-2})	Final biomass (g m^{-2})	Grain yield (g m^{-2})
Wongan Hills[b]	High vigour	0.37	453	678	337
	Low vigour	0.32*[c]	405*	573**	293***
Merredin[b]	High vigour	0.39	511	634	266
	Low vigour	0.30**	527n.s.	574**	247**

Water

2. Trait: IMPROVING TRANSPIRATION EFFICIENCY

- Acquiring more biomass (carbon) in exchange for the water transpired by the crop
- E.g. stomatal behaviour



Source: Rebetzke et al. 2009

Nutrients

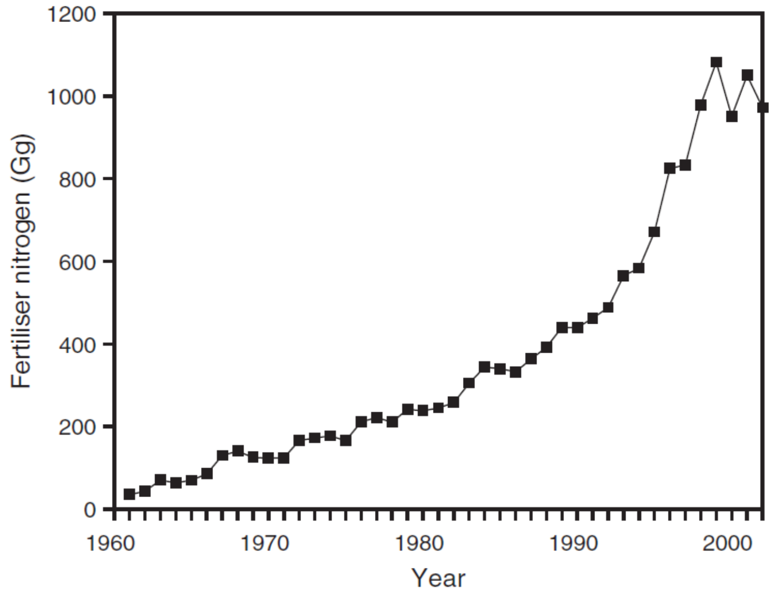


Fig. 1. Fertiliser used in Australia during the period 1960–2002.

1960 – 2000, Australia:

- N fertiliser use has increased from ~35 Gg to ~1000 Gg
- Most of this N is used for growing cereals
- Efficiency is low: for example in wheat only about 40% of the N was assimilated

Optimising fertiliser use through:

- ***Best agronomic management***
- ***Improved germplasm for greater efficiency***

Source: Chen et al. 2008

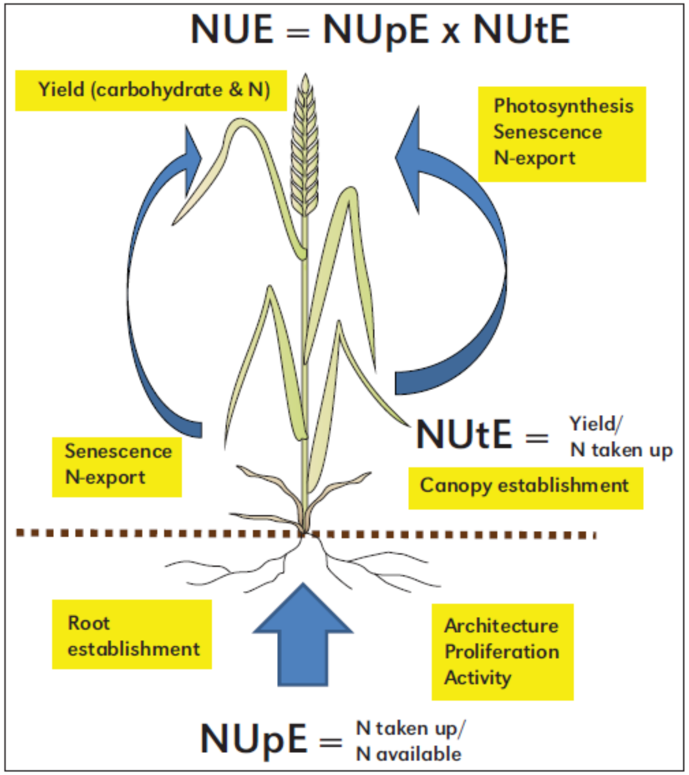
Nutrients

UTILISATION EFFICIENCY:

- ❑ Maximise leaf photosynthetic capacity per unit N
- ❑ Increase radiation interception per unit nutrient uptake
- ❑ **Optimise N remobilisation (e.g.** 69% of the N in heads from remobilisation Palta and Fillery 1993)

UPTAKE EFFICIENCY:

- ❑ Vigorous root systems capture N early when most vulnerable to loss (Palta and Watt 2009)
- ❑ Deeper roots to retrieve leached NO_3



Source: Hawkesford 2012

Climate change

How will future climates impact on future grain production in Victoria and southern Australia?

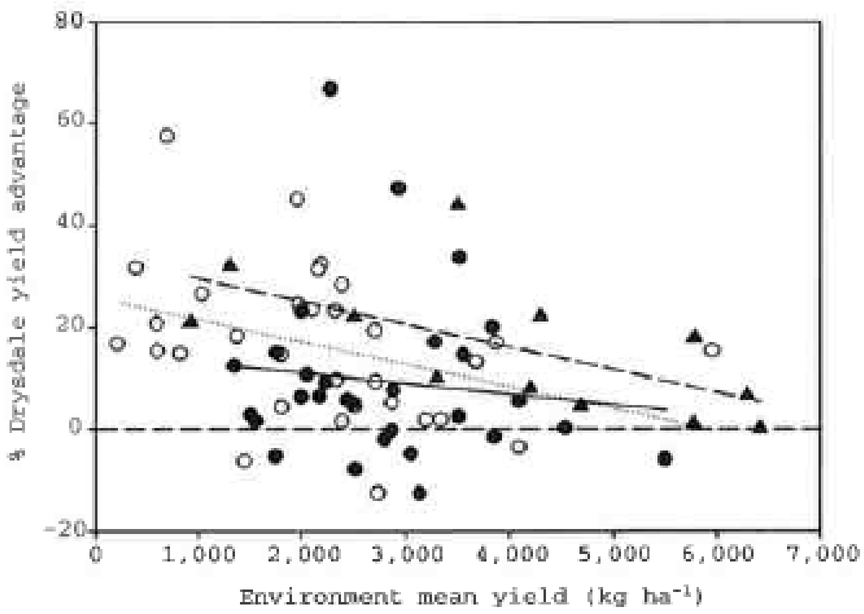
- Warmer temperatures, greater evaporation
- More extreme events
- Changed rainfall patterns
- Increased atmospheric CO_2 concentrations

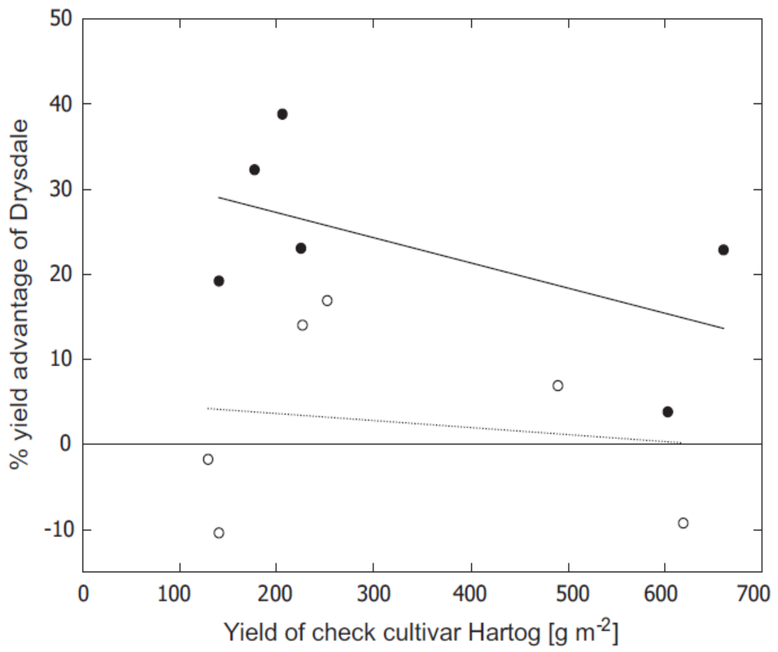
Threats and some opportunities

Effects of Elevated CO_2 on Grain Protein and Nutrients

	% Change Selected AGFACE data	% Change International comparison
Biomass ↑	~18% (Tausz-Posch et al. Field Crops Research 2012)	~20% (Ainsworth and Long New Phytol 2005)
Yield ↑	~18% (Tausz-Posch et al. Field Crops Research 2012)	~17% (Ainsworth and Long New Phytol 2005)

Climate Change





Source: Rebetzke et al. 2009

Source: Tausz-Posch et al. 2012

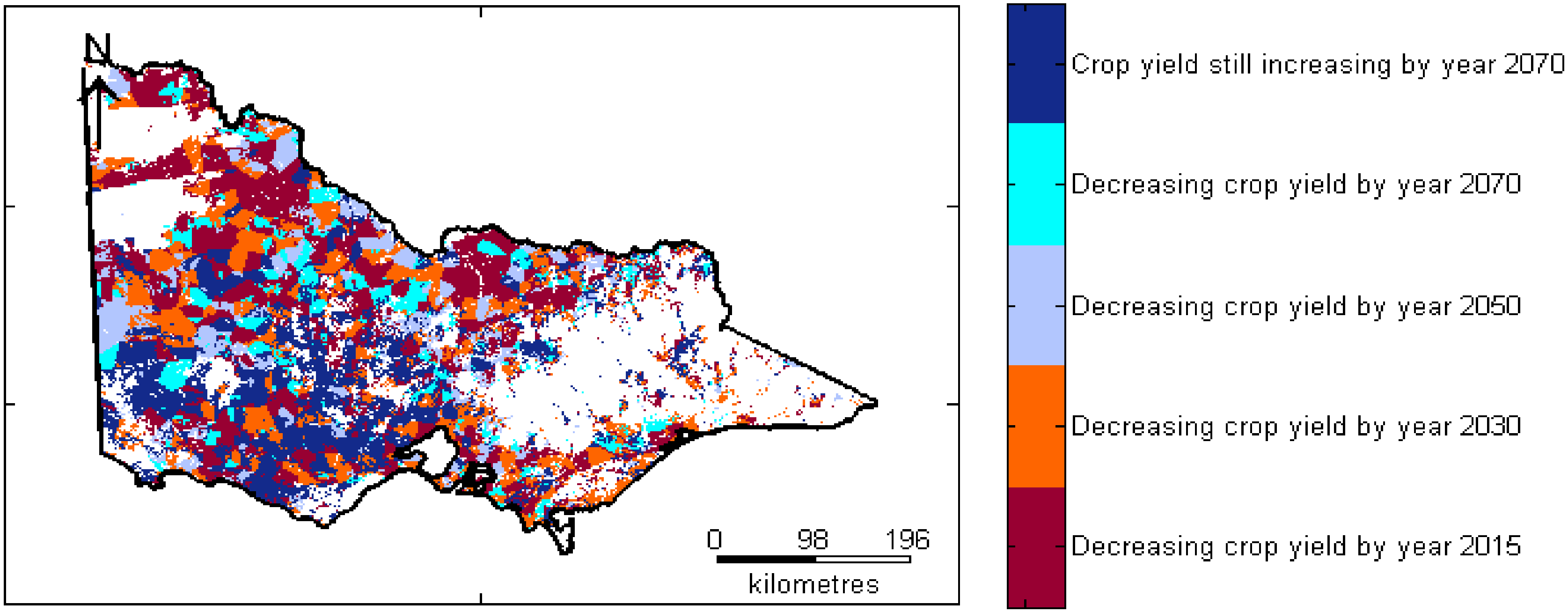
- Choosing traits with the greatest CO_2 responsiveness

Summary: G x E opportunities

Genetic gain under drought will benefit from multidisciplinary skills such as, for example:

- Rapid cost-efficient phenotyping
- Improved physiological understanding
- Molecular techniques aimed at more efficient screening
- Use of simulation models

Wheat yield Prediction under future climates



CSIRO A1Fi CCAM Mark 3 present-day long-season cv.
Includes eCO_2, temperature, soil type

- Landscape "clumpiness" due to soil type by rainfall interactions
- Southern region (HRZ - dark blue) yields still increasing in 2070

O'Leary et al., 2011

Nitrogen supply in future climates

- Increased amount of N fixed by pulses (but % Ndfa unchanged)

CO_2 treatment	Dry matter (g/core)	N uptake (g/core)	Ndfa (%)	N fixed (g/core)
		(i) Walpeup		
Ambient	32.6	0.71	49.9	0.379
eCO_2	28.1	0.58	58.9	0.334
		(ii) Horsham		
Ambient	60.1	1.33	55.0	0.451
eCO_2	96.0	1.95	64.6	0.995
		(iii) Hamilton		
Ambient	47.1	1.02	9.1	0.081
eCO_2	57.7	0.96	10.7	0.063
		ANOVA		
CO_2	0.06	n.s.	n.s.	n.s.
Soil type	< 0.001	< 0.001	<0.001	0.001
CO_2 x soil	0.039	0.06	n.s.	0.038

Management

G * E * M

- 80% of variability in WA wheat yields can be explained by:
  E = 80% ; M = 6% and G = 3%
  (Anderson et al 2010 FCR **116**, 14-22)
- 1884 – 1982: most gains in WA & SA wheat yields via breeding but 2/3rds of subsequent yield increase via management
  (Turner & Asseng 2005 AJAR 56, 1123-1136)

Improved Management

- Rotation options (overcoming disease and weed/pest control)
- Reduced tillage (better rainfall infiltration & soil structure)
- Improved nutrition (fertilisers and legume rotations)
- More timely management e.g. sowing via larger machinery and GPS
- Herbicides

Increasing productivity in the Australian grain production since 1840

D.J. Connor / Europ. J. Agronomy 21 (2004) 419–431

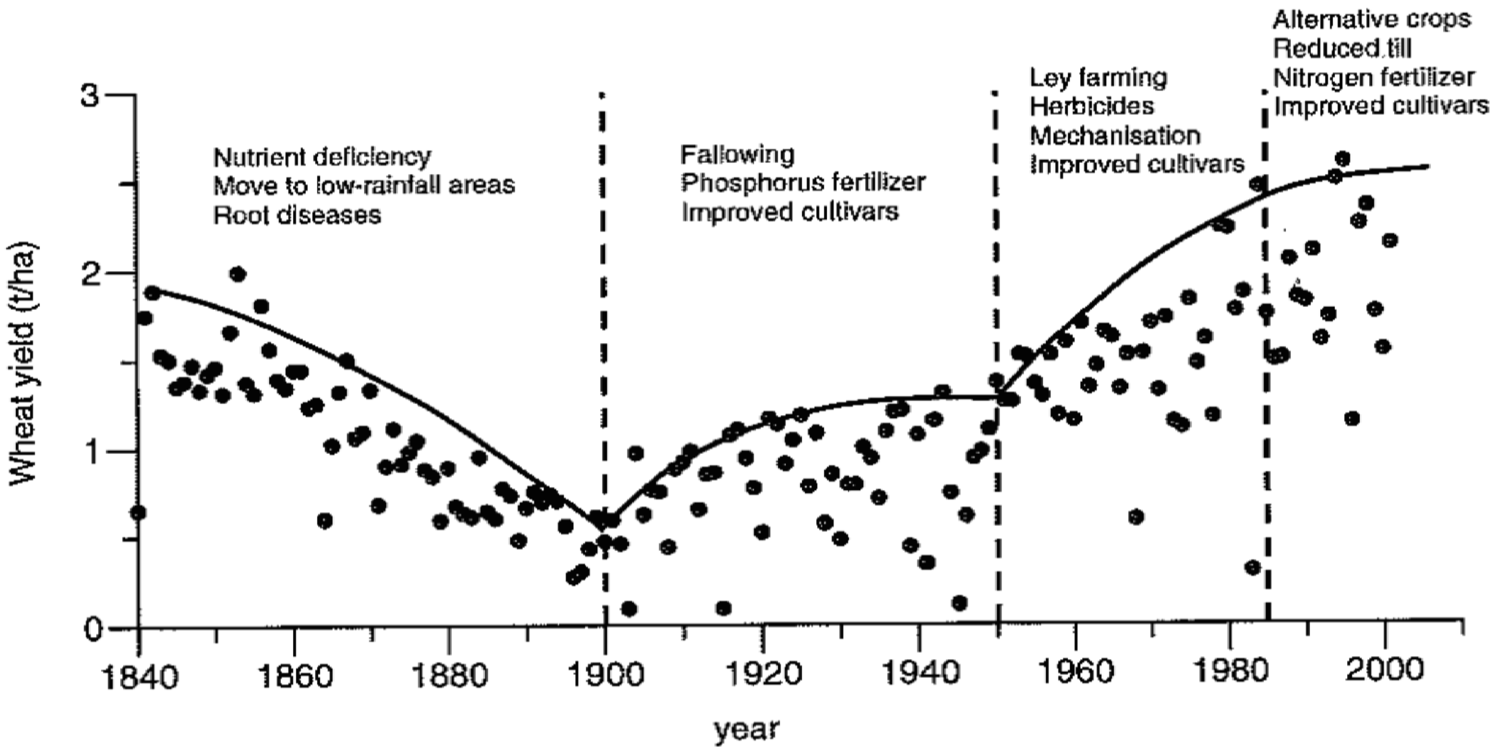


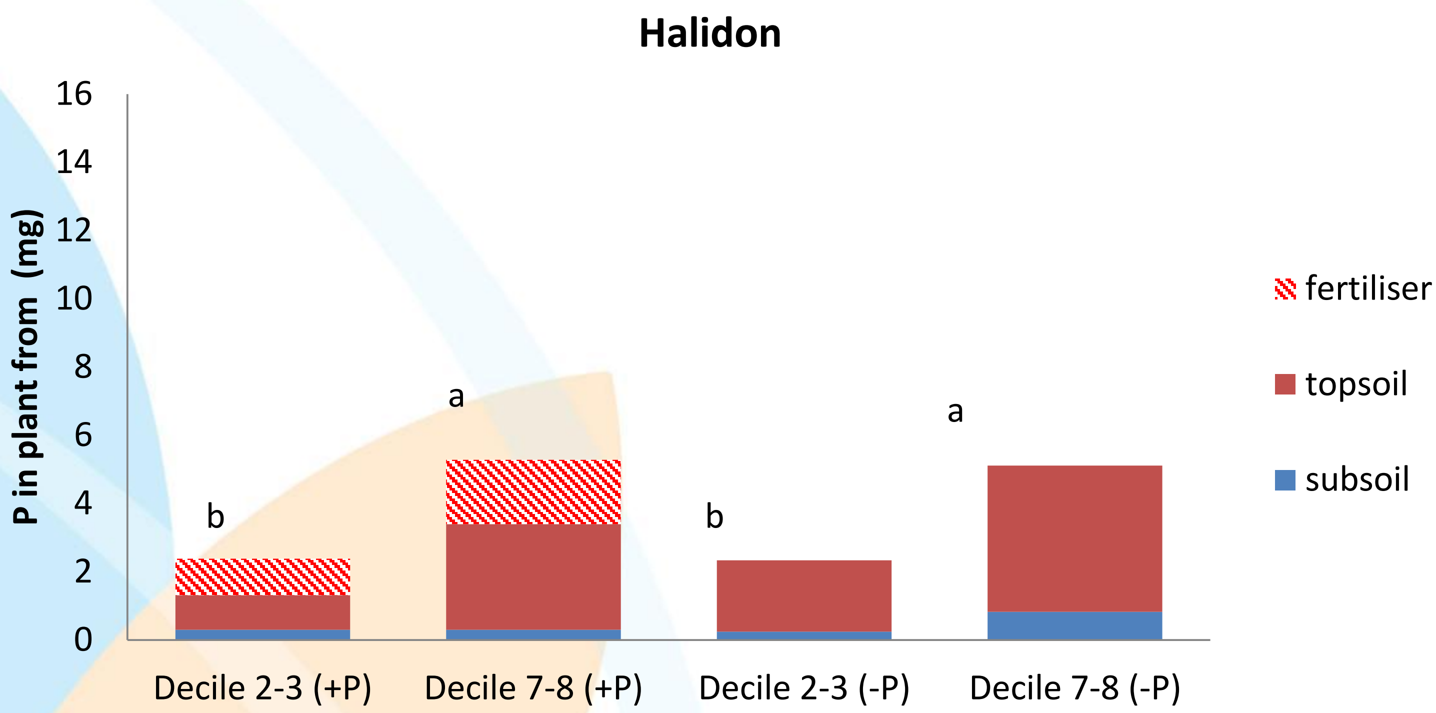
Fig. 1. Cropping strategies and yield in the development of the wheat industry in the State of Victoria, Australia.

Nutrient Use Efficiency
Where Australia sits internationally

Region	Cereal PFP kg grain / kg N	Cereal PNB kg N / kg N
Australia	52	0.82
North America	45	0.68
SS Africa	123	1.89
East Asia	32	0.46
World	44	0.66

Source: R Norton (IPNI)

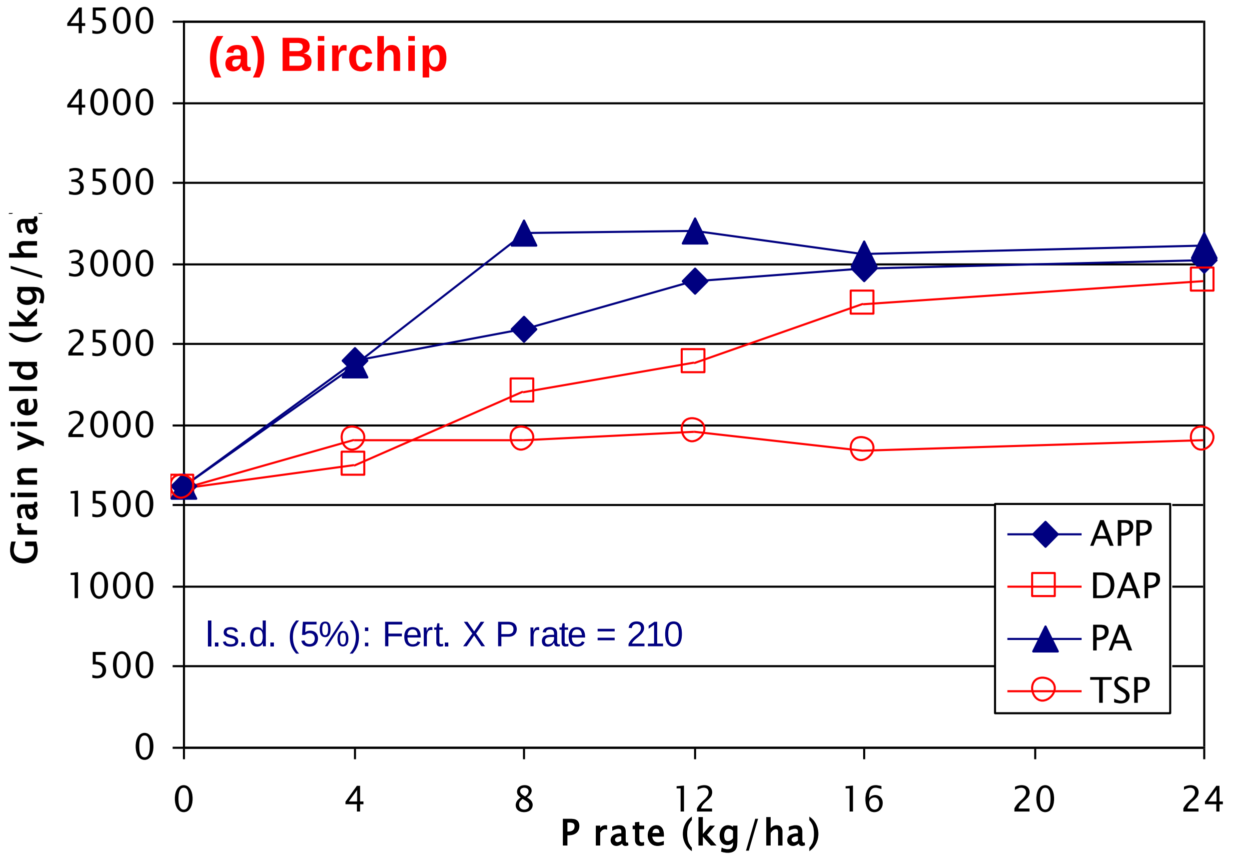
Plant use of Fertiliser, Topsoil and Subsoil P



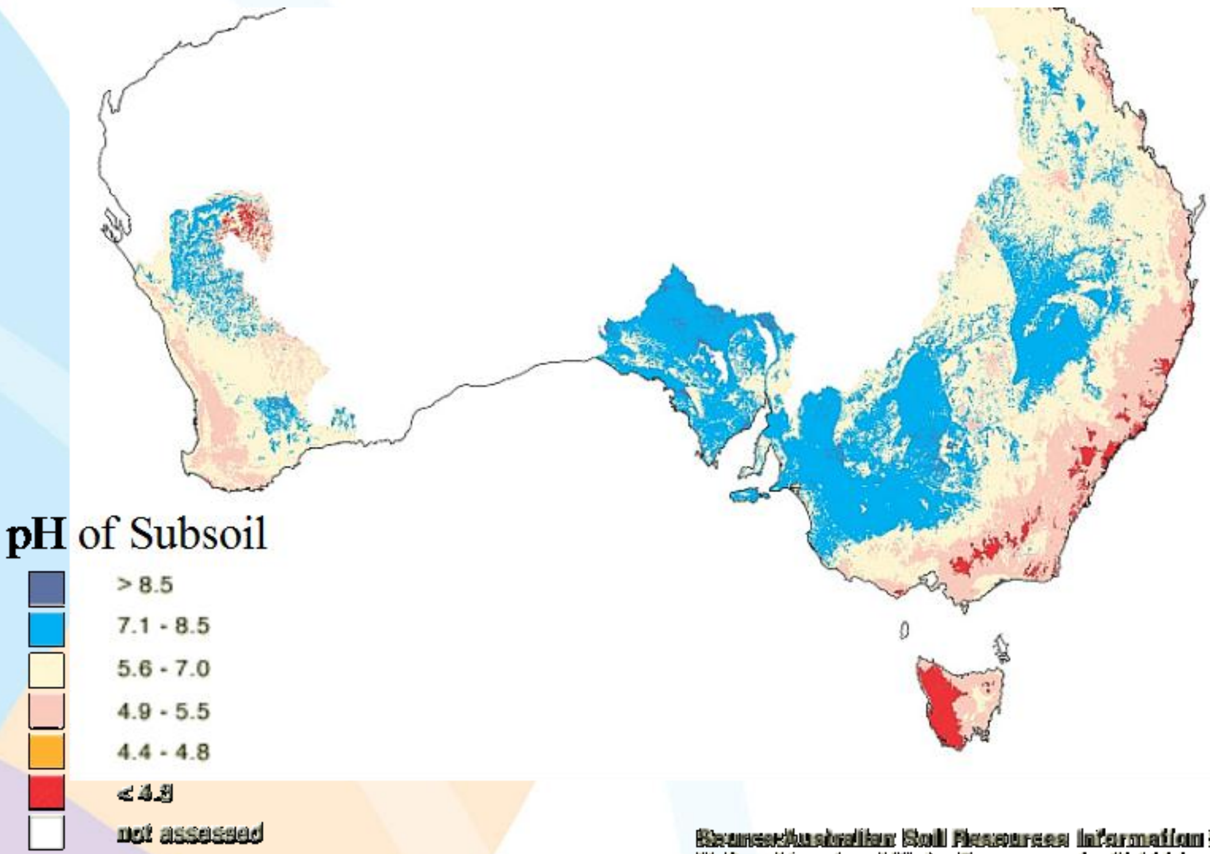
- Very small proportion of crop P derived from fertiliser (< 30% ; average ca. 15%)

Source: Mcbeath et al (2012)

Different fertiliser formulations can improve nutrient use efficiency (but rarely cost effective)

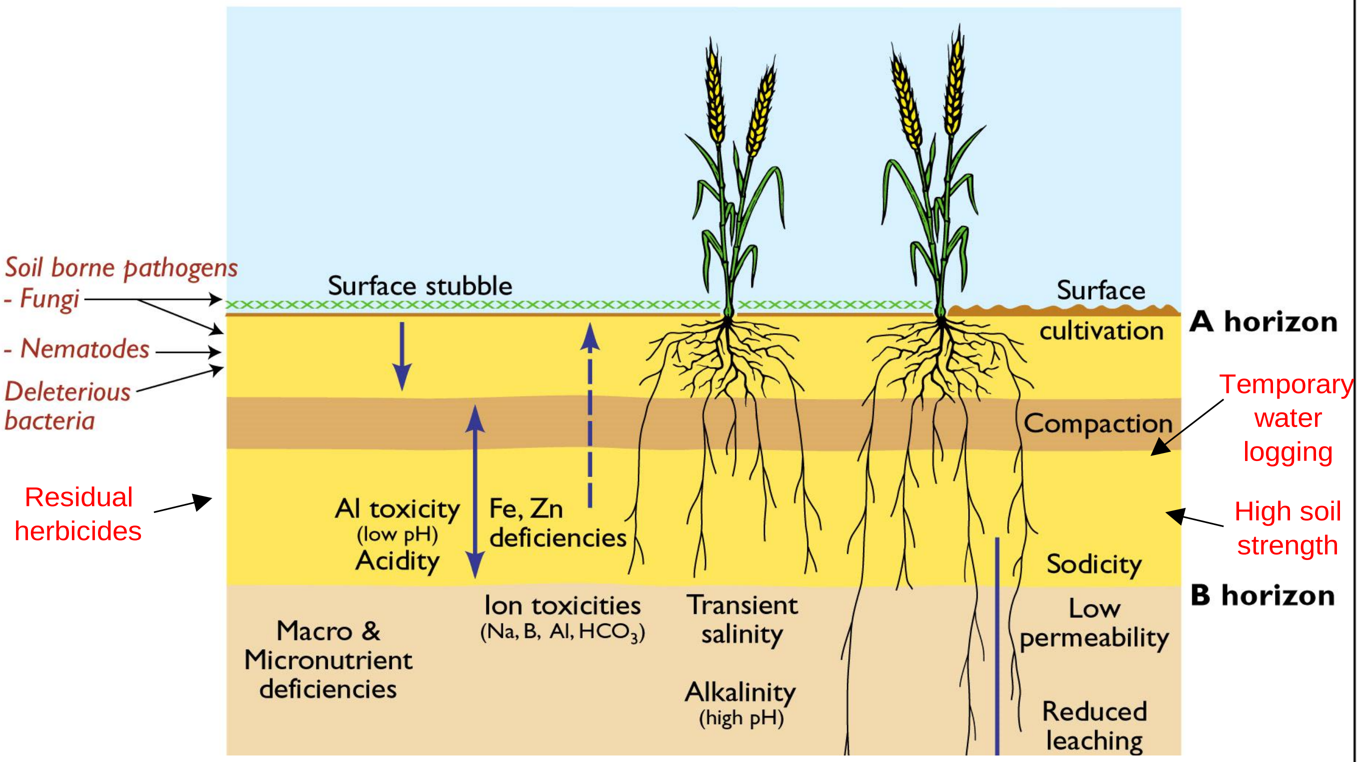


Australian grain production is already significantly limited by poor soil fertility (chemical , physical and biological)



Source: Australian Soil Resources Information System, National Land and Water Resources Audit 2001

Rootzone Soil Constraints- Physical, Chemical and Biological

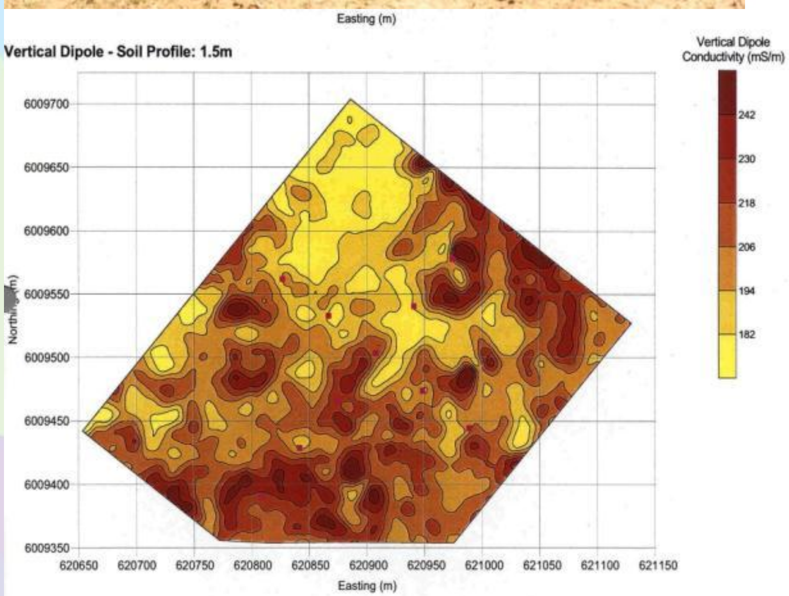


Source: © Rengasamy et al. (2003). *Plant & Soil* **257**, 249-260. With kind permission of Springer Science.

profitable subsoils group

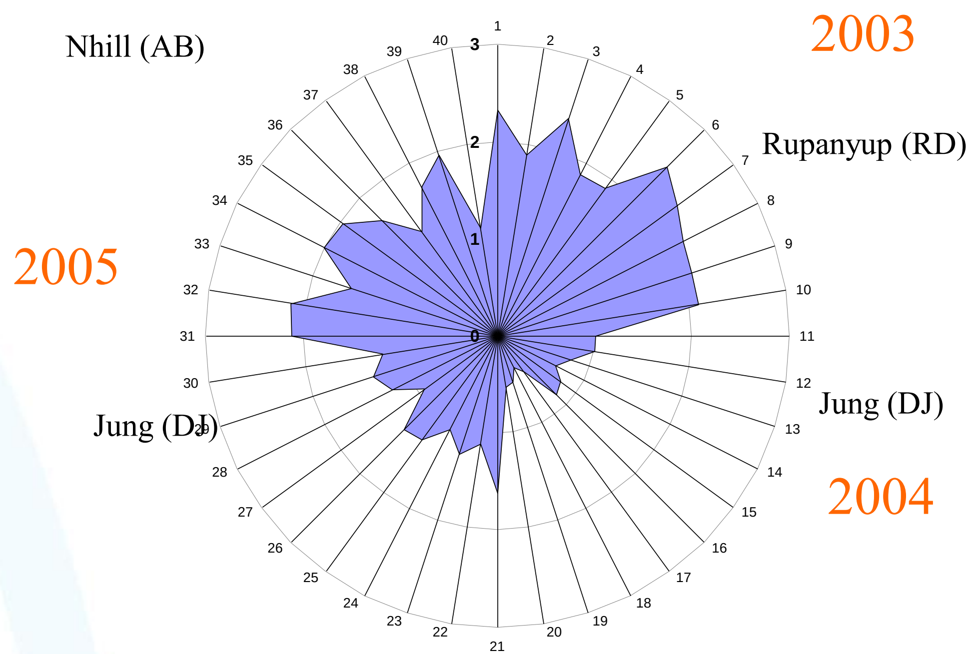
GRDC Grains Research & Development Corporation

Management challenges: Soil constraints



Managing high spatial and temporal variability

Grain yield of lentil



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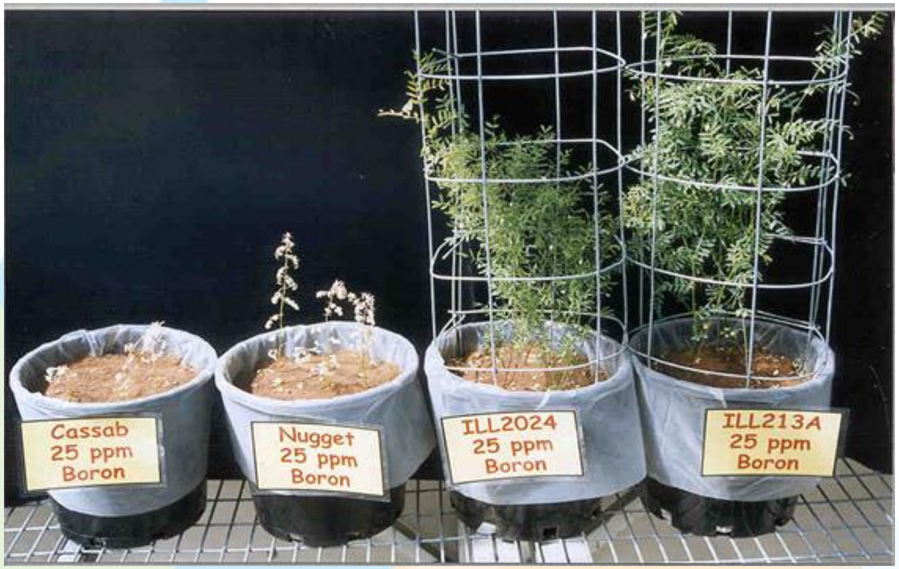
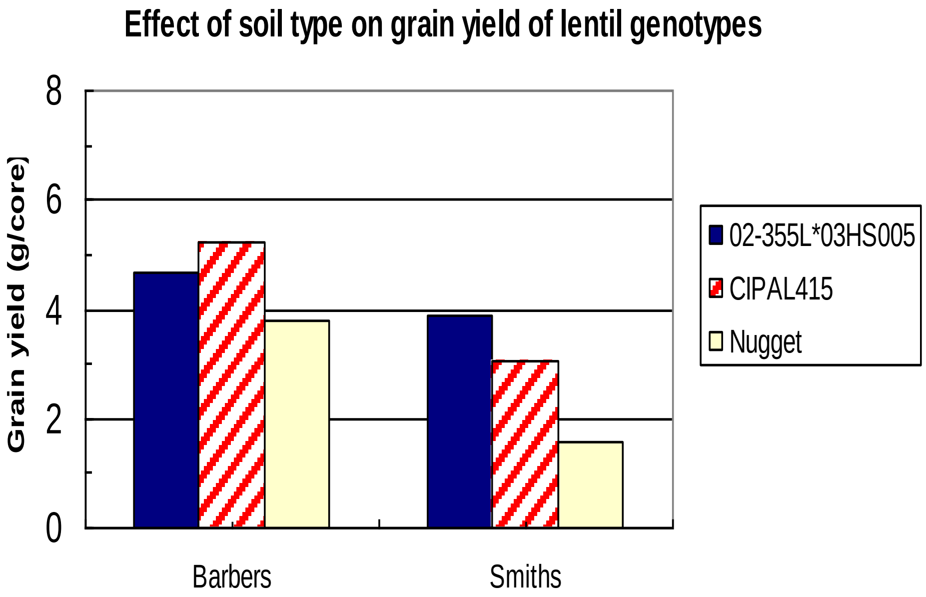
Genetic solutions to subsoil constraints





Genetic solutions rely on knowing what are the main constraints

New technologies to improve management

- Greater access to data/knowledge (e.g. Internet/ E-Agriculture)
- Remote sensing / micro-sensors (real time information)
- Understanding G * E * M - Better targeting of constraints that impact on Australian growers (cf. those in Europe and North America)
- Robotics (Labour saving)
- Weather & Seasonal forecasting

But:

- Profitability ($) rules, not greater production *per se*.
- Focus on value of production (less produce sold at higher prices)
- Increased energy / transport costs - access to O/S markets
- Intensification implies greater **risk** e.g. high yielding crops require greater inputs e.g. fertiliser N
- Greater management skill required
- Need for greater resilience (especially for extreme climate events)
- Consolidation of enterprises (e.g. larger corporate farms?) : political and social implications

Most issues require political & social solutions, not just better technology

Thank you

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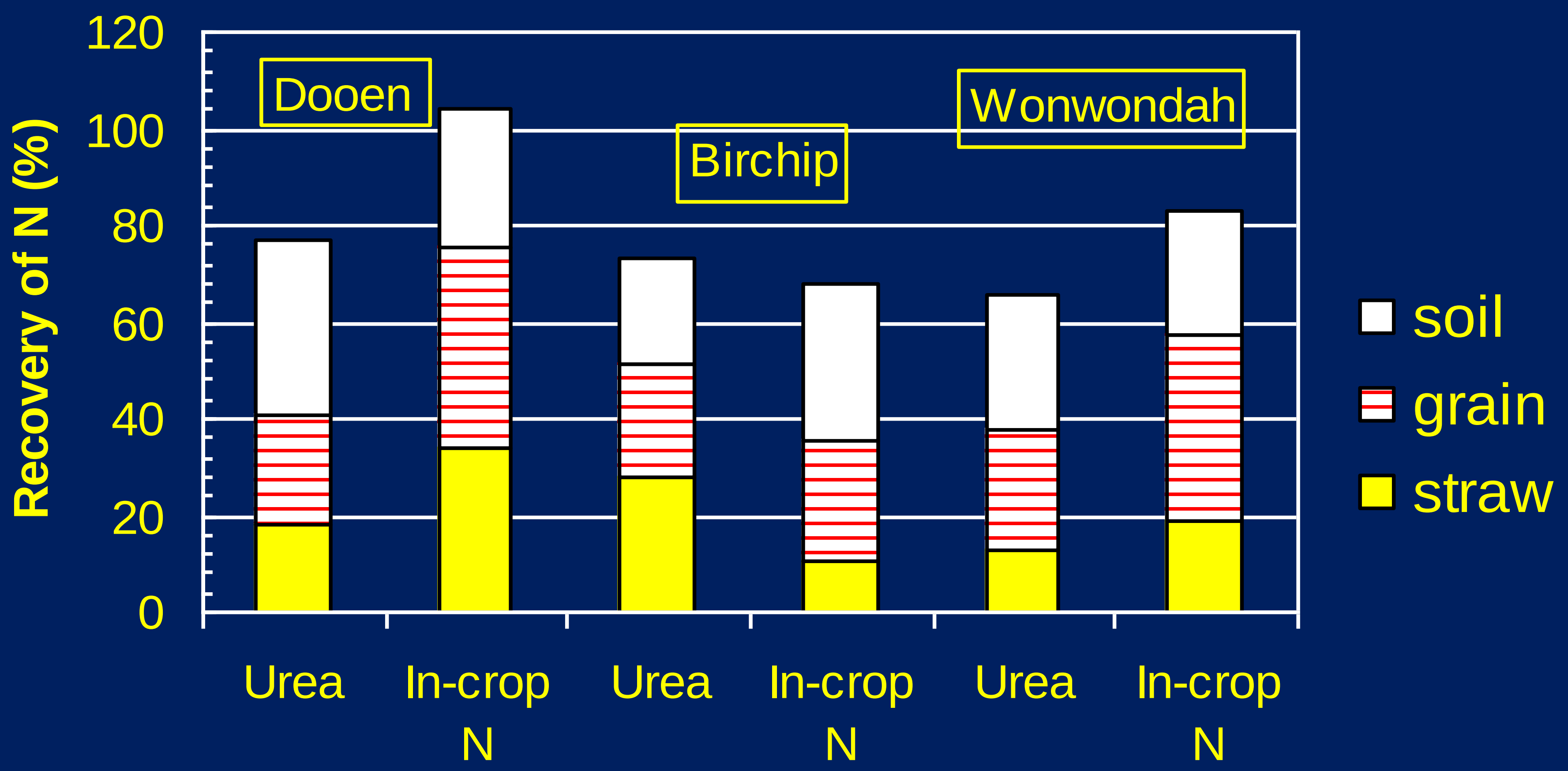
Department of Environment and Primary Industries

Direct assessment of crop utilisation and recovery of ^{15}N labelled urea at 3 sites of NW Victoria (1998)



SoilFACE

	0-10 cm	0-10 cm	80-100 cm	80-100 cm
	Total N(%)	pH ($CaCl_2$)	pH ($CaCl_2$)	EC (dS/m)
Hamilton	0.403	4.5	6.8	0.16
Horsham	0.083	7.7	8.3	1.85
Walpeup	0.052	5.9	8.6	0.53

Mallee Calcarosol (MP4)

Wimmera Vertosol

Hamilton Chromosol (PV13)

Increases in productivity over the past 60 years

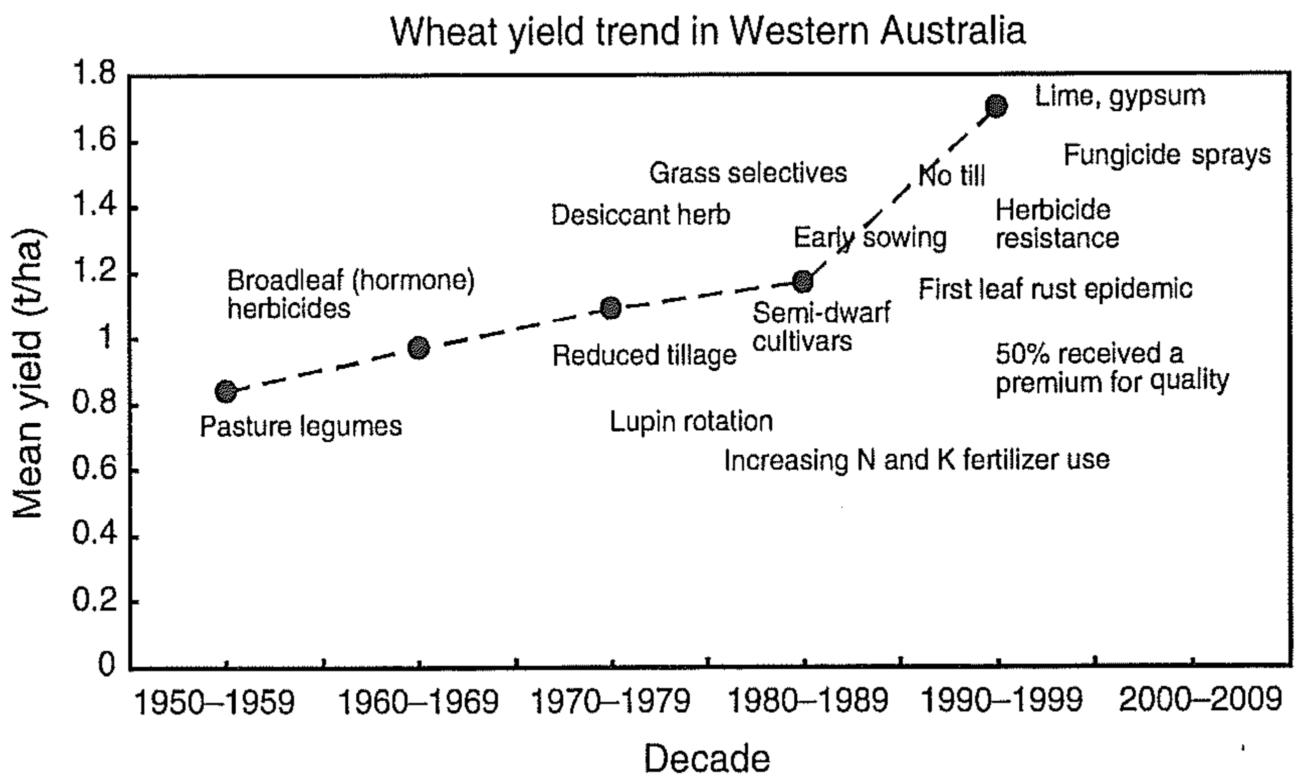


Fig. 1. Average wheat yields in Western Australia by decades 1950/59–1990/1999, showing various management practices adopted over the period. Data from Australian Bureau of Statistics.

Source: Anderson et al (2005) AJAR 56, 1137-1149