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# Meeting the productivity and sustainability challenges to Australian agriculture

**CSIRO Sustainable Agriculture Flagship**


**Peter Carberry**

**Deputy Director**


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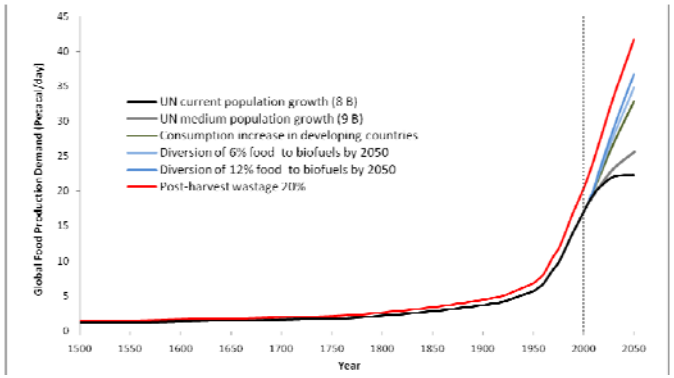
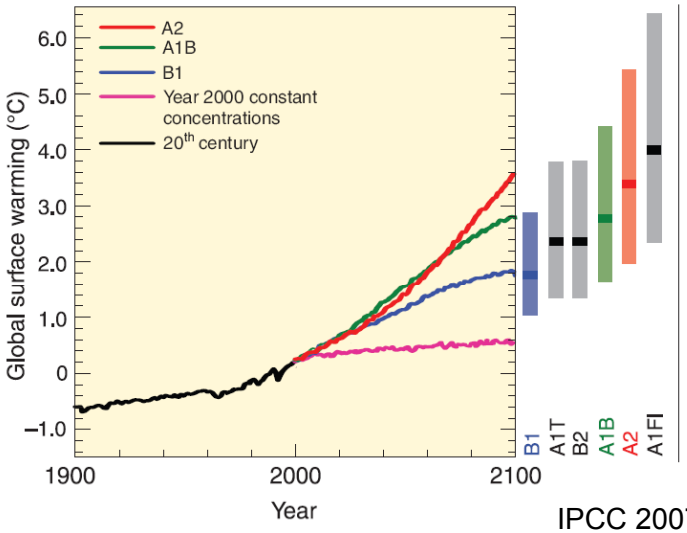
# Global challenges

- Raising agricultural productivity to ensure global food security
- Reducing greenhouse gas emissions to ensure climate security
- Adapting to unavoidable climate change
- Protecting the environment




Demand for global food production

Keating *et al. in review.*




IPCC 2007

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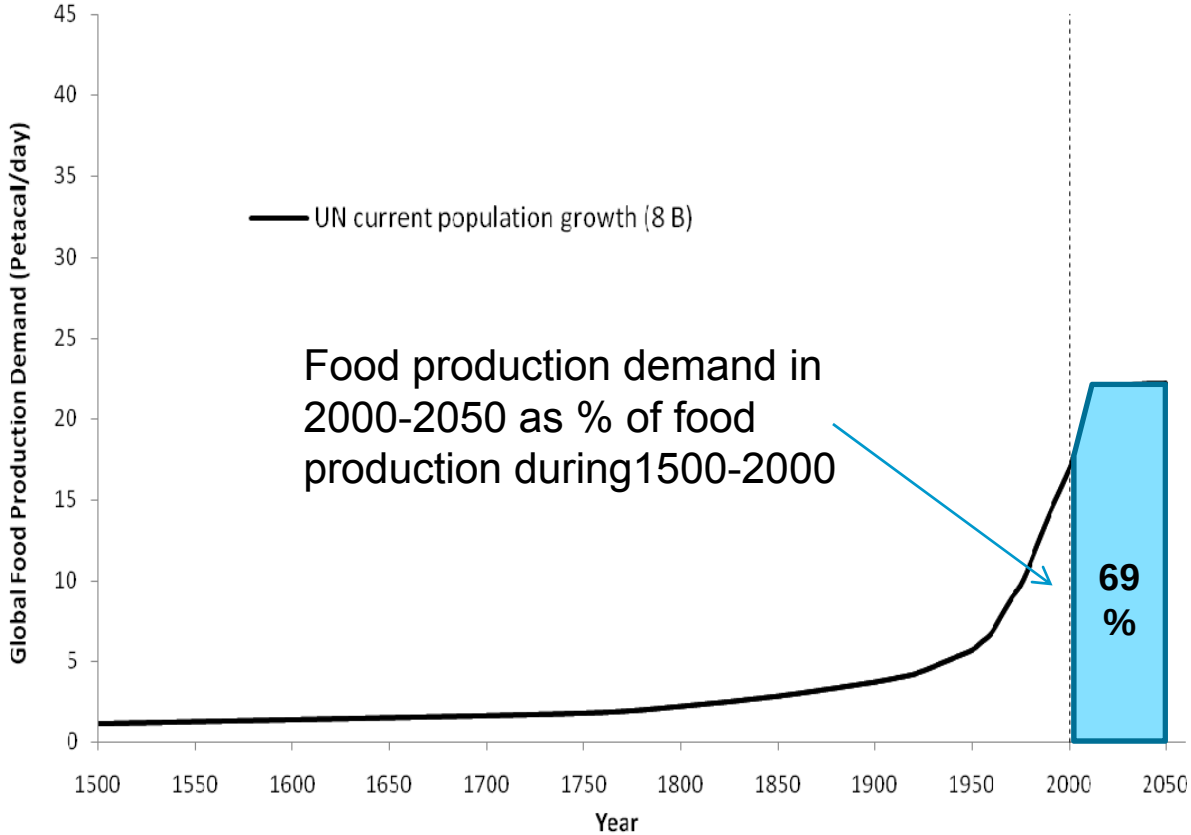
# Demand for global food production
## - 8 billion people in 2050




**The demand for global food production over the period 1500 to 2050 for additive scenarios.**
Global food production demand is an estimate (in Petacal) of the food production demand driven by population growth and consumption increases associated with economic development. Some scenarios also include a food production demand equivalent associated with either food or land diversion to biofuels and post-harvest wastage. Citation: Keating et al 2010 (in review).

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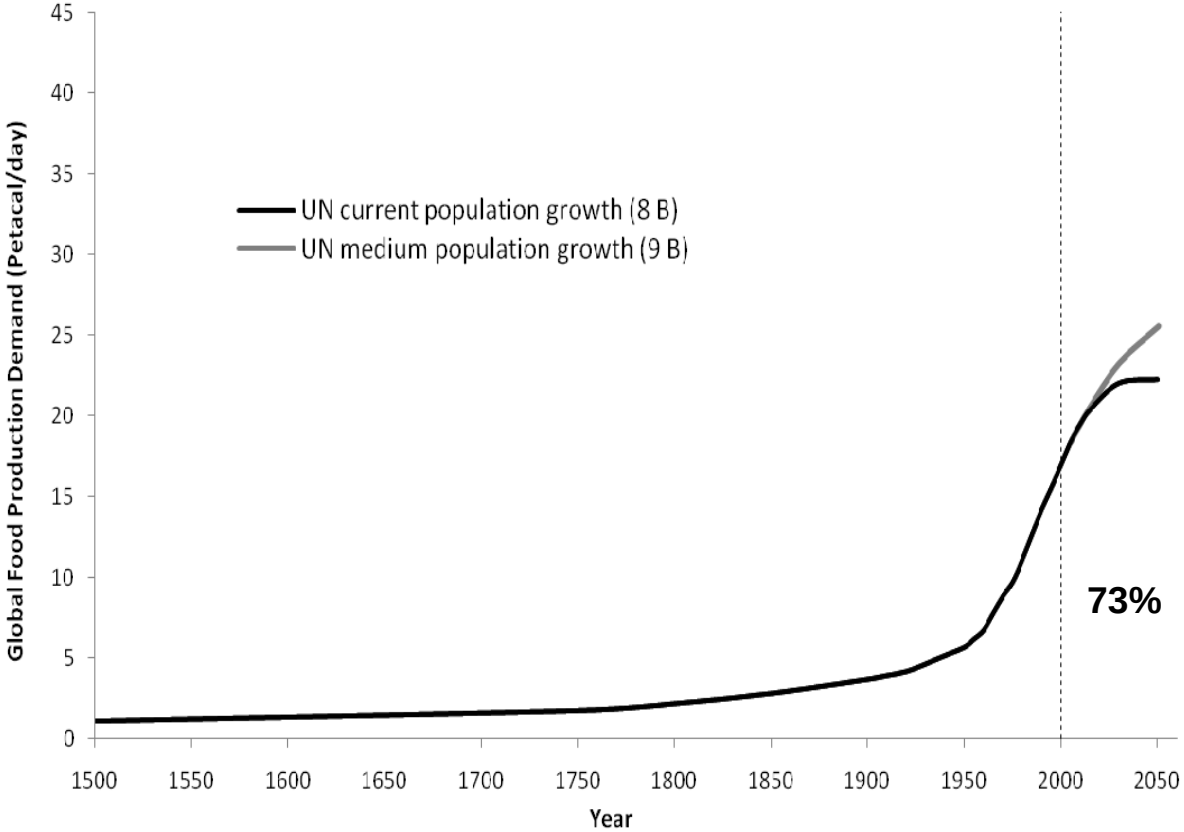
# Demand for global food production
## - 9 billion people in 2050

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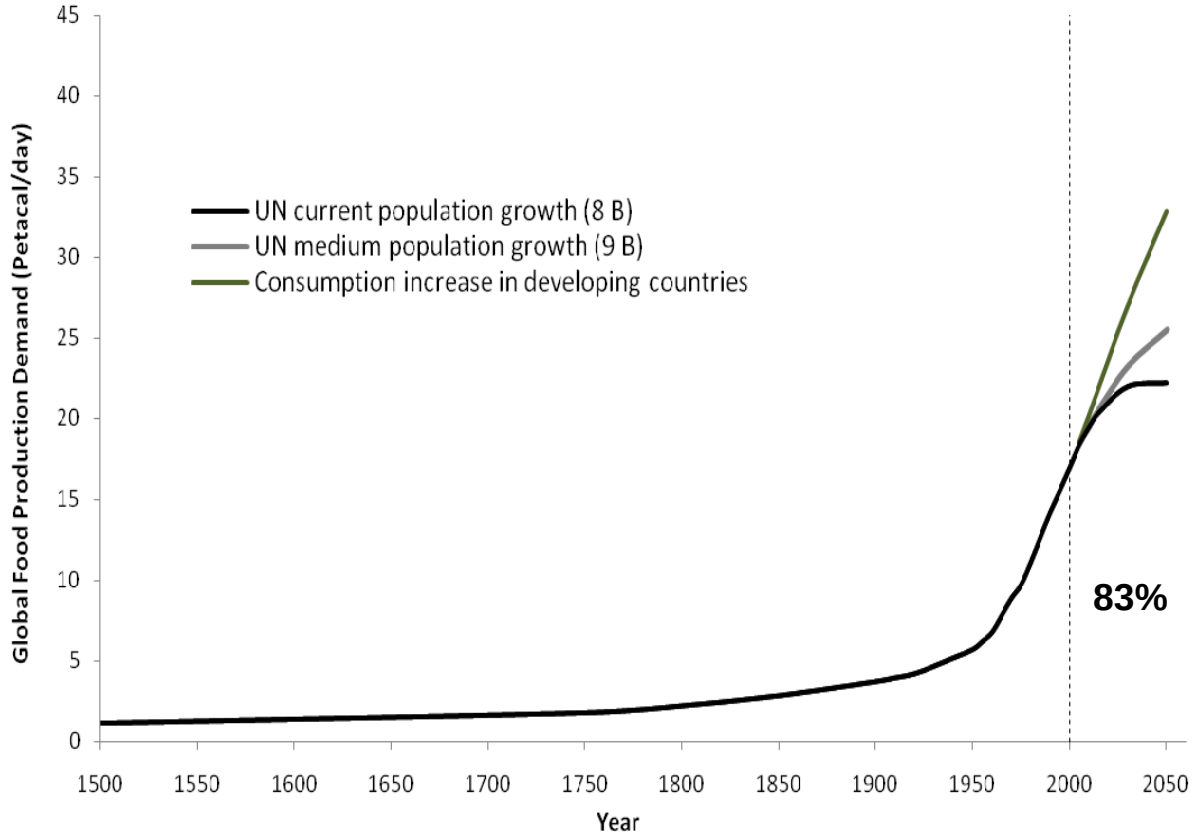
# Demand for global food production
## - Increased consumption in developing countries

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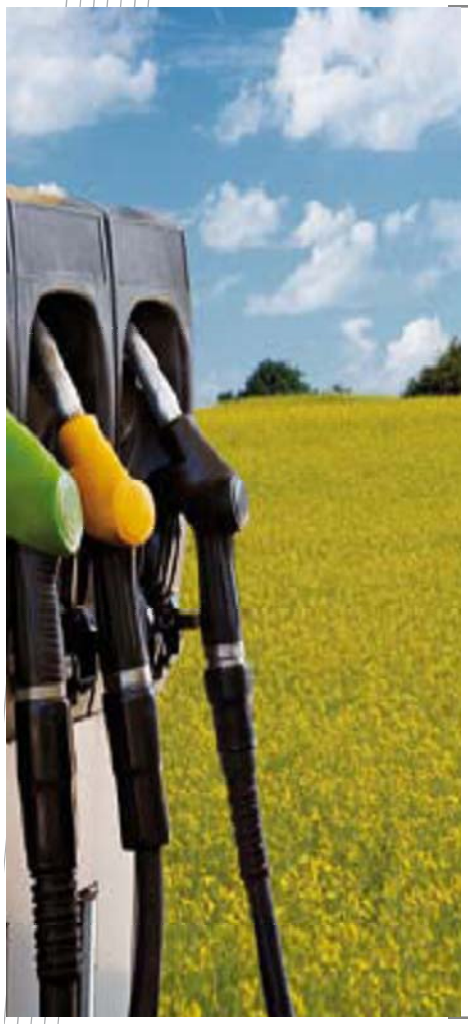
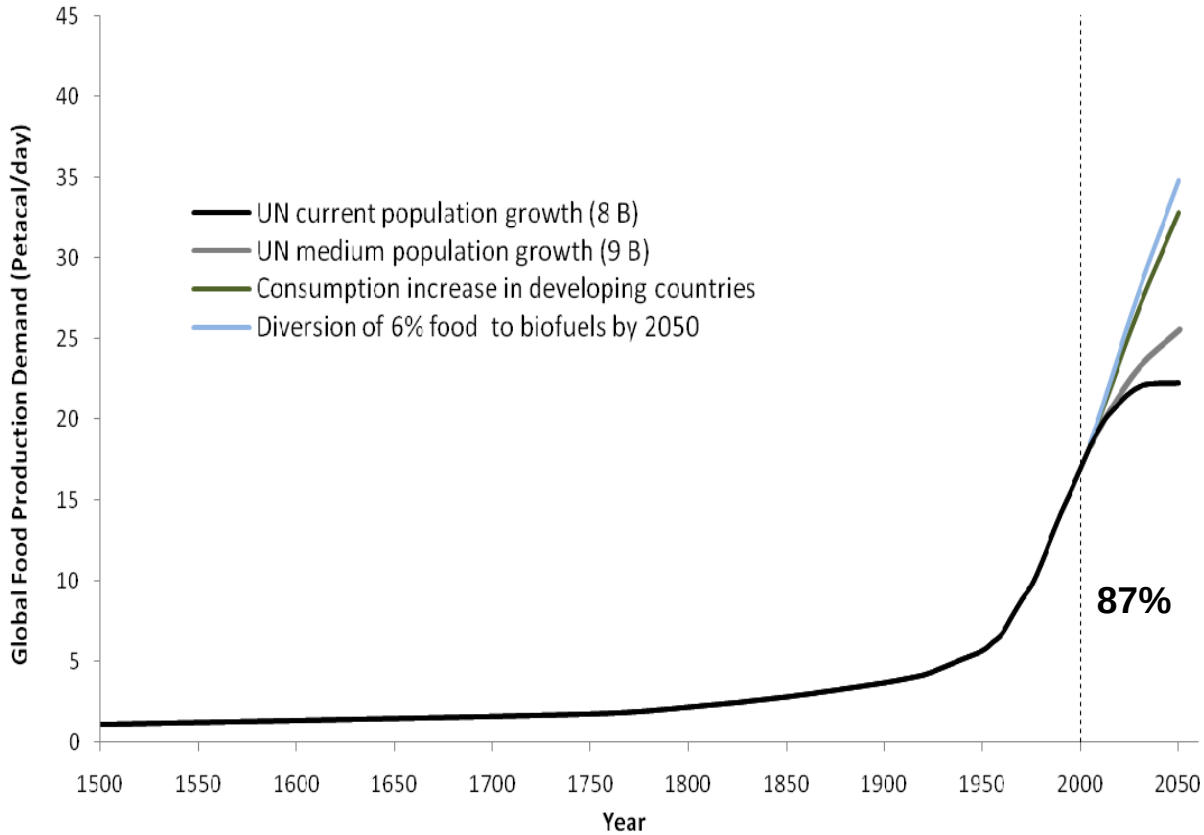
# Demand for global food production
## - 6% biofuel diversion by 2050



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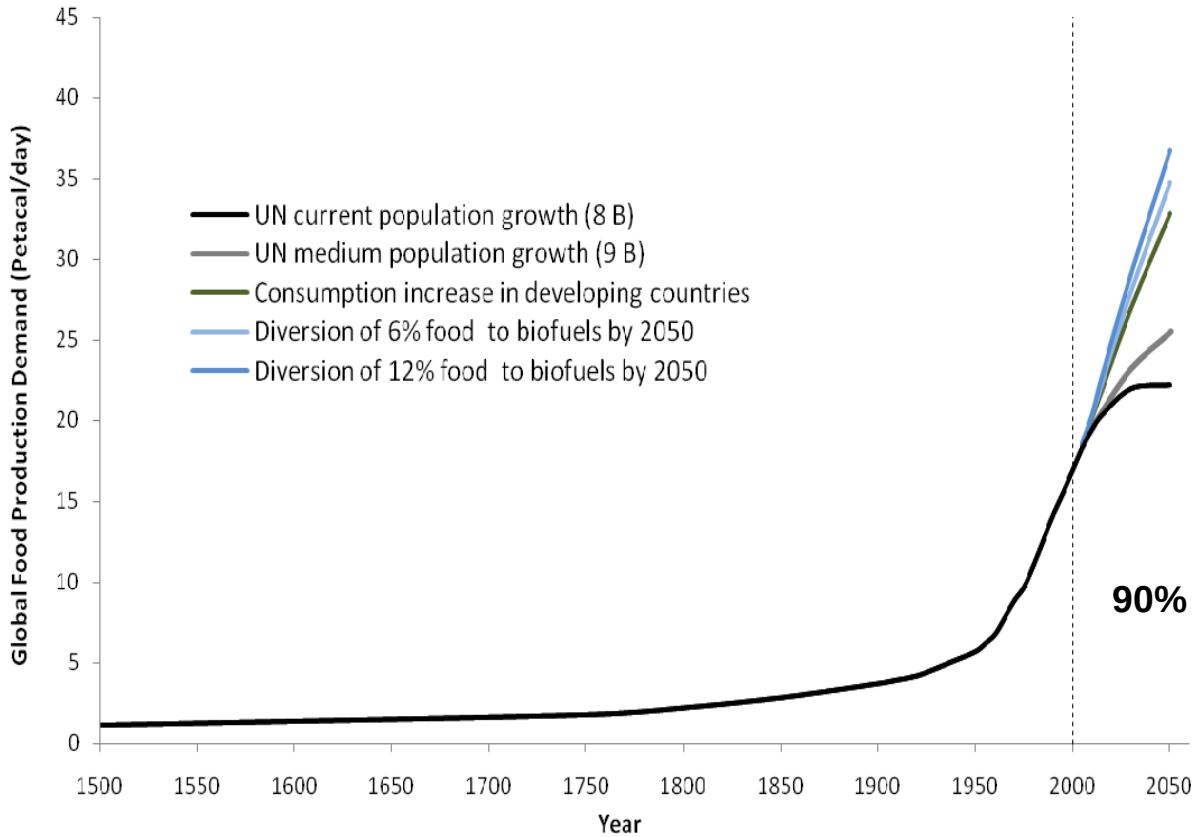
# Demand for global food production
## - 12% biofuel diversion by 2050

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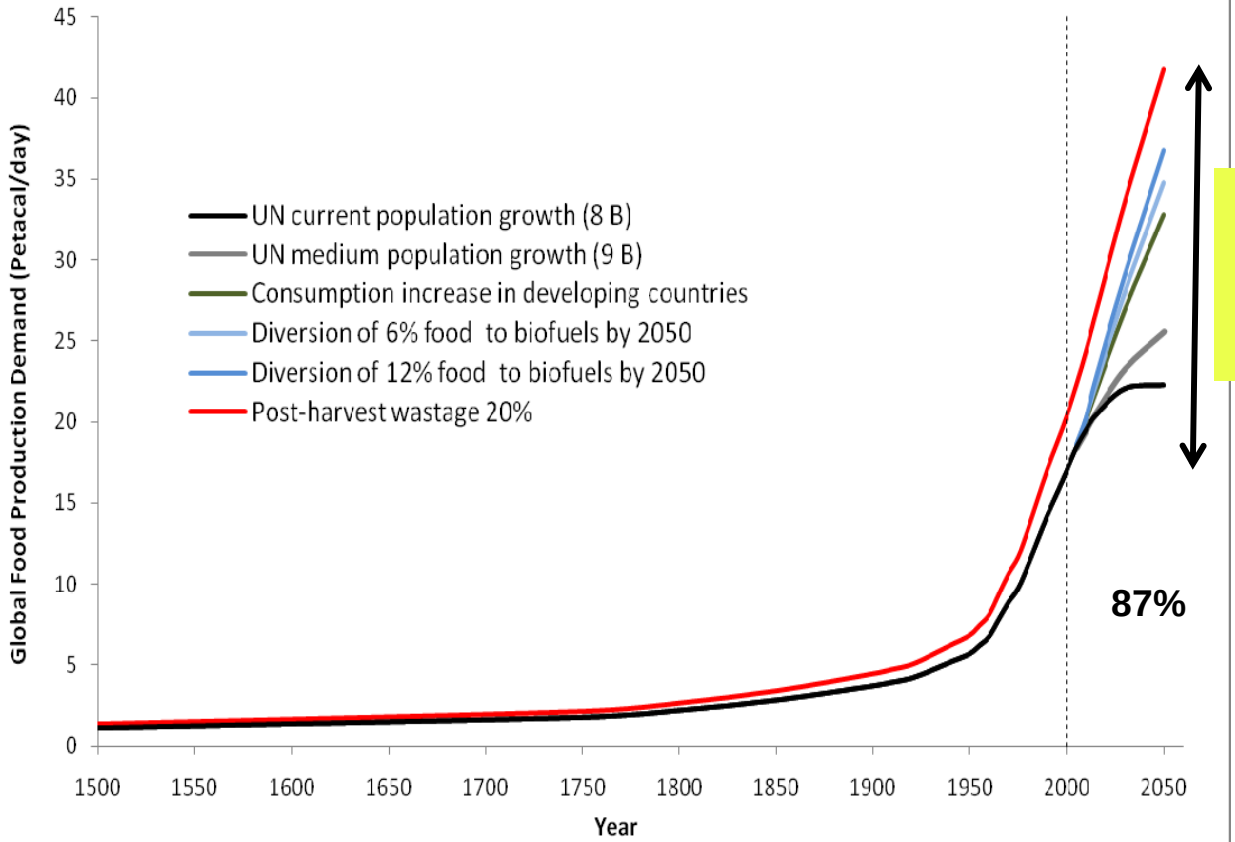
# Demand for global food production
## - 20% post-harvest losses




**Need to double production of year 2000**

**The demand for global food production over the period 1500 to 2050 for additive scenarios.**
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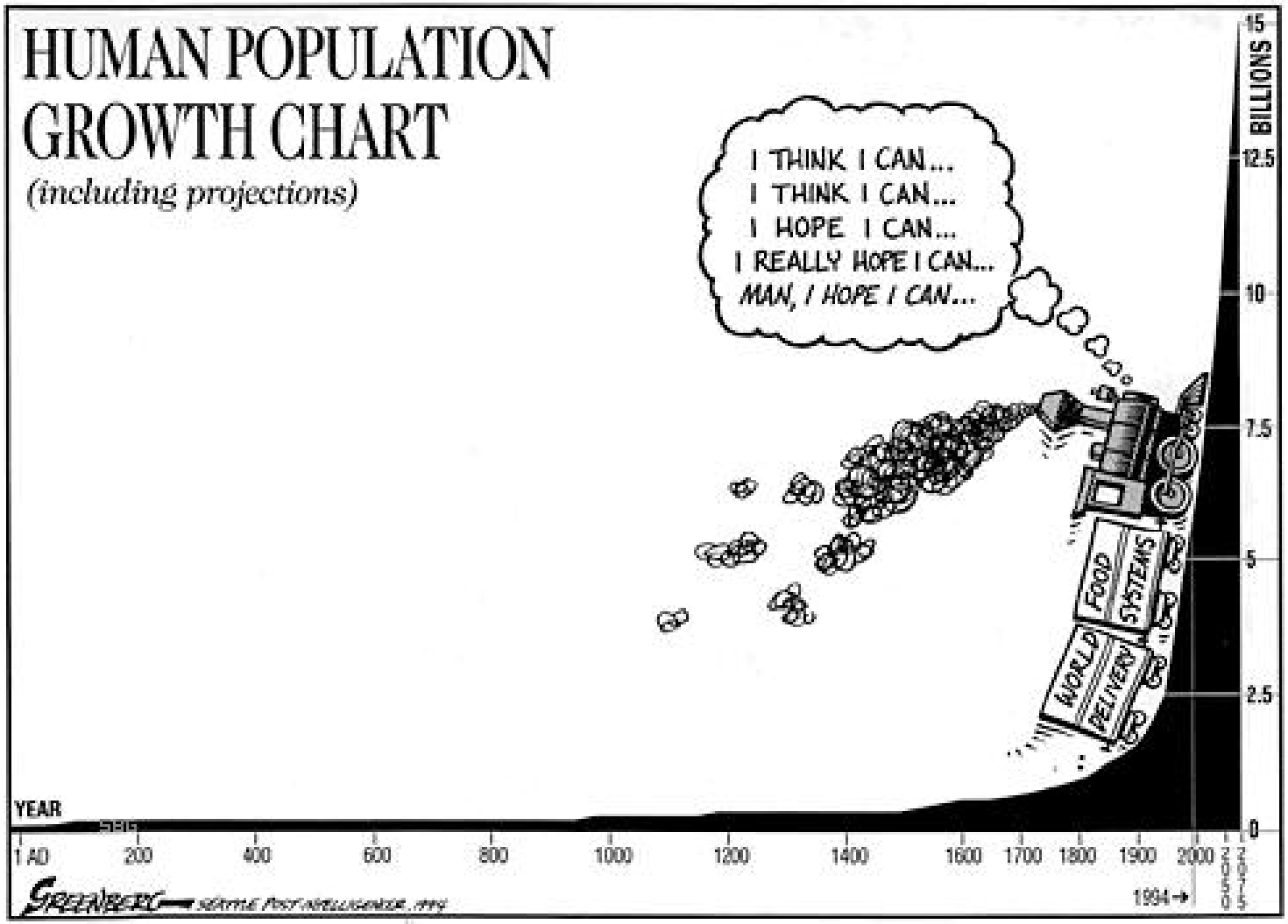
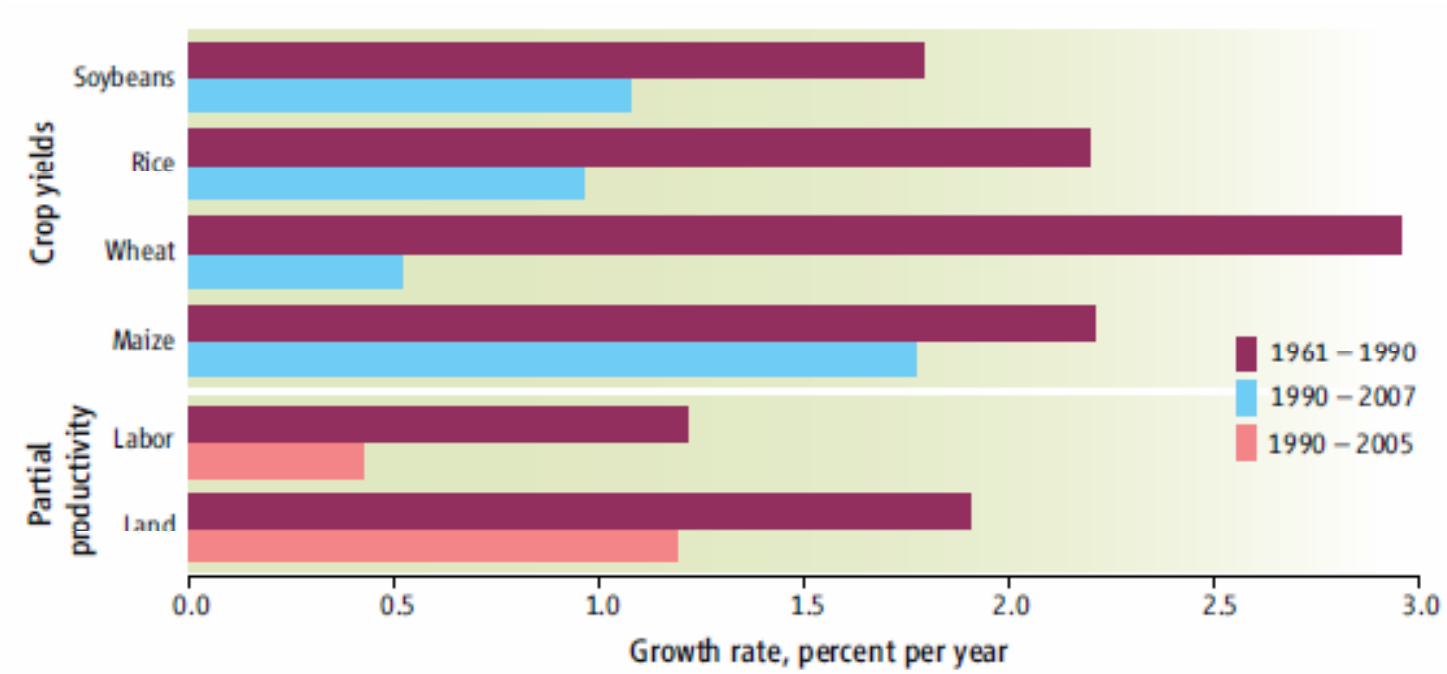
# Demand for global food production

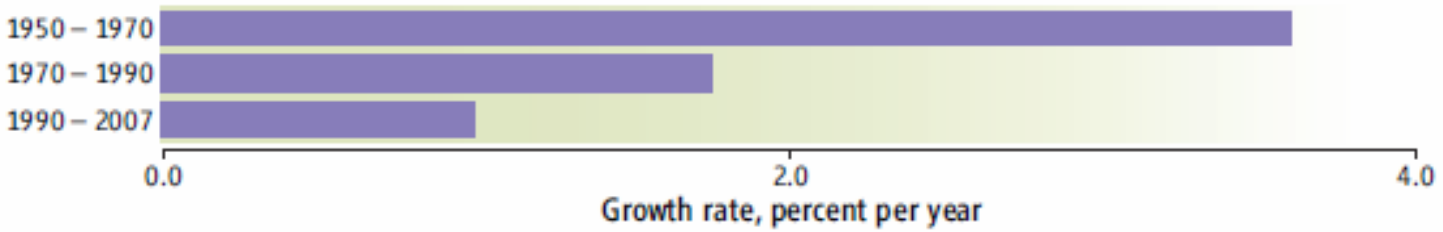


# Slowdown in productivity growth in the world's major crops

Alston et al 2009

**Global yield and agricultural productivity growth rates**, percent per year for 1961 to 2007. Yield is measured as metric tons per hectare. Labour and land productivity are total agricultural output per agricultural worker and agricultural area.




**Percent annual growth of U.S. public agricultural R&D spending**

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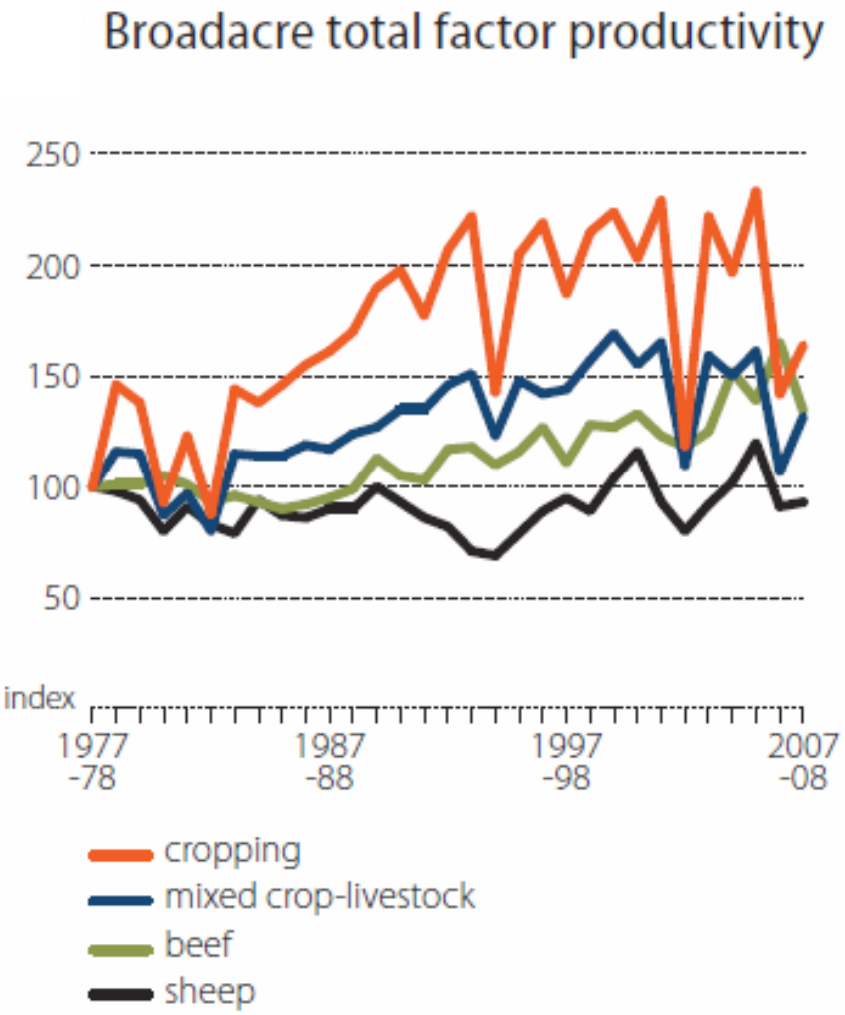
# Total factor productivity growth in Australia's cropping industries (ABARE)




## Broadacre industry productivity growth, 1977-78 to 2007-08

average annual growth

| | TFP growth | output growth | input growth |
|---|---|---|---|
| | % | % | % |
| Total broadacre | 1.4 | 0.8 | −0.6 |
| Cropping | 1.9 | 2.1 | 0.2 |
| Mixed crop–livestock | 1.4 | −0.1 | −1.6 |
| Beef | 1.5 | 1.6 | 0.2 |
| Sheep | 0.3 | −1.5 | −1.7 |

Nossal and Sheng, 2010. ABARE

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# Food price index

Food and Agriculture Organization of the United Nations

*for a world without hunger*

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FAO Home

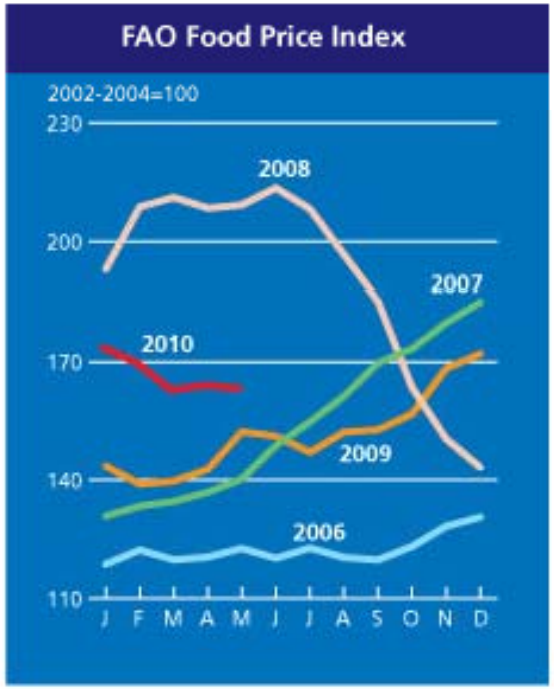
World Food Situation

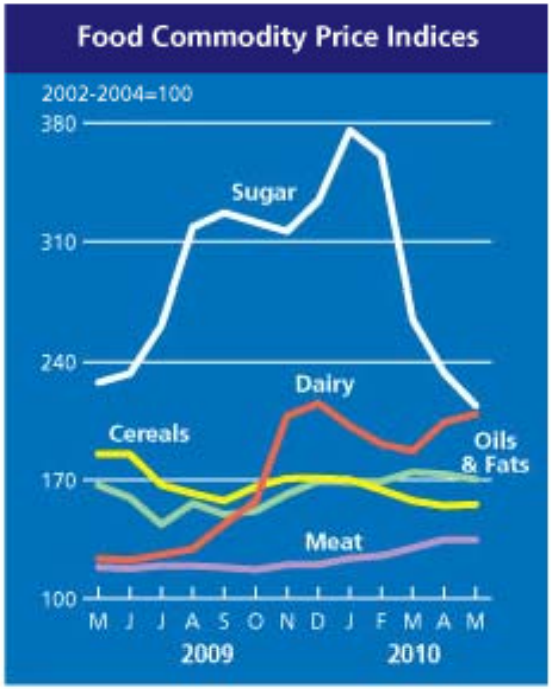
FAO Initiative on Soaring Food Prices

## World Food Situation

**Food Price Indices**

**June 2010**

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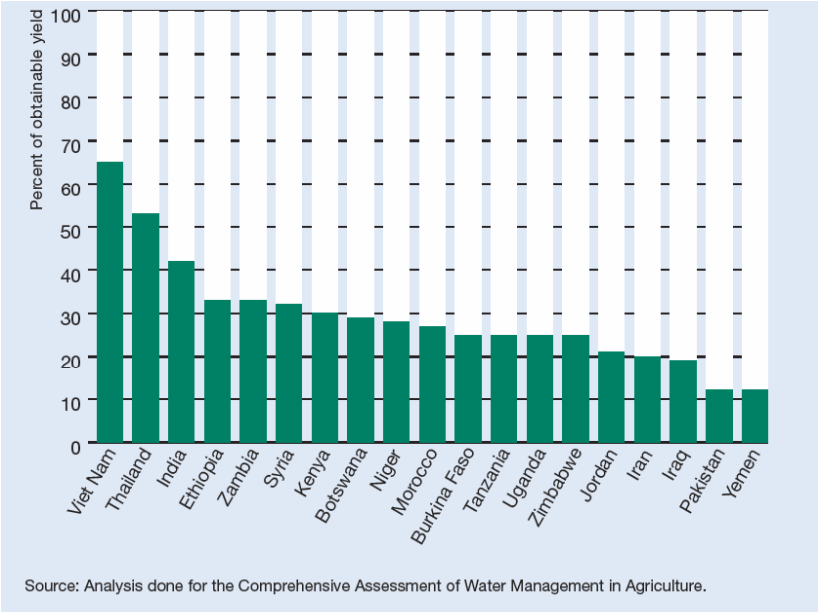
# How will increased production be achieved ?

- Protecting existing productivity against emerging threats
  - Land degradations
  - Pests and disease
- **Closing the yield gap in existing farming systems?**
- Increasing intensity of cropping on existing arable lands?
- Creating new arable lands on existing grasslands or forestlands ?
- Raising yield potential through “break-through” technologies?




Percent of obtainable yield estimated for selected African, Asian and Middle Eastern countries (CAWMA, 2007).

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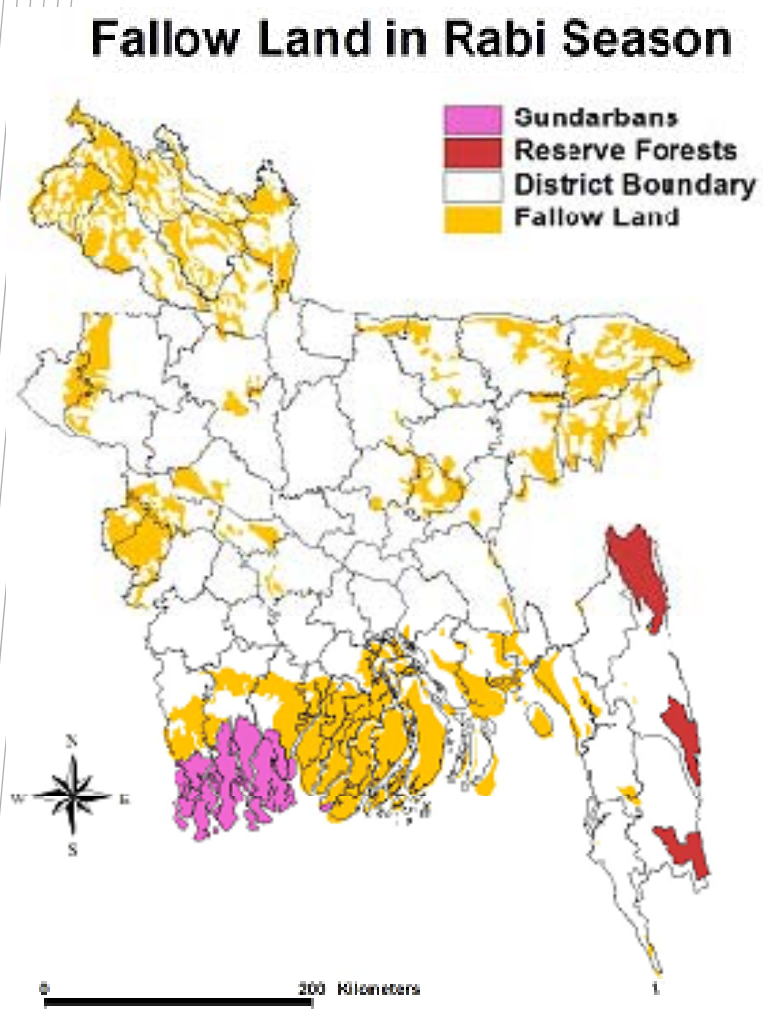
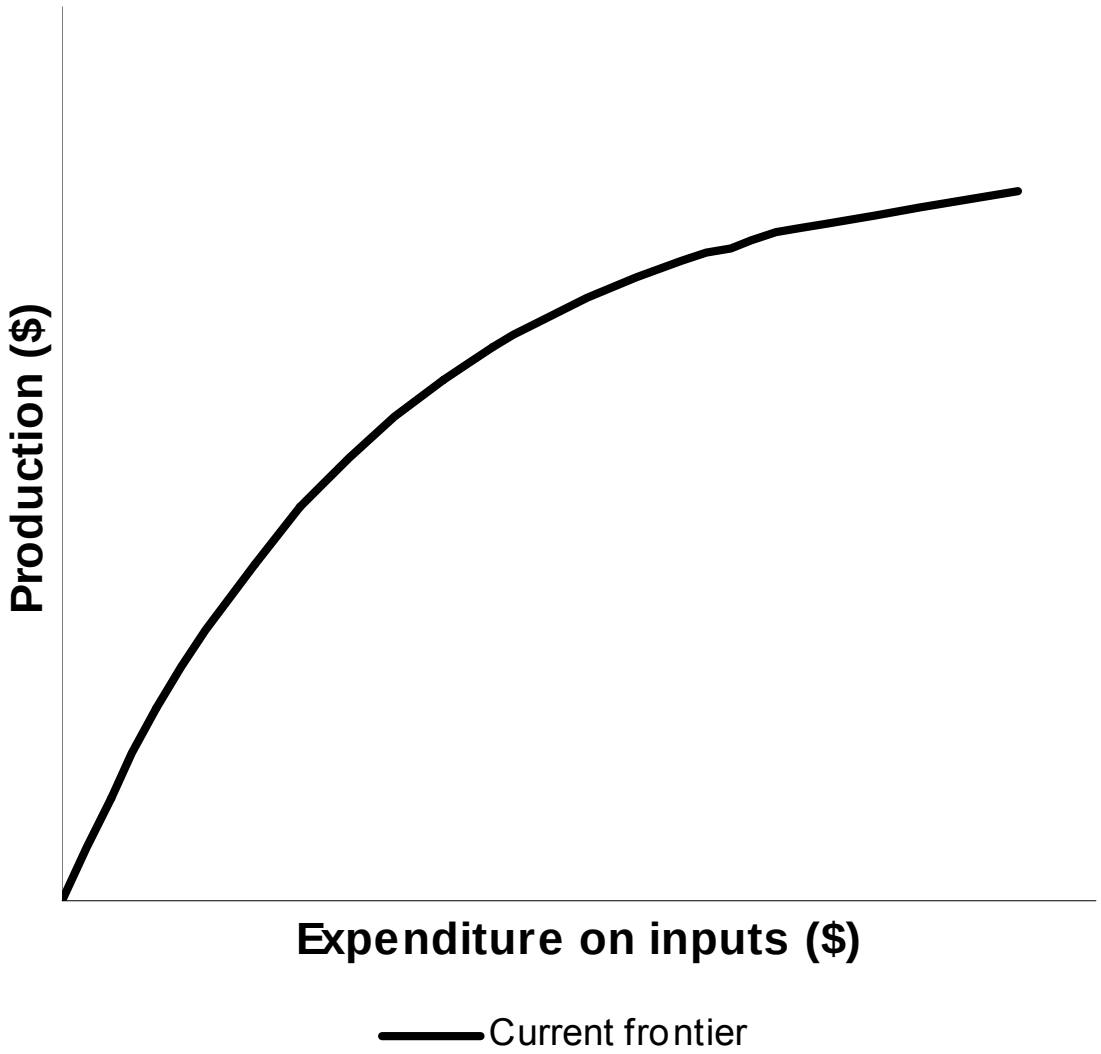
# Crop intensification in southern Bangladesh




- Lands fallow because few tube wells for irrigation; hot & saline environment
- But some surface water at start of rabi (dry) season
- 5 yrs trials show irrigated wheat yields = 4t/ha; dryland yields 2t/ha
- Modelling suggests good prospects but with agronomy changes
- Widespread adoption of wheat

# Investment framework
# Production v's investment ($)




Production – input responses

Based on John Dillon, 1977. An Analysis of Response in Crop and Livestock Production (2nd edition), Pergamon Press, Oxford

Developed by CSIRO & GRDC

www.grdc.com.au/uploads/documents/Optimising_Investment_in_RDE_for_the_Northern_Grains_Region.pdf

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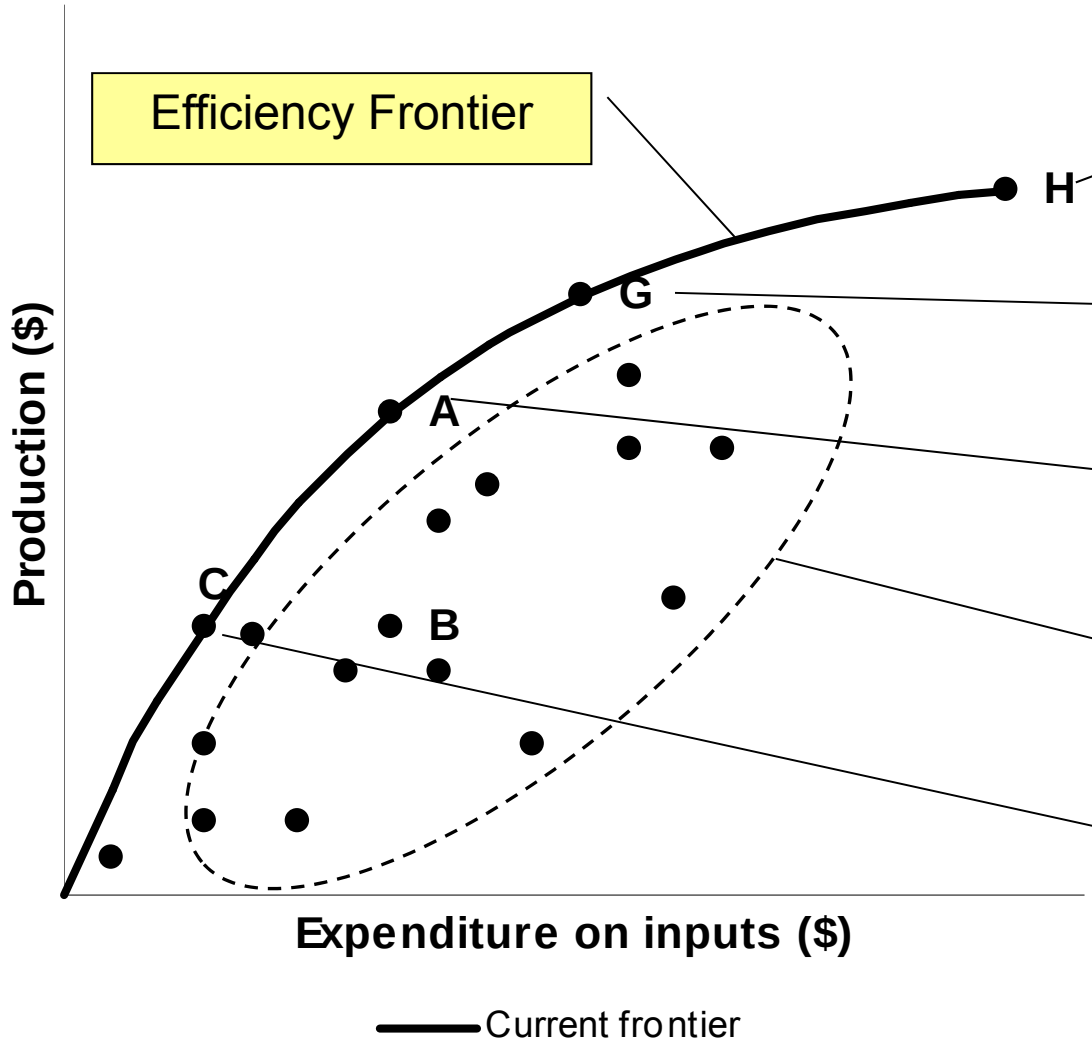
# Investment framework
# map current grower performance




H = Environmental potential

G = Maximum marginal return

A = region's best growers

B = underperforming growers

C = risk-adverse growers

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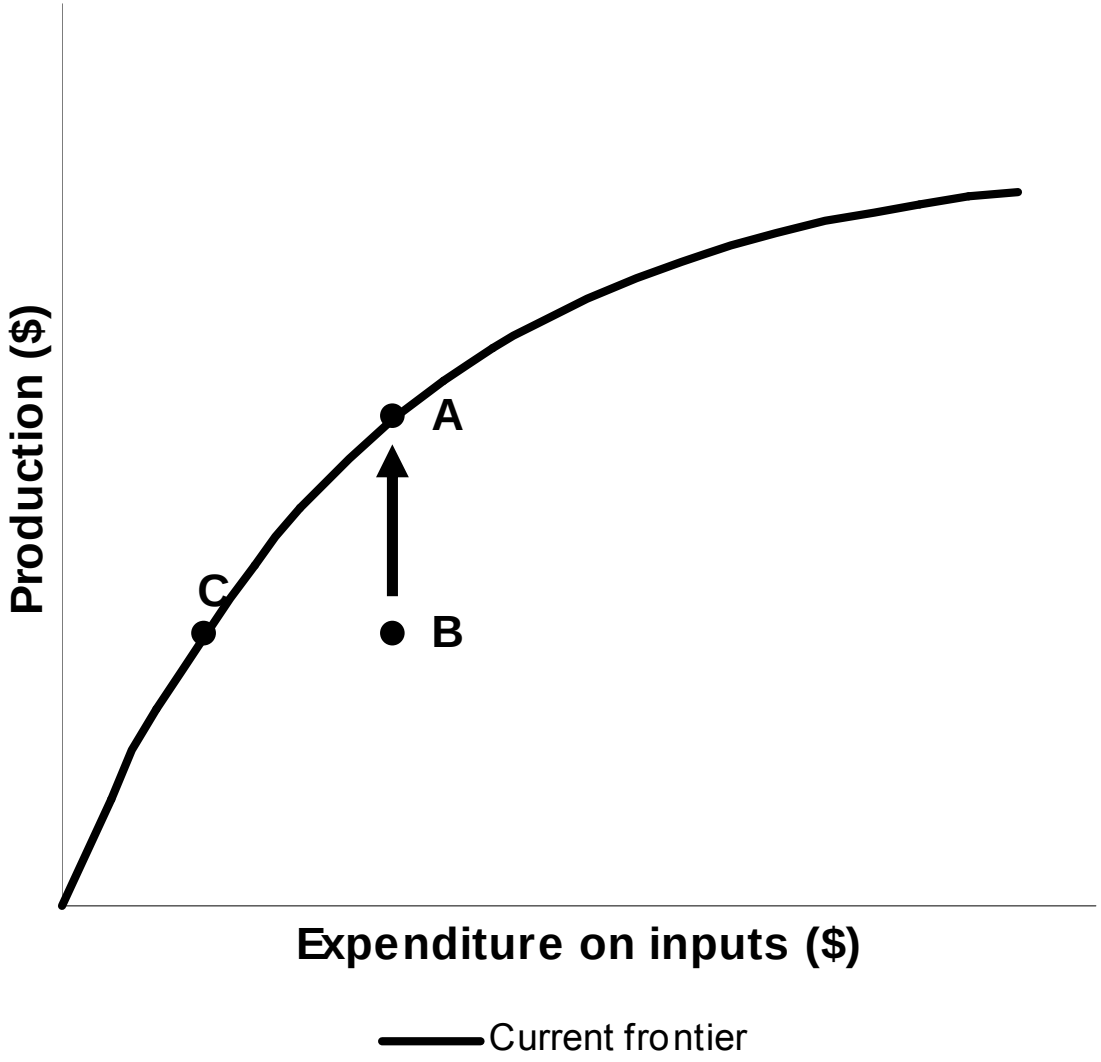
# Pathway 1: Improve the agronomic performance of growers




- Increase the number of growers performing close to industry best practices
- Source of traditional productivity improvement for industry over many years
- Better uptake and exploitation of technology that are currently available
- Requires both confronting with evidence of inefficiencies and access to better agronomic advice

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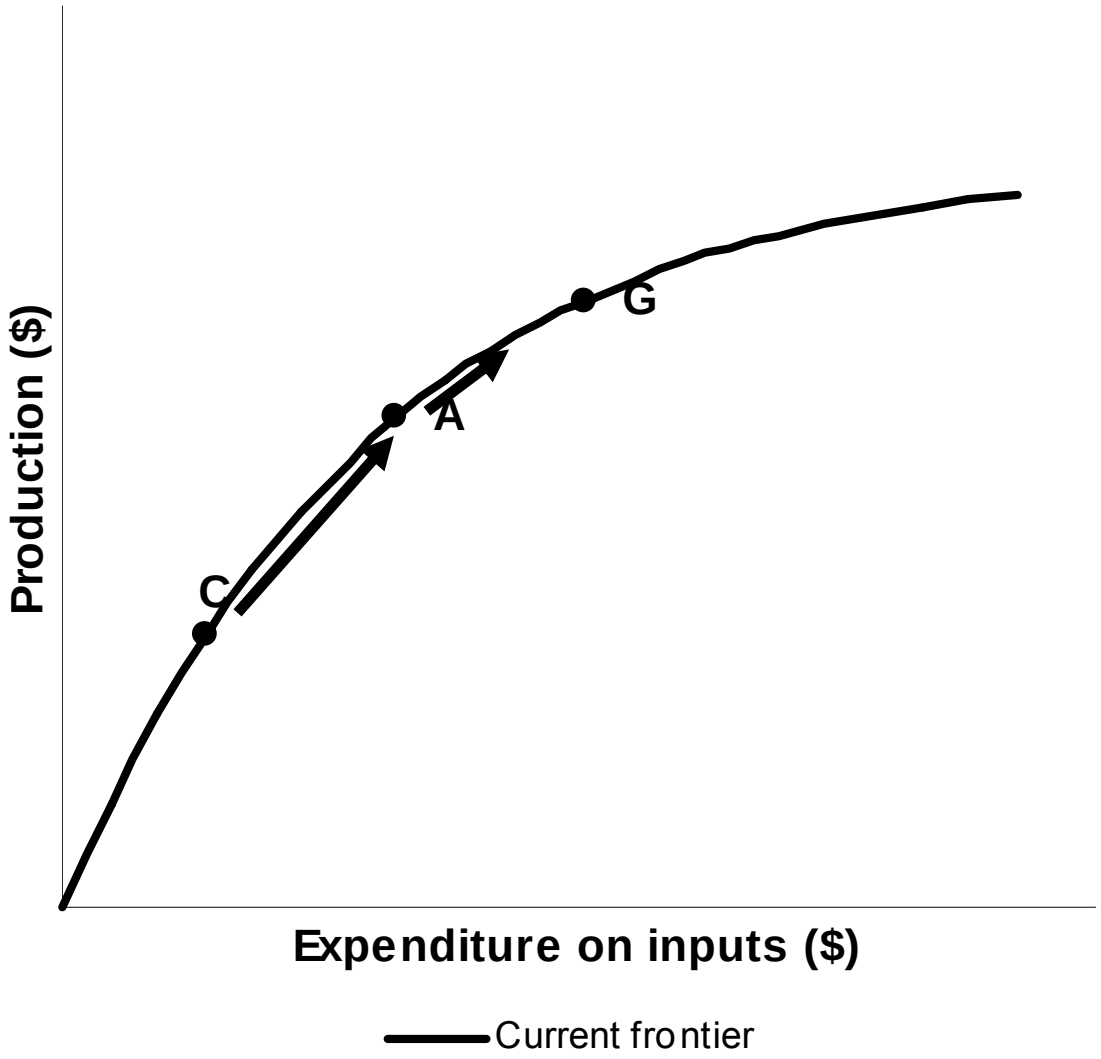
# Pathway 2: Encourage growers to adopt risk management practices




- Encourage growers to move along the current efficiency frontier to higher returns whilst addressing the added risks
- Need to be convinced that the increased investment justifies higher risk exposure
- Achieved through growers accessing farm business management
- Decision support for managing climate variability and risk

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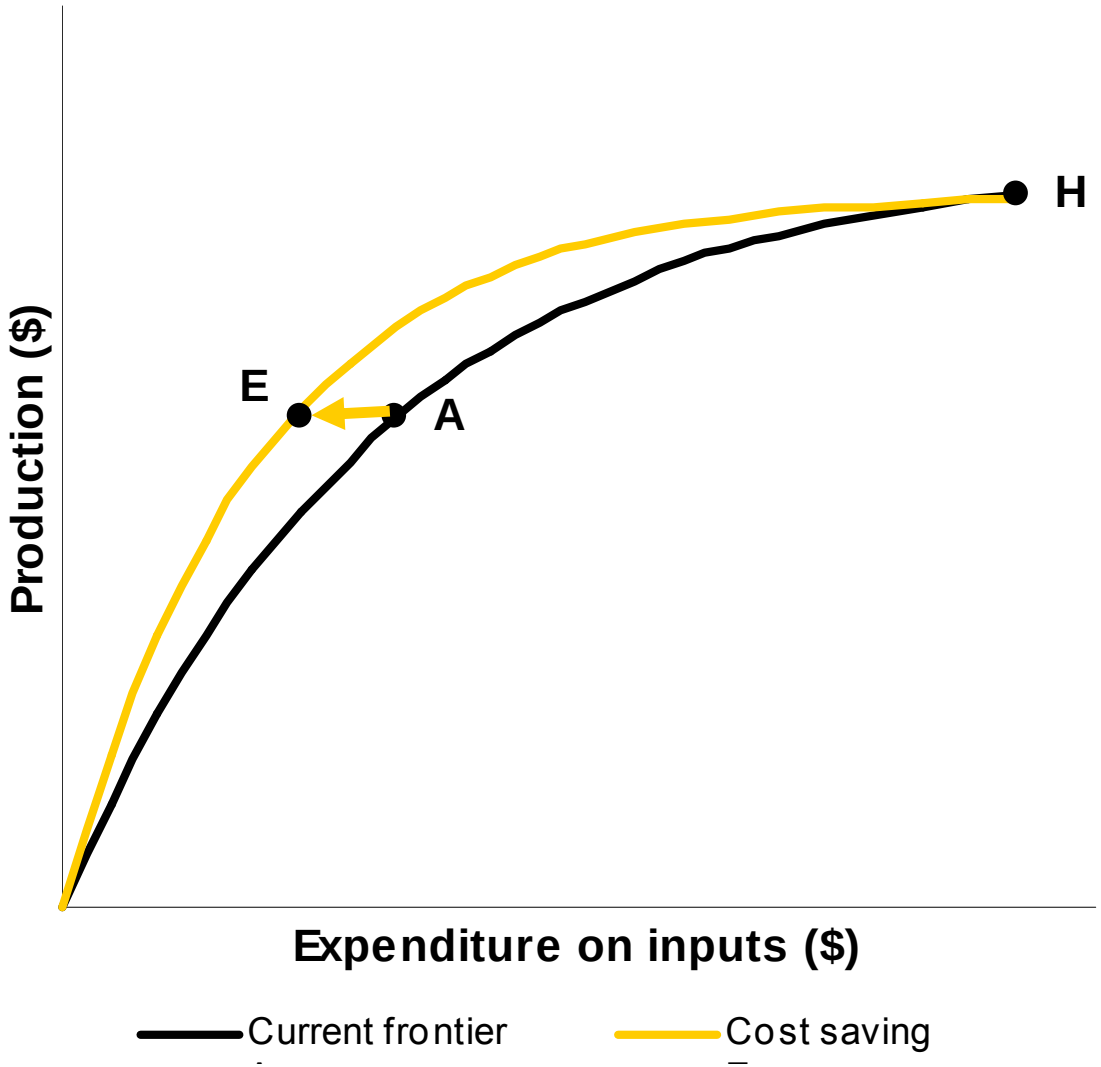
# Pathway 3: Increase efficiencies of resource use




- Create new efficiency frontiers which generate similar returns for less investment and risk
- Increasingly more efficient resource use is a mainstay of agriculture's response to the cost-price squeeze
- Technologies can be both agronomic (eg. precision agriculture) or varietial (eg. phosphorus-efficient cultivars)

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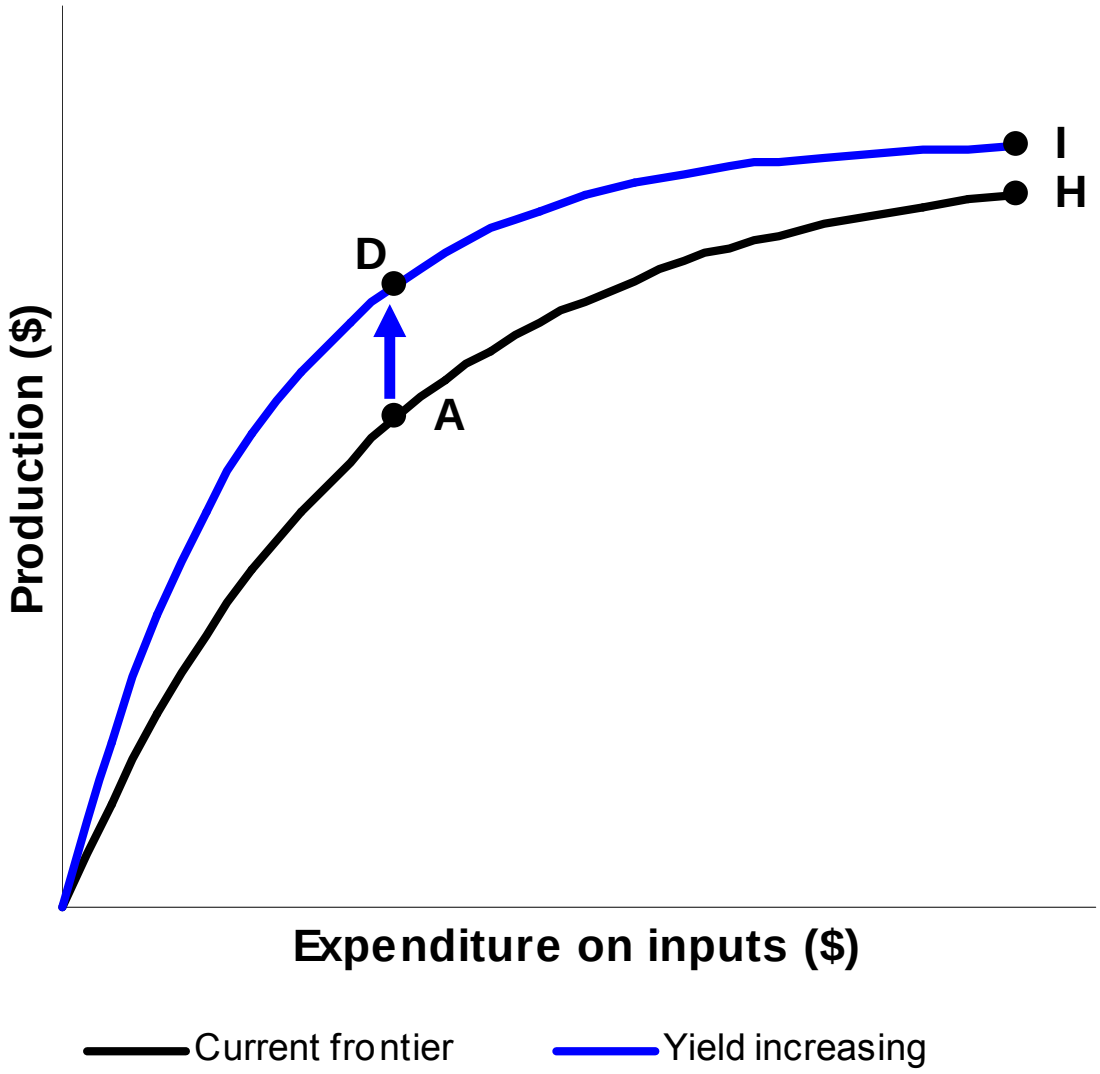
# Pathway 4: Create new production frontiers




- Agricultural productivity continues to rise as new genetics and technologies are adopted
- Discover the practices that will result in the next step-change in productivity and profitability
- Create new efficiency frontiers by increasing the production potential (Point H → I)
- Likely evolve from the synergies between novel plant genetics and innovative management technologies
- Requires strong investment in Research

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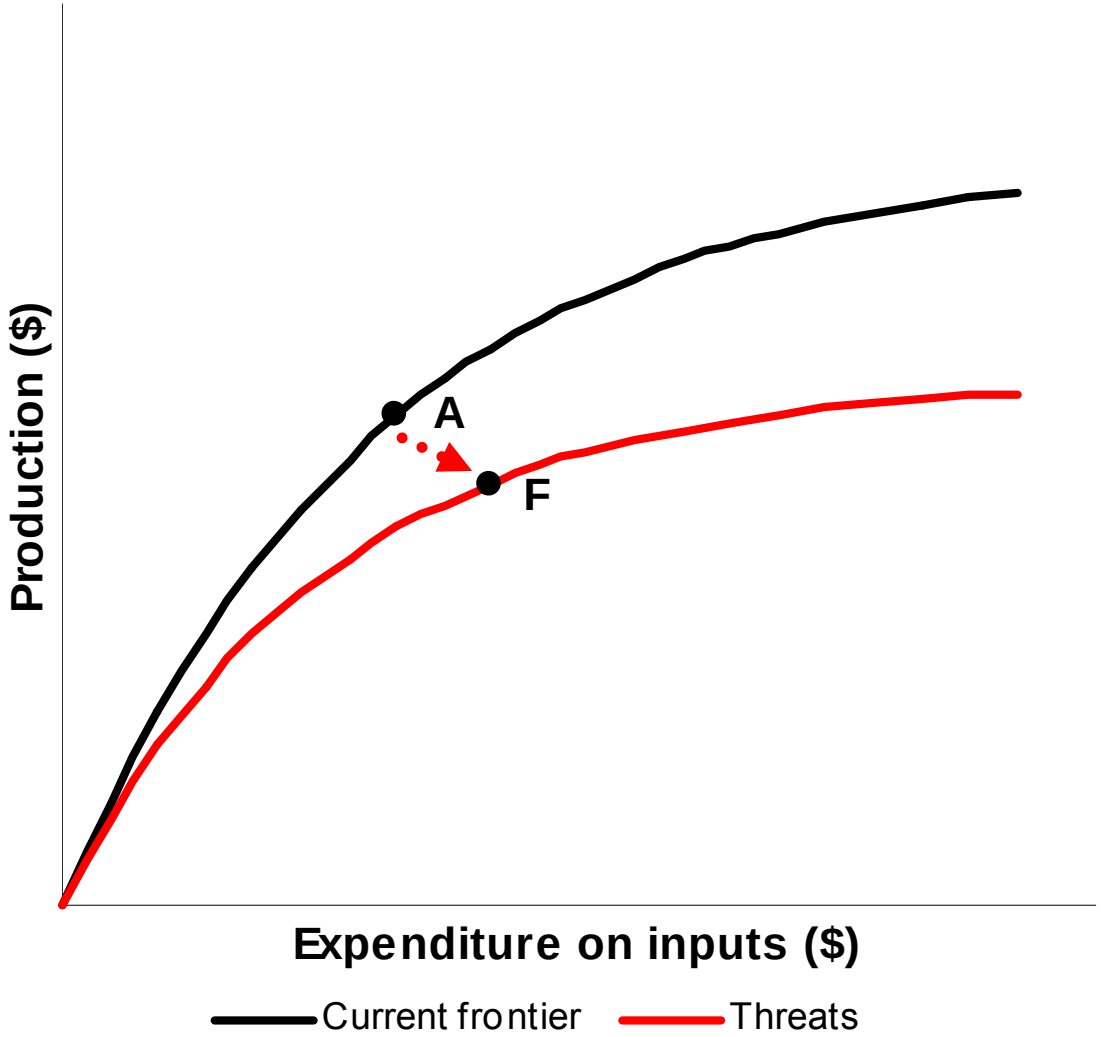
# Pathway 5: Maintain current production potential




- Protect against any loss of current production systems
- Preventing any breakdown in existing disease, weed or pest management strategies
- Maintaining facilities to rapidly respond to future outbreaks of exotic disease, weeds or pest
- Avoid practices which threaten the natural resource base for agriculture eg. soil salinity, acidification and nutrient rundown

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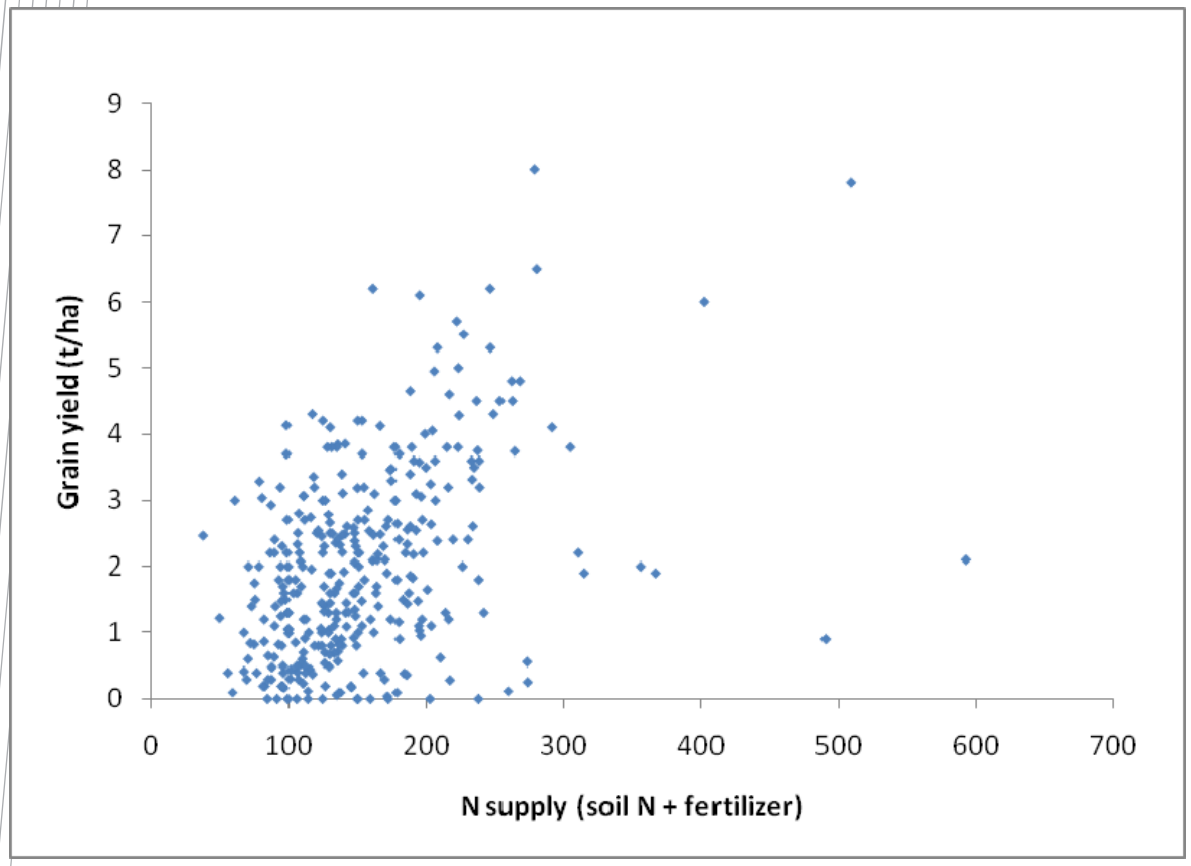
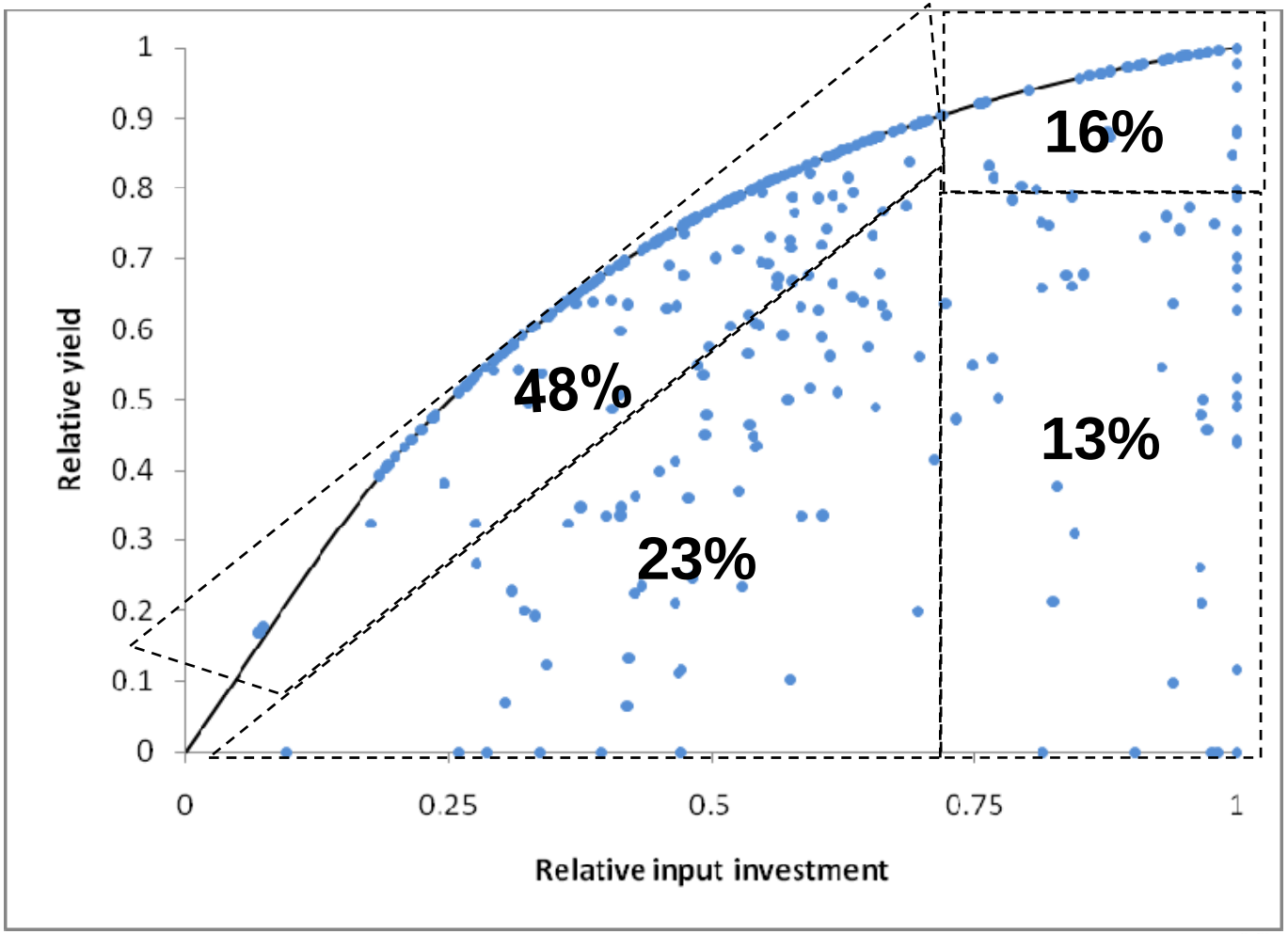
# Performance of Yield Prophet farmers

www.yieldprophet.com.au




- Internet-based subscriber system to predict current wheat yields and management response using APSIM
- Observed data for 334 commercial wheat crops monitored nationally between 2004-07

# Yield Prophet crops (334) – relative yield v's relative input investment

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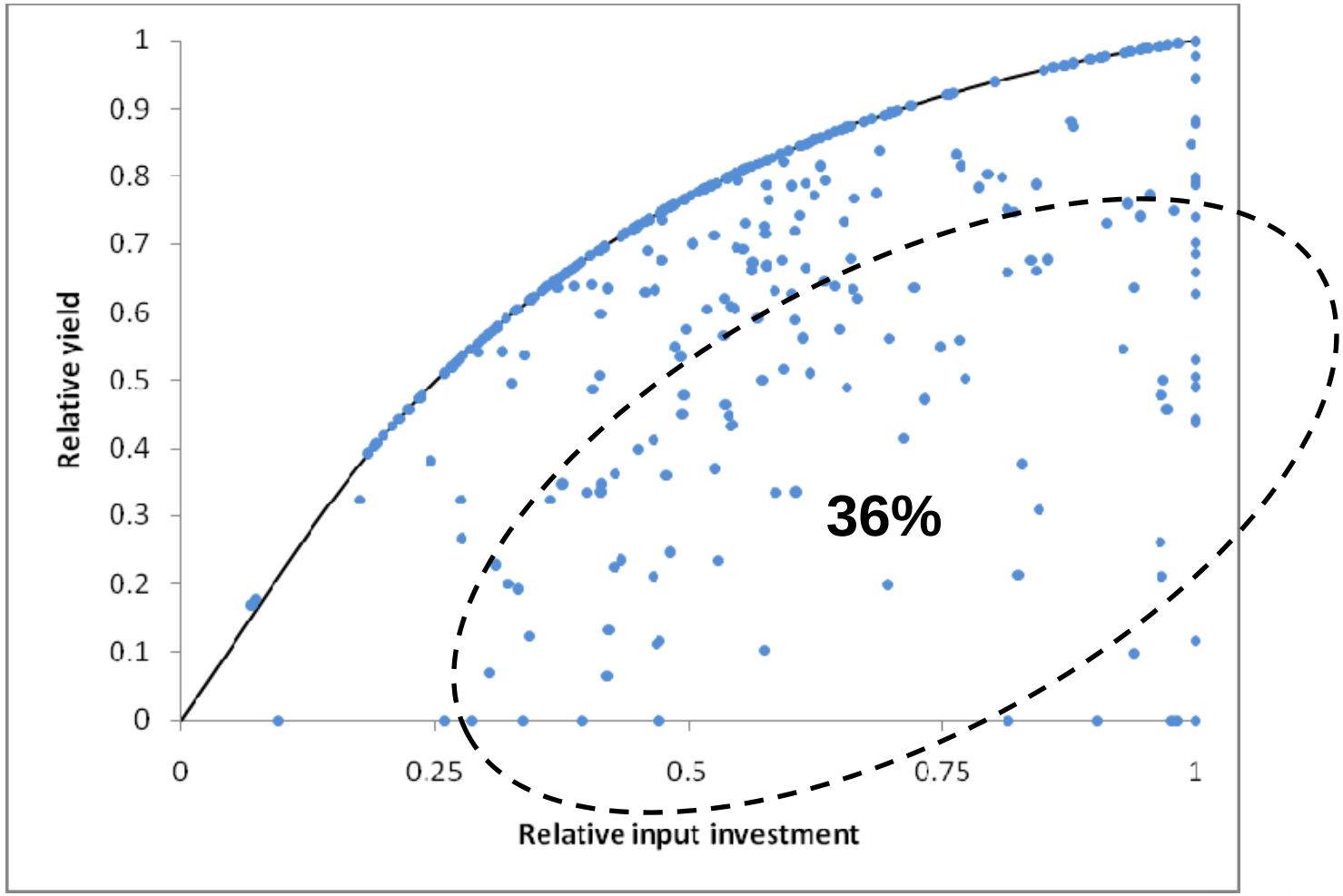
# Increase production through improved practices

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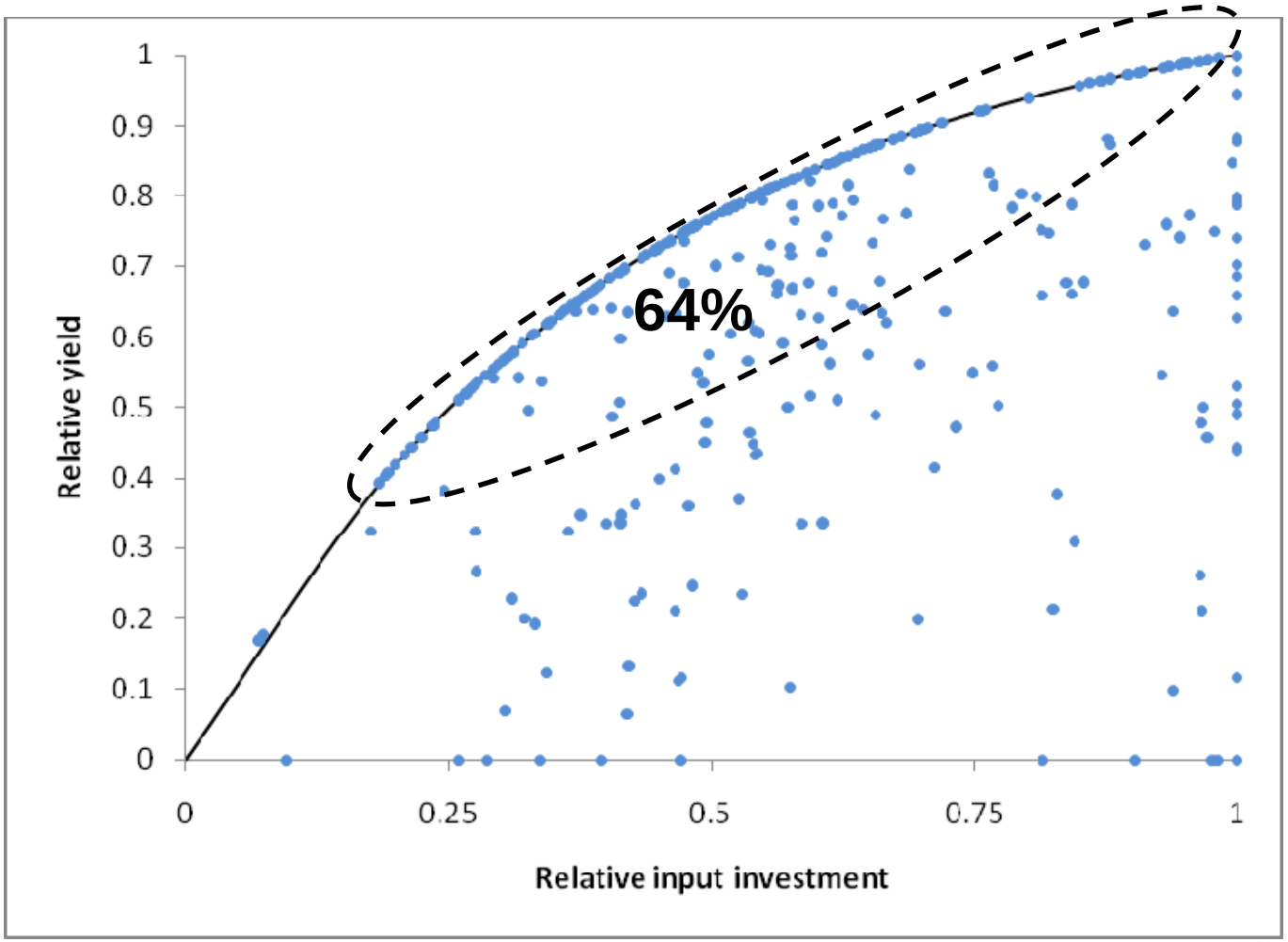
# New technologies needed to improve performance

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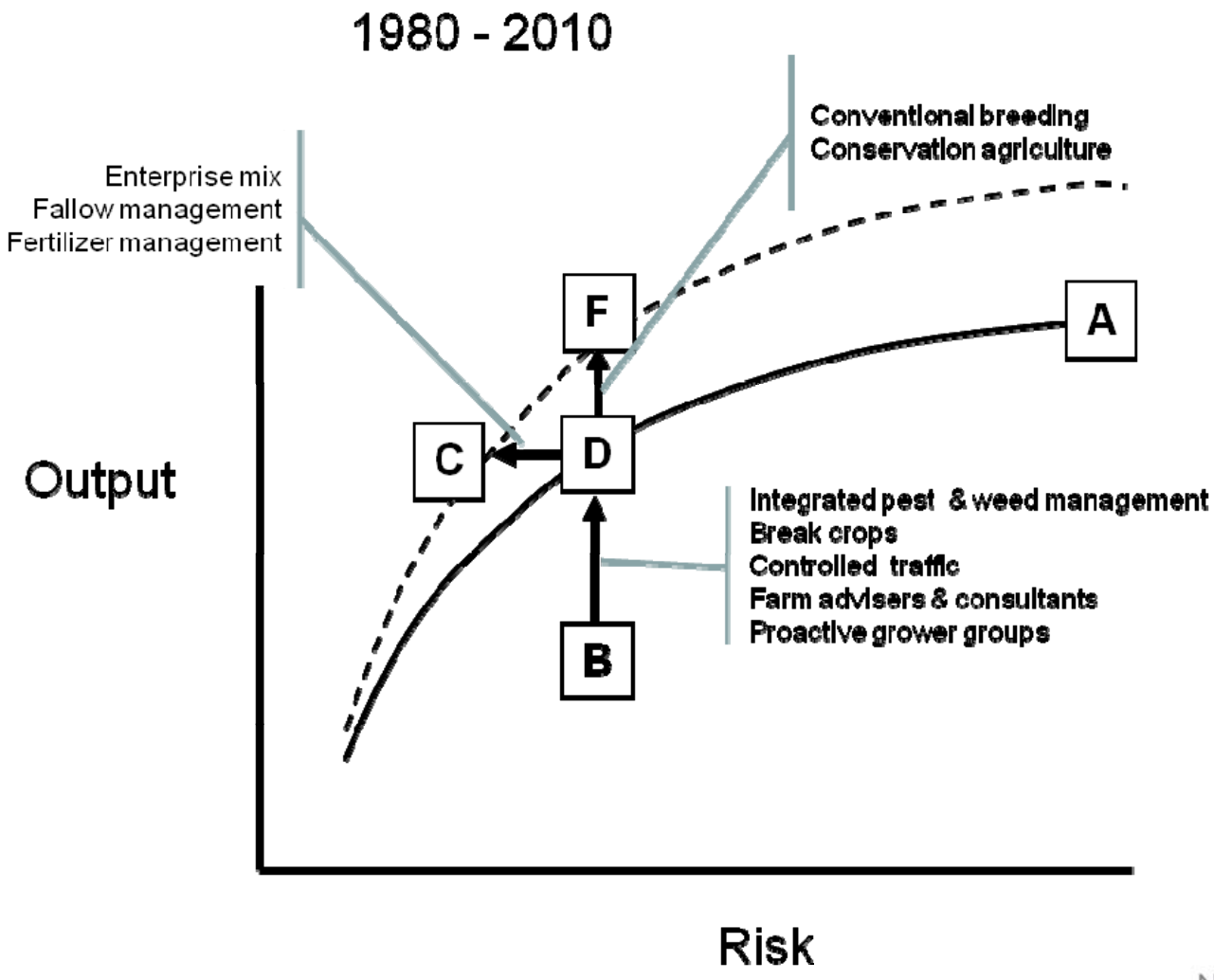
# Past technologies

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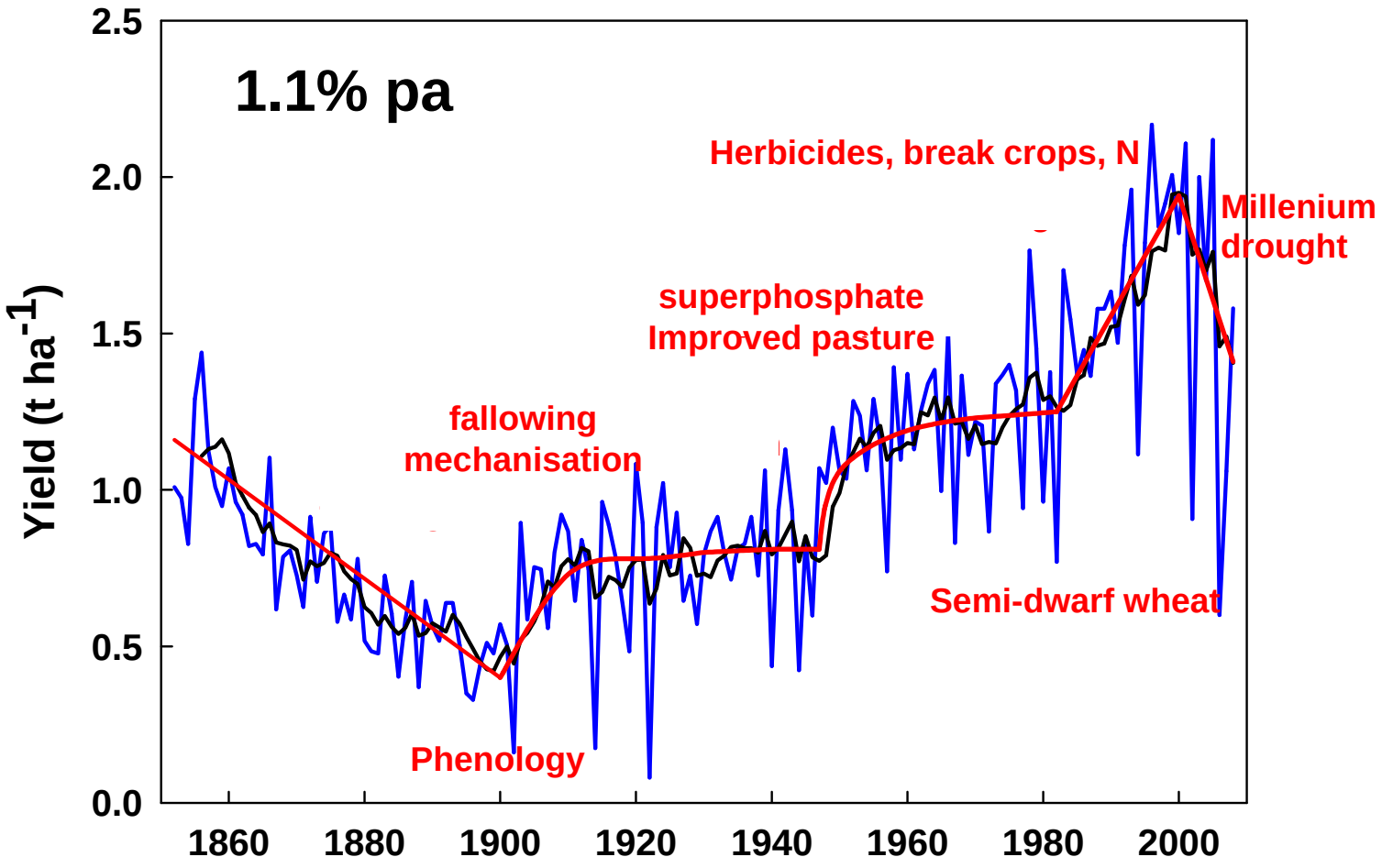
# Australian national wheat yield trends




*Angus (2009); Fischer (2009)*

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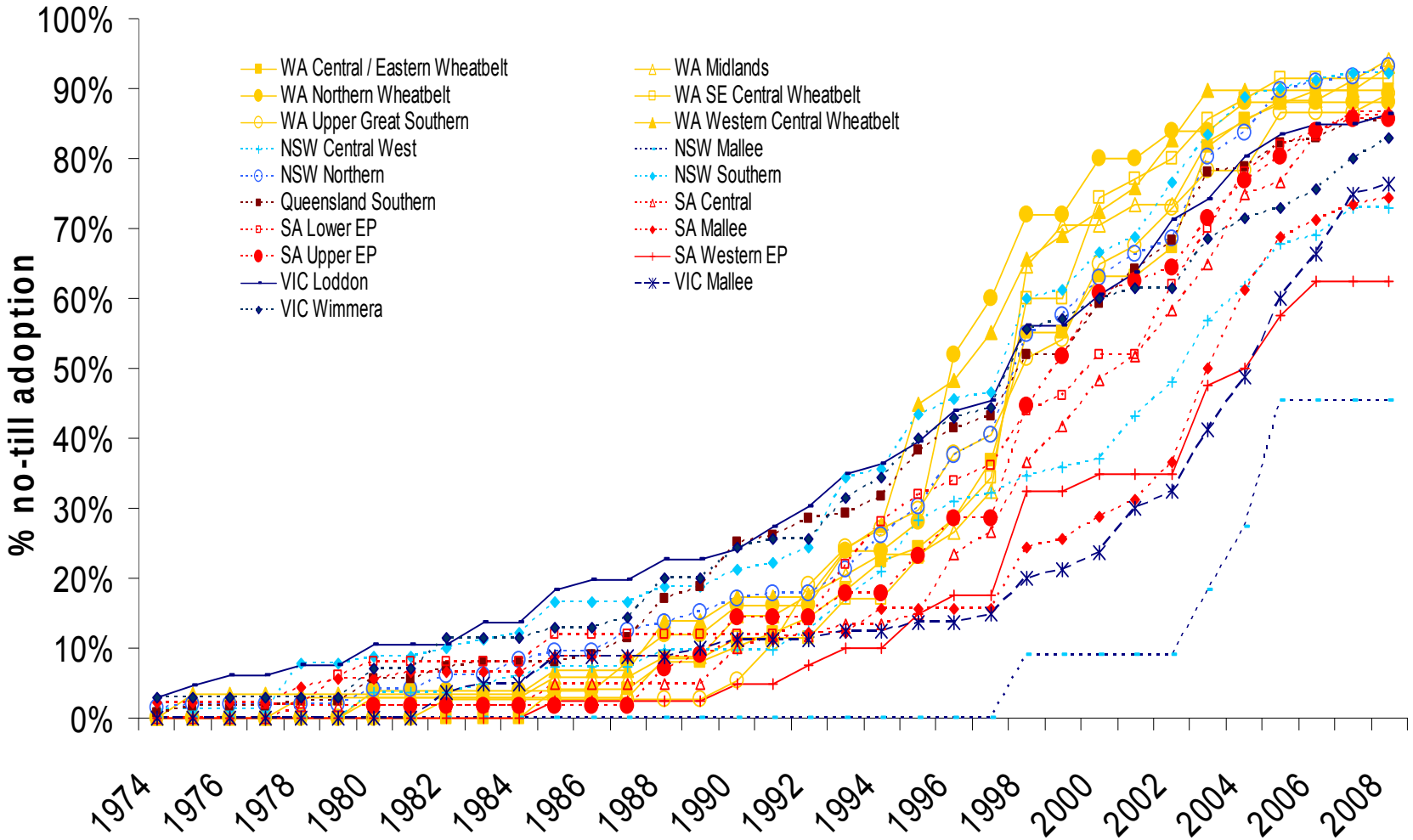
# Conservation agriculture

# No-till adoption across Australian cropping regions




Llewellyn et al 2009

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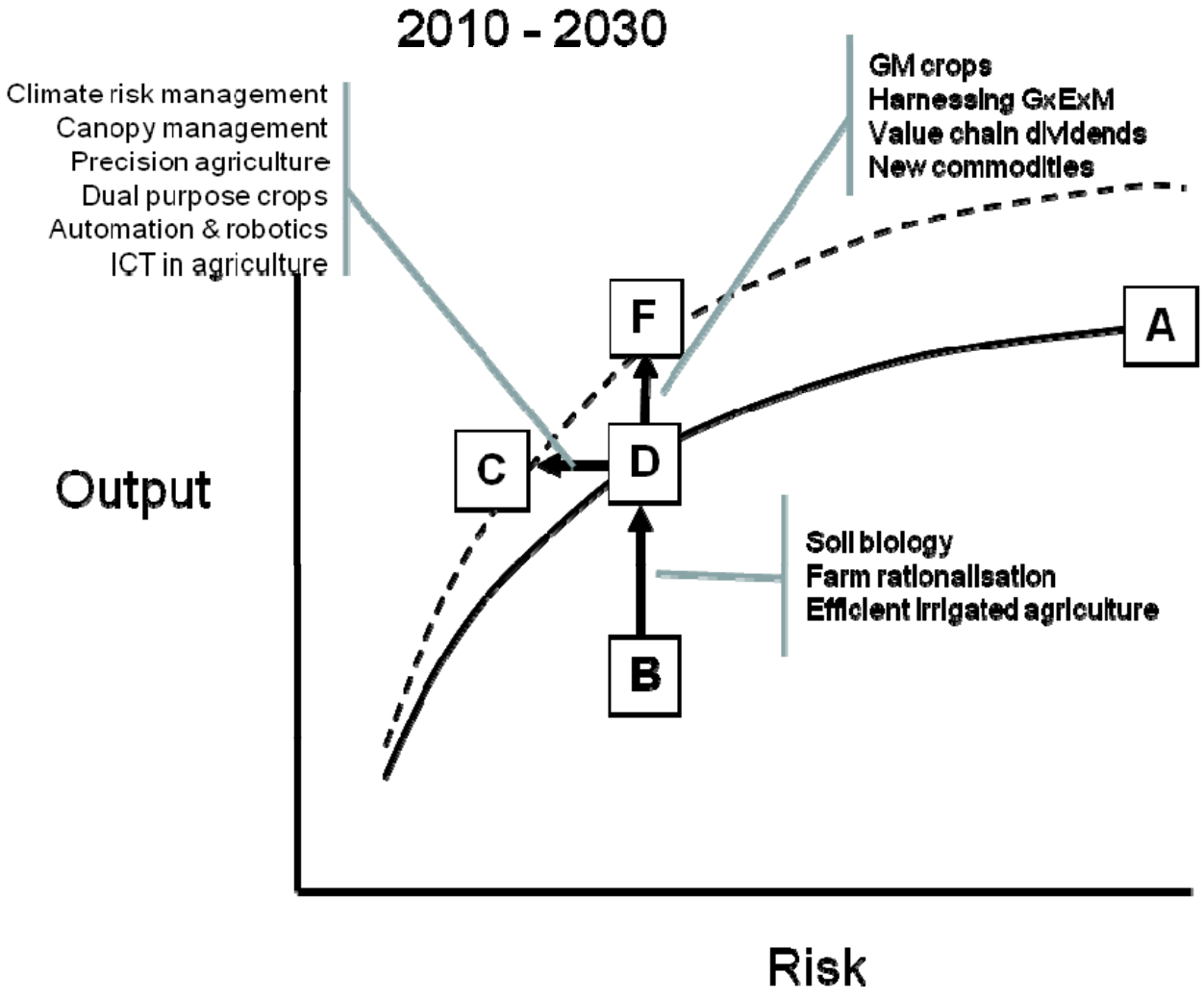
# Future technologies

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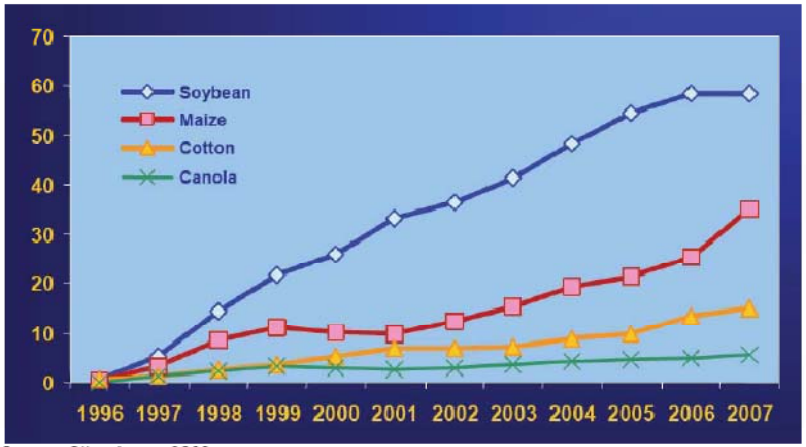
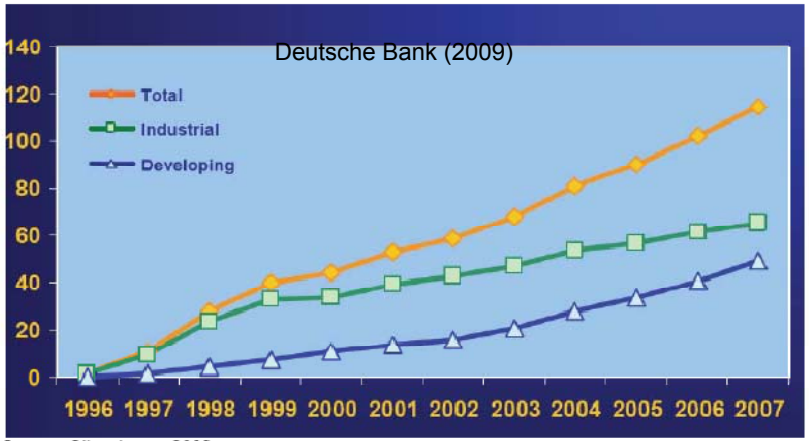
# GM crops

EX 78: Global area of biotech crops, 1996 to 2007: By crop (million hectares)




Source: Clive Jones, 2008.

EX 79: Global area of biotech crops, 1996 to 2007: Industrial and developing countries (million hectares)




Source: Clive Jones, 2008.

- The adoptions of transgenics is on the rise, except in Europe and Africa
- Bt cotton is having a positive impact on yields, profits and reduced chemical inputs in India, China, Argentina, Mexico
- Impacts on global food security less clear.

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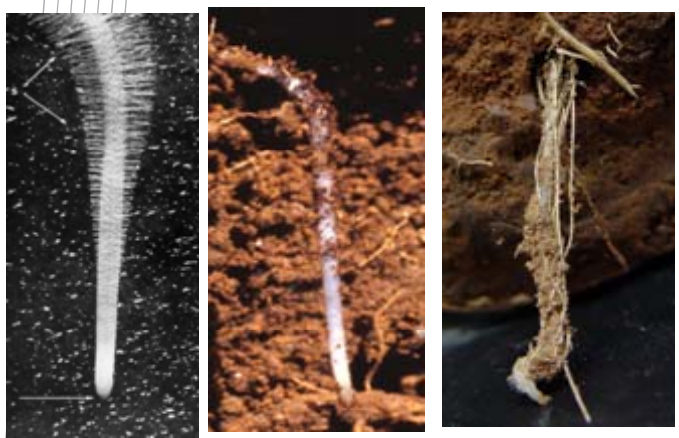
# G x E x M – eg. soil biology

John Kirkegaard

**Understanding**



Lab Tilled No-till

**Farming systems**

**Synergies of new genetics in modern farming systems**

- Soil structure and rhizosphere biology can limit yield In modern intensive no-till wheat by 20%
- Varieties differ in sensitivity to these factors.
- New root genetics related to vigour and exudates can minimise these effects
- Synergies of new root genetics with precision placement of root systems and inputs offer efficiency and productivity gains

**Productivity constraints in modern, no-till intensive wheat of 20% are related to structural and biological constraints to roots in these systems**

# Precision agriculture

**Adoption of PA by Australian grain growers**

- Use of guidance widespread and growing rapidly
- Adoption of VRT 20% (up from 5% in 5 years)
- Appreciate and manage paddock variability (2/3 growers)
- Adopters - educated, have consultant, large farm, more crop
- 70% yield monitor but < half of these map
- Few other data sources are used

*Robertson et al 2010*

# What is holding you back in PA? (WA Study)

| Issue | Esperance | North | Central | Average |
|---|---|---|---|---|
| Software/machine interaction | 38 | 27 | 50 | 38 |
| Data interpretation/complexity | 33 | 39 | 26 | 33 |
| Cost | 13 | 7 | 13 | 11 |
| Time | 4 | 9 | 13 | 8 |
| Not yet convinced | 4 | 9 | - | 4 |
| Inexperienced workers | - | 4 | - | 1 |
| Reliability | - | 4 | - | 1 |

*Robertson et al 2010*

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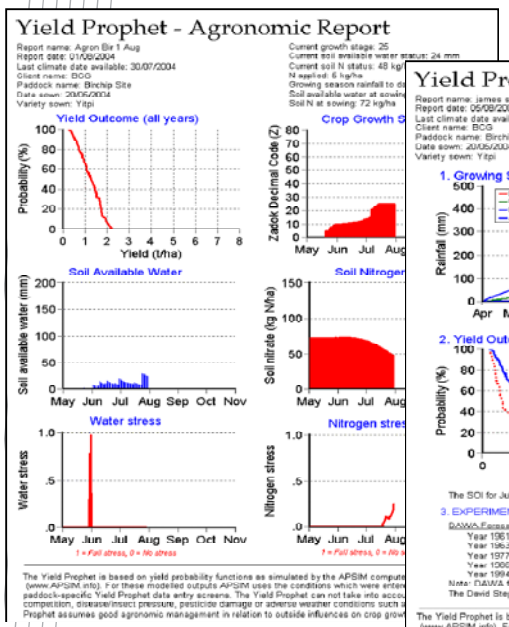
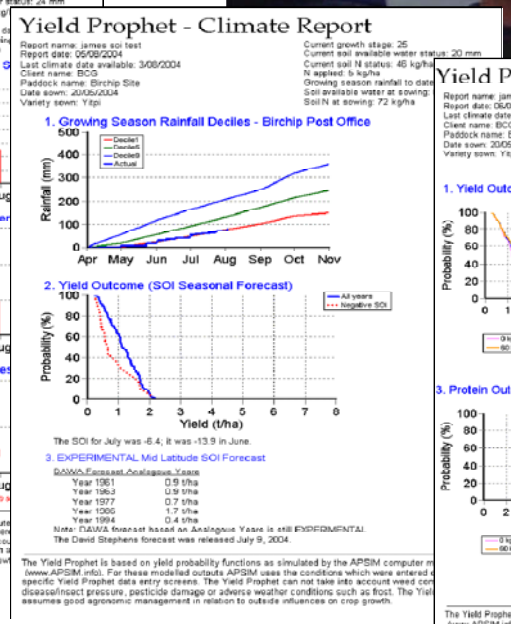
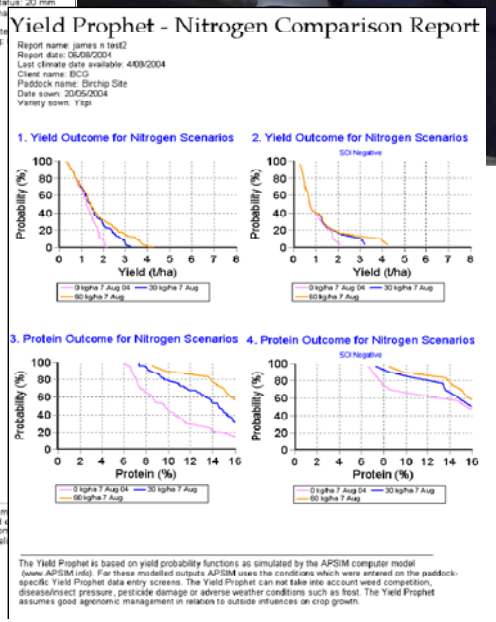
# Climate risk management

www.yieldprophet.com.au


Birchip Cropping Group

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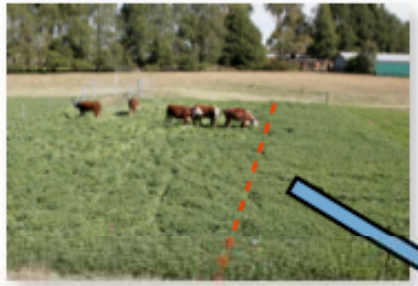
# ICT in Agriculture – “virtual fencing”

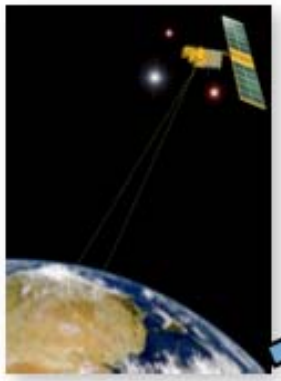
## Sensor networks:

- Gather information about an environment or system at a level of spatial and temporal detail not previously available

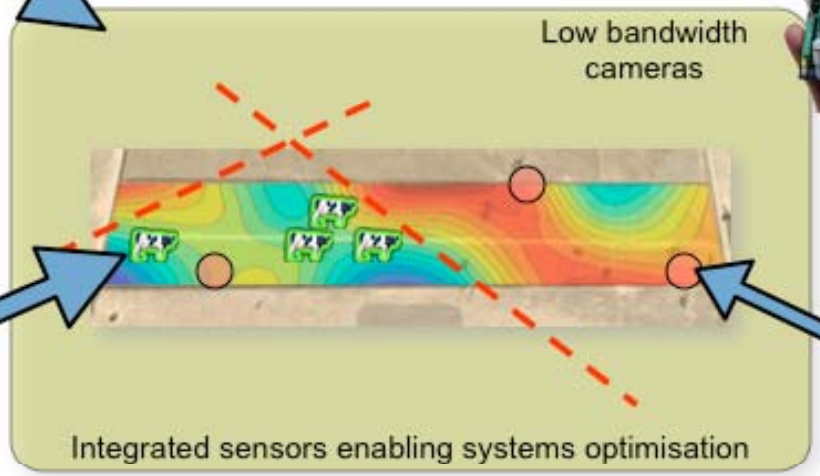


System control e.g. virtual fencing

- Provide industry tools e.g. virtual fencing
- Link science and application
- Built around multi-disciplinary teams
- Address system goals e.g. nutrient fluxes



Remote sensing linked to ground based sensors

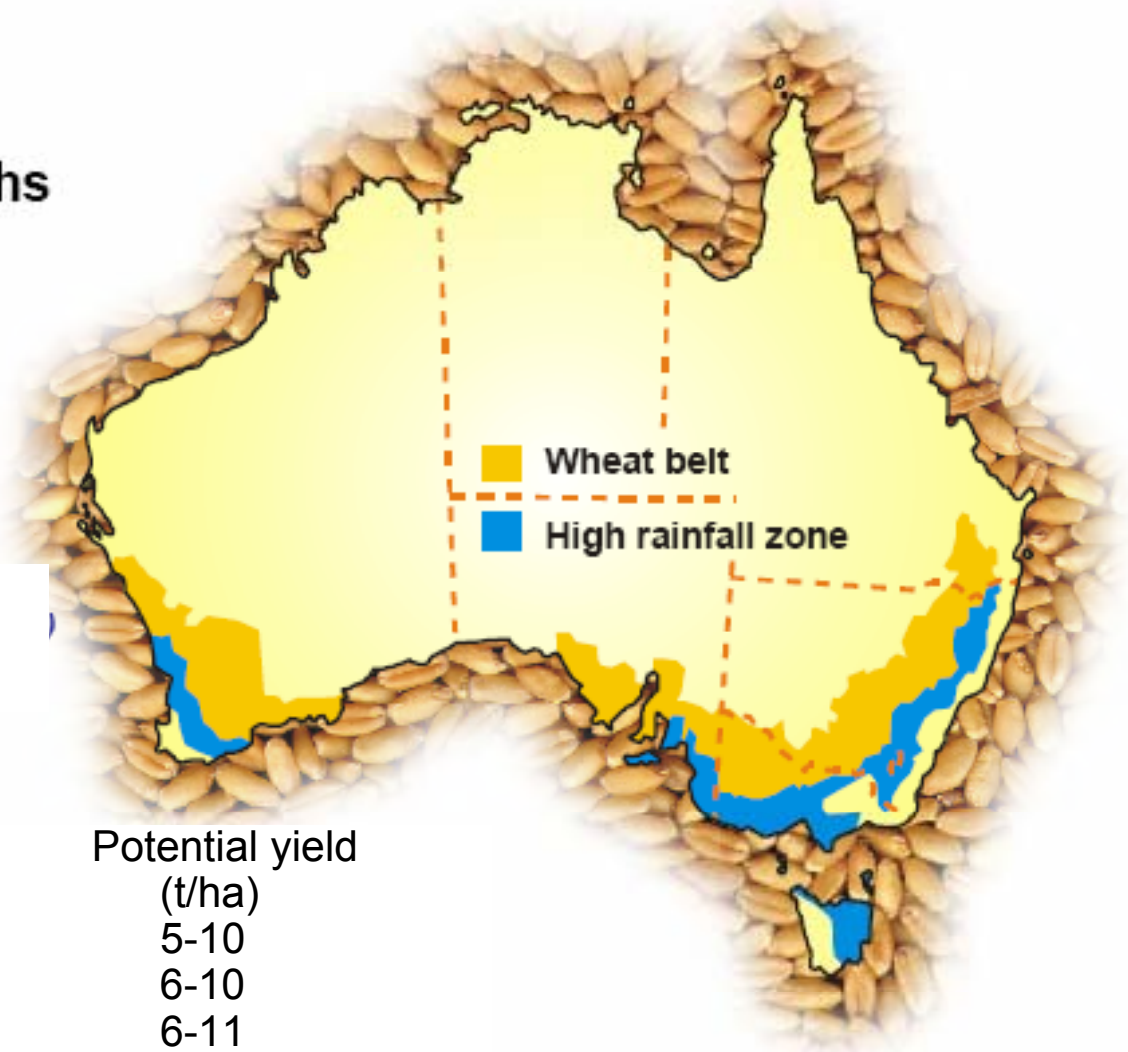


# Improved irrigation water use efficiency

- Returns on use of irrigation water supplies can be increased significantly
- Whole farm decision making – managing in face of uncertainty in allocations
- Research at the paddock scale
  - Measuring devices and systems to help
  - infrastructure investment decisions
  - Simple water balance programs
  - Control of storage evaporation
  - Improved rainfall infiltration
  - Soil characterisation for PAWC
- Degradable polymer film

# New commodities or regions – high rainfall zone (HRZ)

| | |
|---|---|
| Growing season | > 9 months |
| Total area | 32 Mha |
| Area for farming | 20 Mha |
| Arable area | 2-6 Mha |




Requires adapted varieties and soil management techniques

| | Area (ha) | Average Yield (t/ha) | Potential yield (t/ha) |
|---|---|---|---|
| NSW | 900,000 + | 2.5 | 5-10 |
| Vic | 400,000 + | 2.5 | 6-10 |
| Tas | 25,000 + | 2.5 | 6-11 |
| SA | 200,000 + | 2.3 | 4-8 |
| WA | 1,400,000 + | 1.5 | 4-10 |

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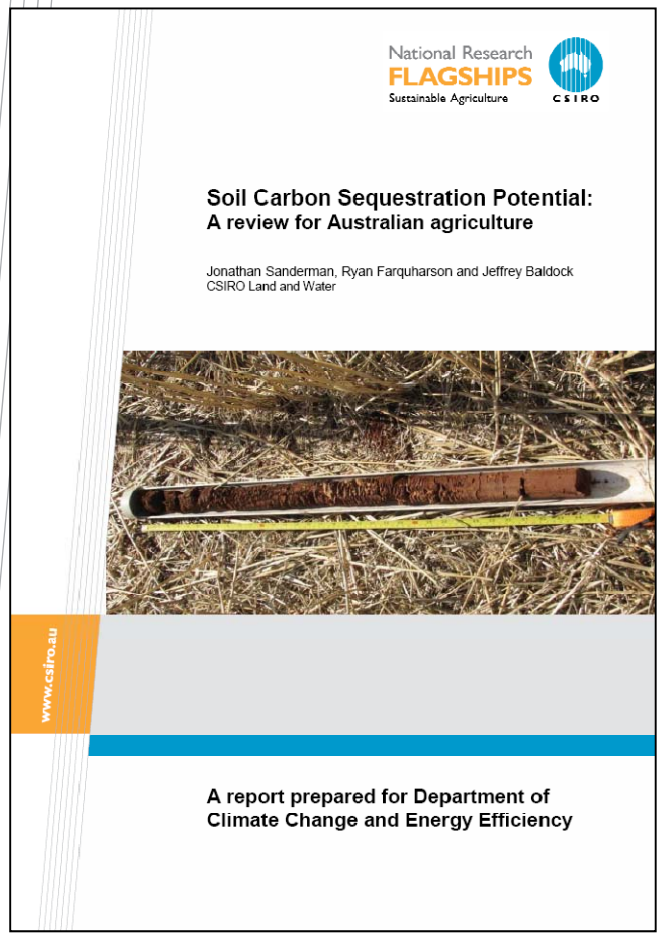
# Soil carbon sequestration




- Reviewed available trial data on soil C change in response to management
  - Reports data for 96 trials and/or treatments across Australia
- Rates of soil C change with "C friendly" management
  - Within cropping or grazing management in range **0.1 to 0.3 Mg C ha$^{-1}$ yr$^{-1}$**
  - Conversion of cultivation to permanent pasture in range **0.5 to 0.6 Mg C ha$^{-1}$ yr$^{-1}$**
- Many current systems are still running soil C down so some "C friendly" practices simply reduce this rundown rate

Available at
http://www.csiro.au/resources/Soil-Carbon-Sequestration-Potential-Key-Findings.html

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# Our track record is impressive ….

- Agriculture developed over 10,000 years ago
  - Domestication of crops & livestock
- 1st Agricultural Revolution 1750 to 1850
  - Co-evolved with the industrial revolution in Europe
  - Development of animal traction and improved agronomy
- 2nd Agricultural Revolution 1950 to 2000
  - Doubling of global production
  - Underpinned by cheap fossil fuels for mechanisation and fertilisation
  - Rapid gains due to systematic plant breeding combined with expansion of land, water, nutrient and energy usage
  - BUT - Massive greenhouse load on atmosphere

# ….. our task ahead is critical.

- 3rd Agricultural Revolution 2000 to 2050 ??
  - To double food and fibre production from current land, water, nutrient and energy inputs with much reduced greenhouse gas outputs
  - Will need a revolution in “resource use efficiency”
- 21st Century Agronomy will be;
  - integrative and predictive systems science
  - Linked to climate and atmospheric science, ecological science, social and economic science
  - Delivered through policy development for government alongside traditional links with landholders and industry

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# Thank you

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