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Meeting the productivity and sustainability challenges to Australian agriculture

CSIRO Sustainable Agriculture Flagship

Peter Carberry

National Research FLAGSHIPS Sustainable Agriculture

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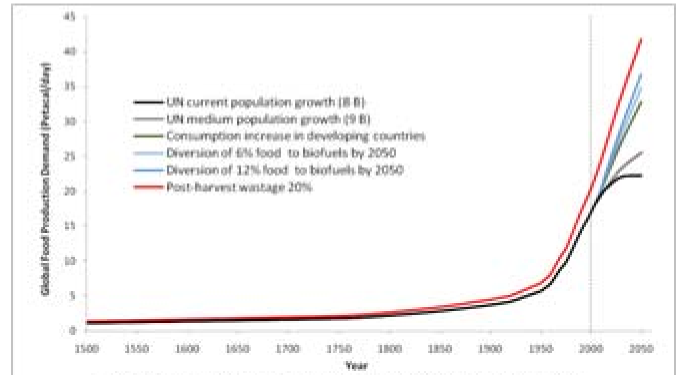
In summary

- Global demand for agricultural production of food commodities is increasing
  - as world population increases, diets change and the demand for alternative uses of food products grows
- But there has been a slowdown in productivity growth in the world's major crops
  - Productivity growth in Australia's cropping industries has also slowed
- What are the pathways for increasing productivity?
  - Technologies have been adopted over the past 30 years
  - What technologies are on the horizon?

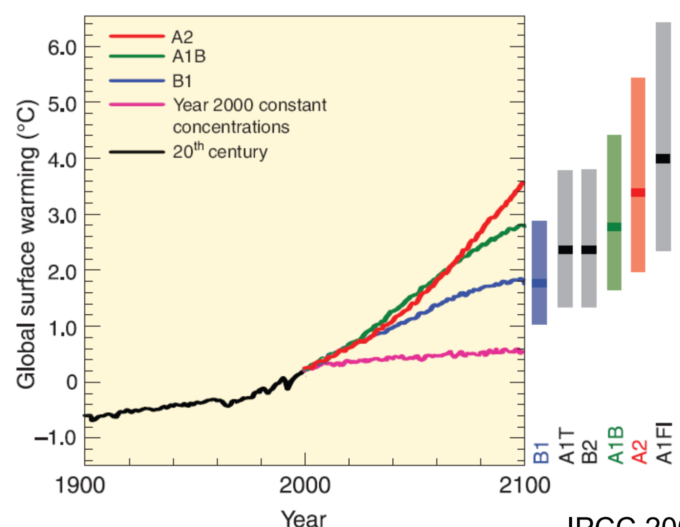
Global challenges

- 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 & Carberry. 2010)



IPCC 2007

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Sustainable Agriculture Flagship

To secure Australian agricultural and forest industries by increasing productivity by 50% and reducing net carbon emissions intensity by at least 50% between now and 2030.

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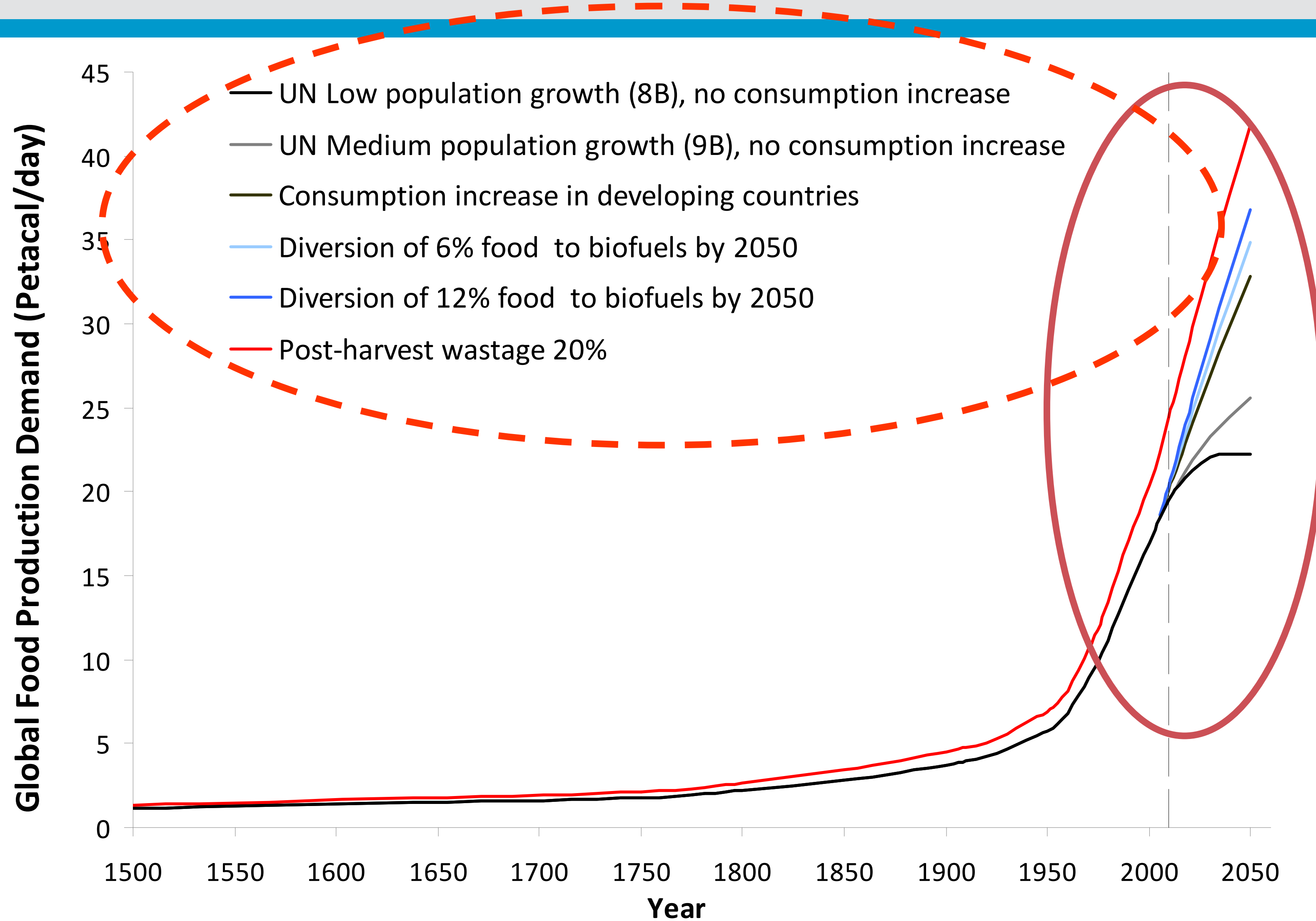
The food demand challenge – in perspective



Keating & Carberry, 2010

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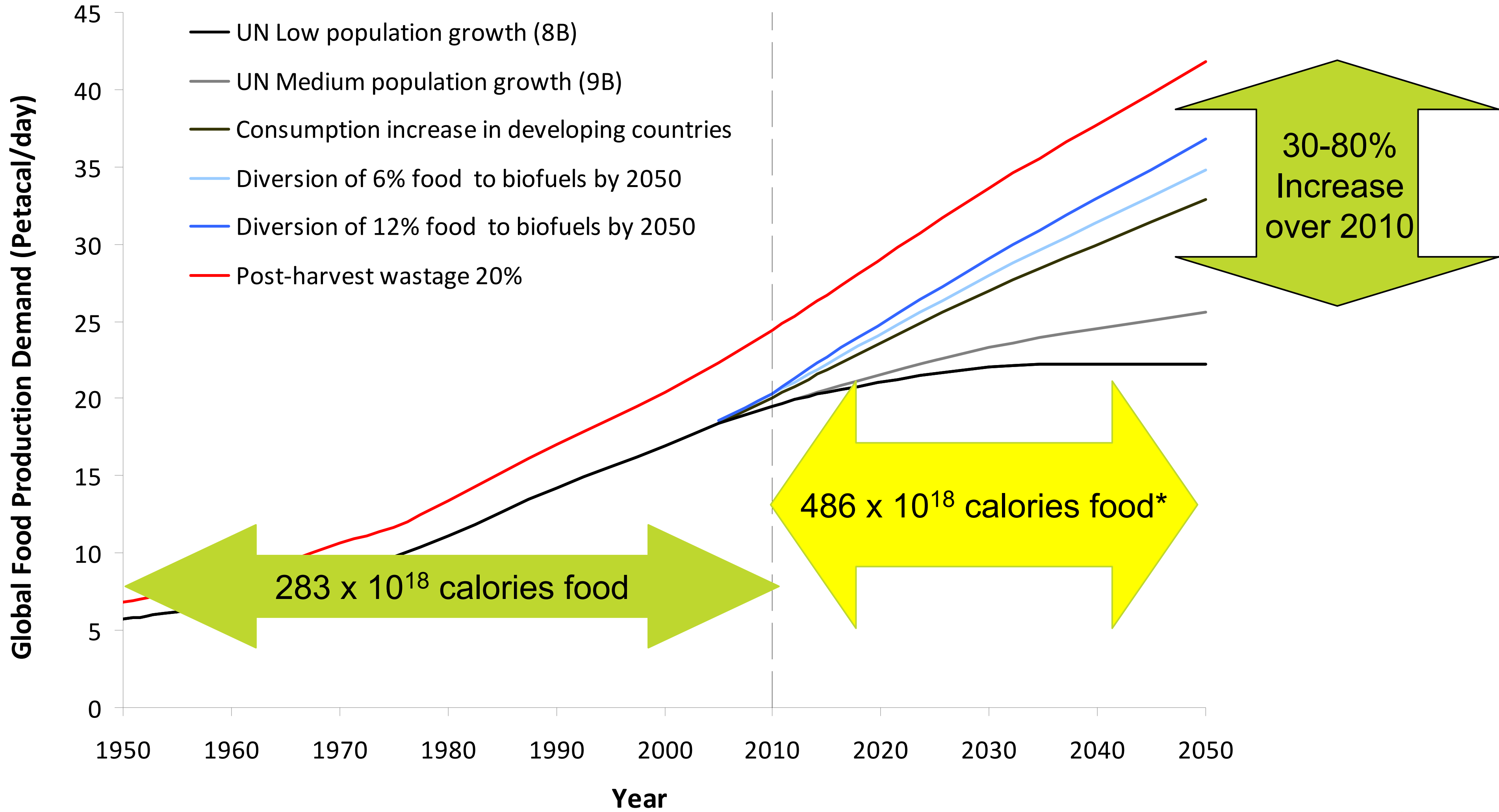
The food demand challenge



Keating & Carberry, 2010

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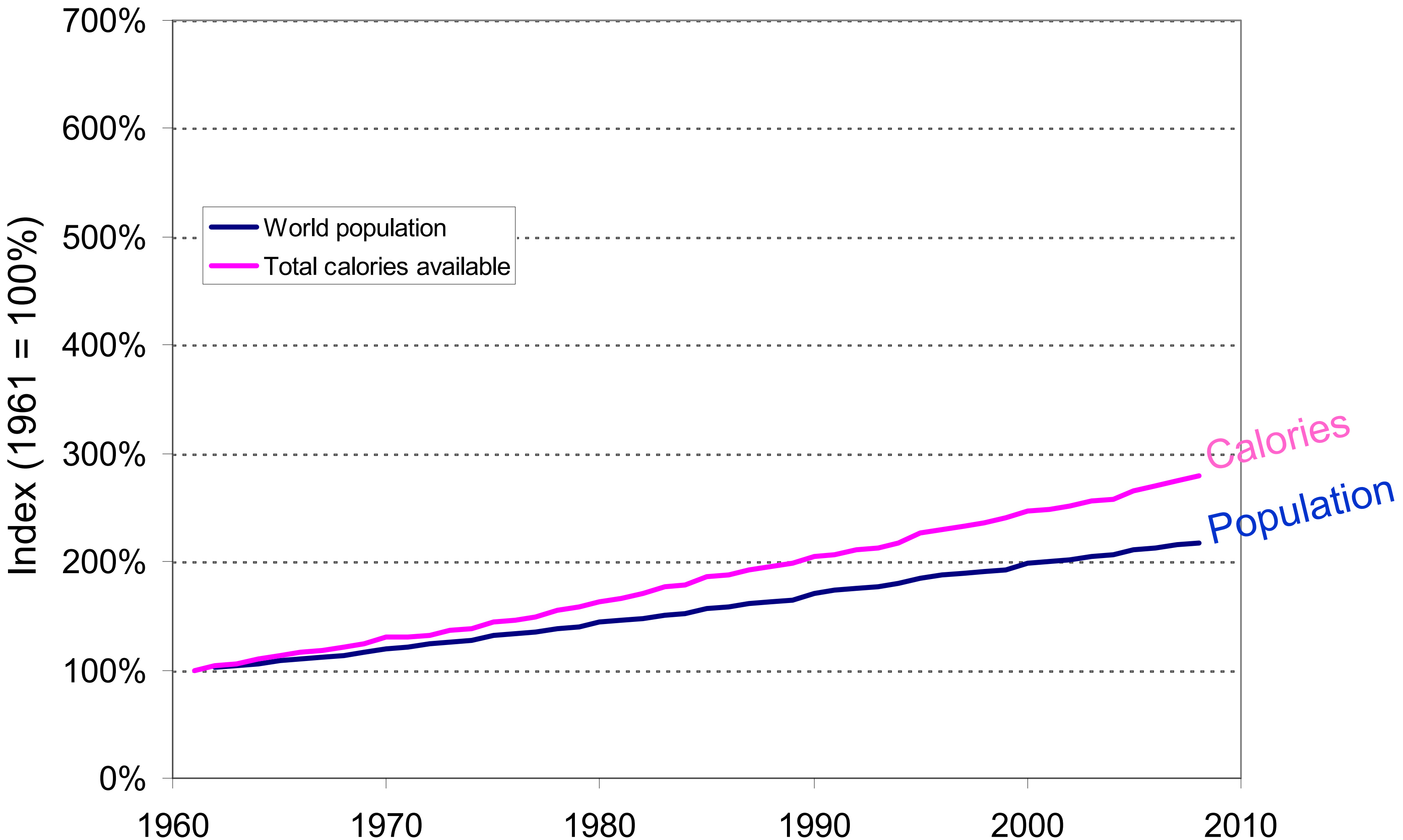
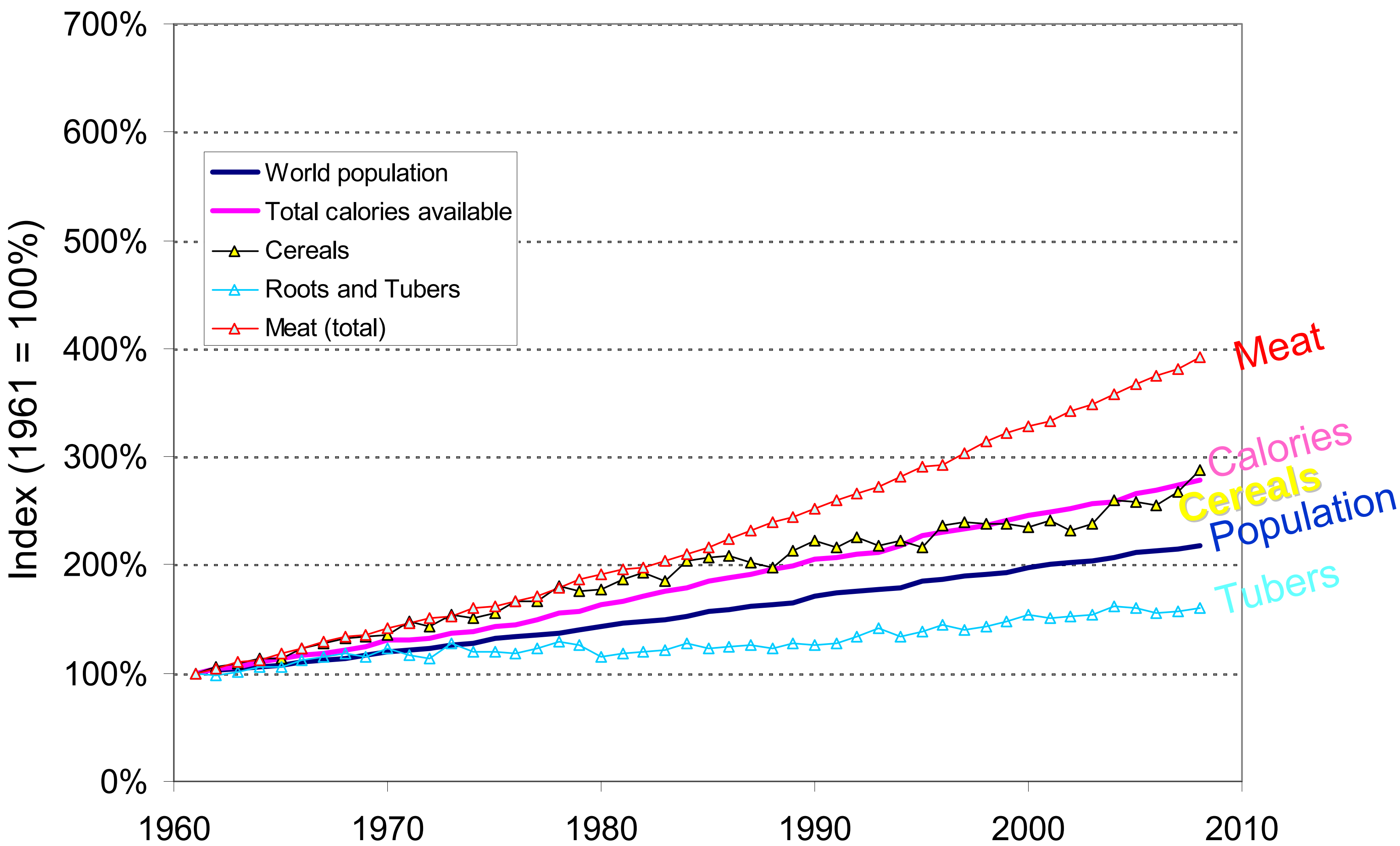
The food supply challenge – looking back



Keating & Carberry, 2010

The food supply challenge – looking back



Keating & Carberry, 2010

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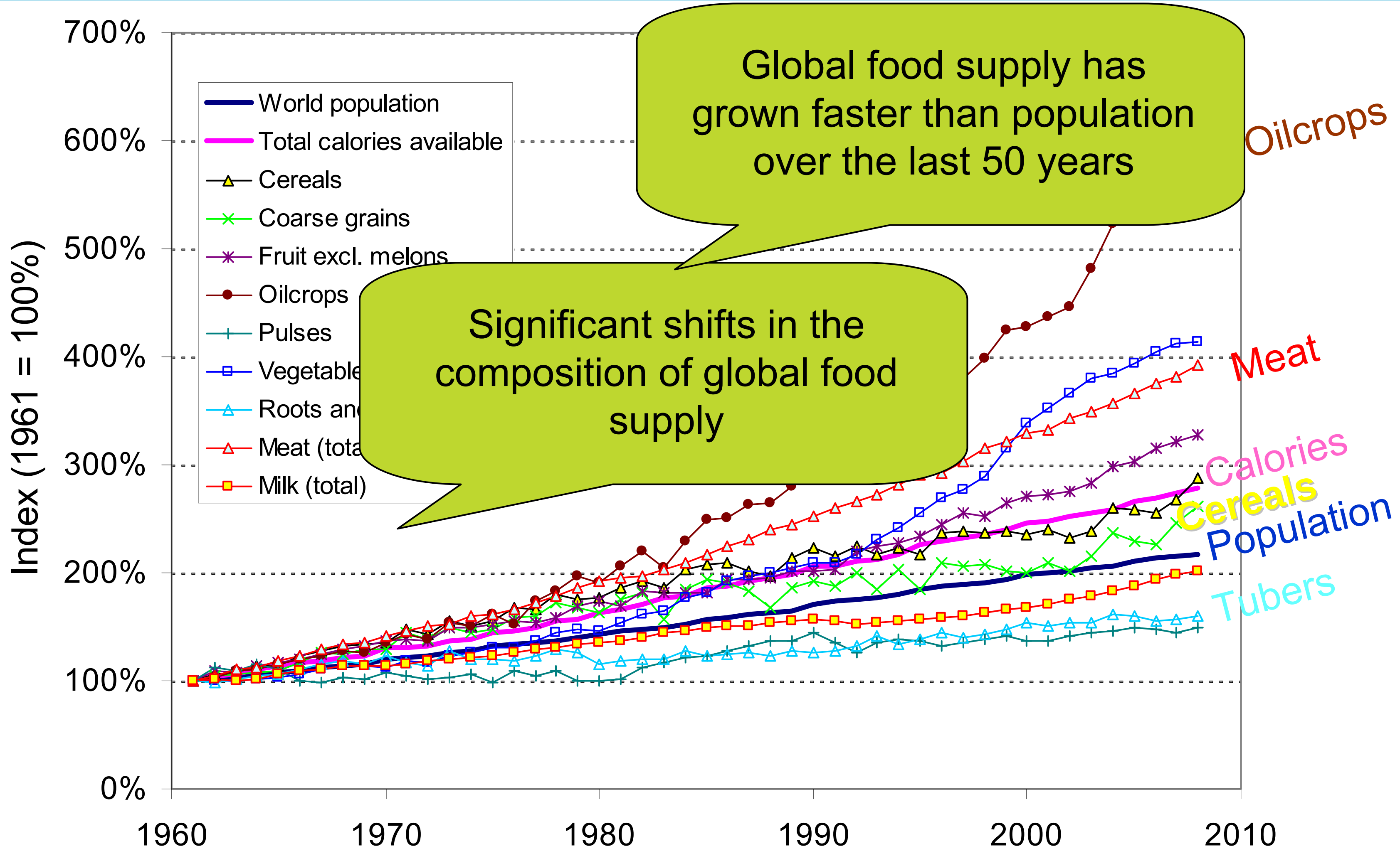
The food supply challenge – looking back



Keating & Carberry, 2010

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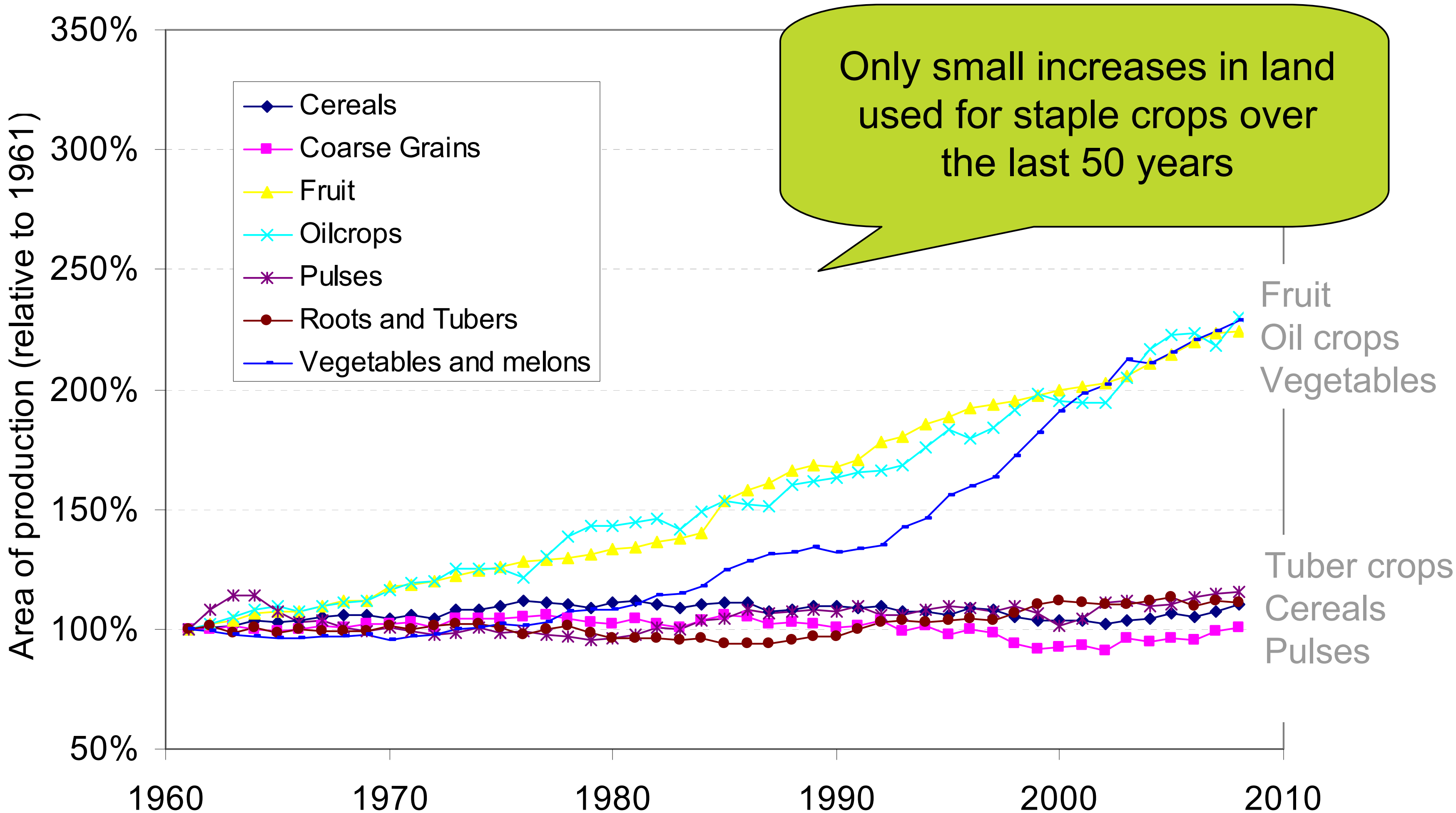
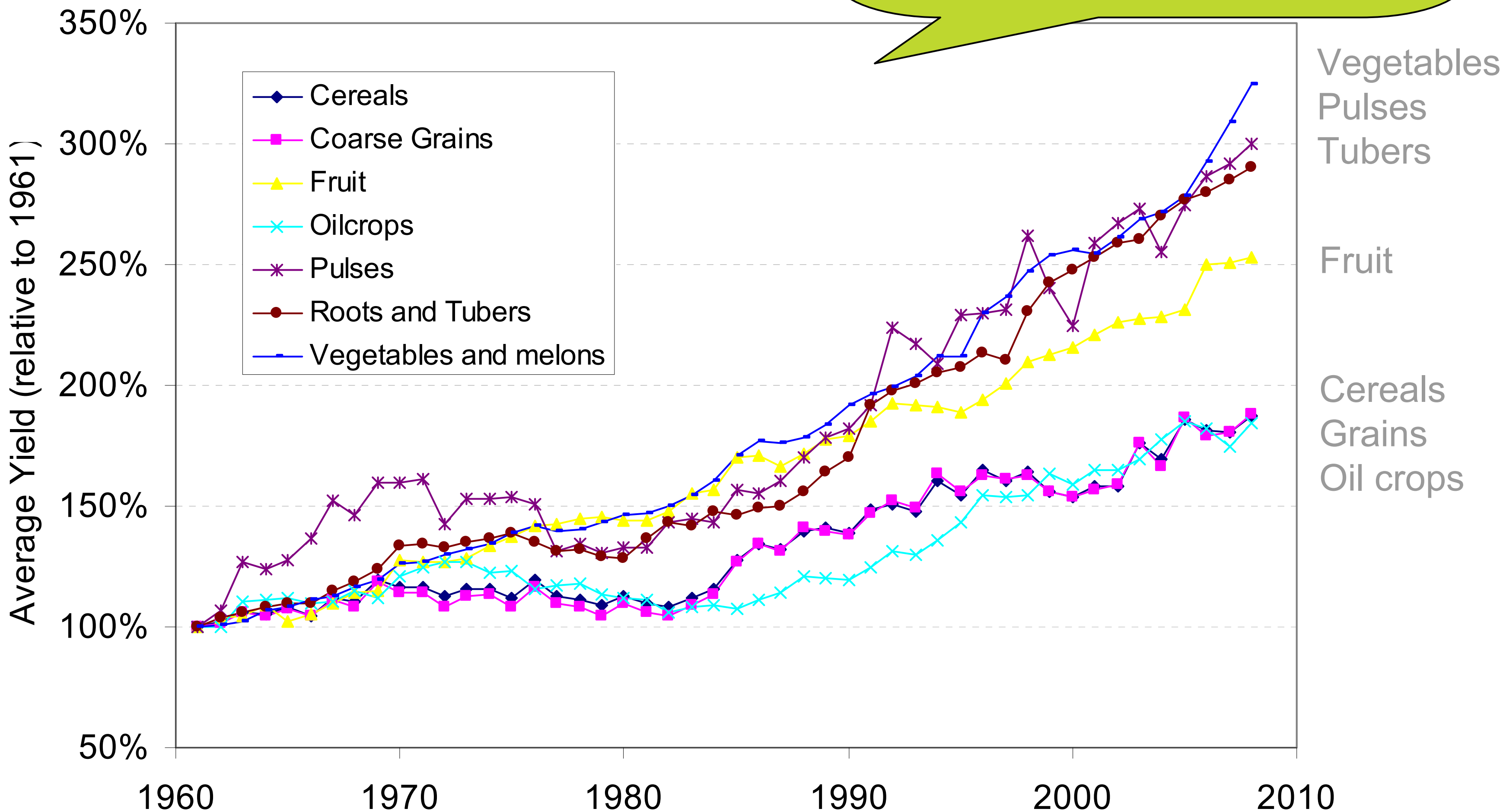
Land area devoted to global food production



Global average yields

Dramatic increases in crop yields over the last 50 years



The food supply challenge: in summary

- **Looking back 50 years**
  - 117% increase in world population
  - 179% increase in total calories produced
  - Land devoted to major staples increased by less than 15%
  - Average yields of major staples doubled or more
  - 400% increase in meat production
  - Major increases in input use
    - 7 times more N fertiliser, 3 times more P fertiliser, 2 times more irrigation
  - Major impacts on biodiversity and natural resources

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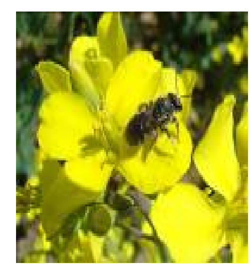
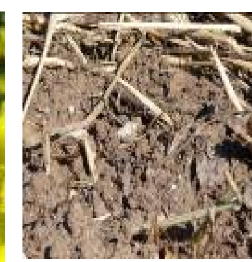
The food supply challenge: in summary

- **Looking forward to 2050 …**
  - Input resources more constrained
  - Land and water increasingly contested
  - Greenhouse mitigation imposes new constraints
  - Uncertainties arising from climate change
  - Continuing demographic shifts
    - Geography of production and consumption
    - Economic development and diet
- **Implications**
  - Raising efficiency of resource use in food production is critical
  - Trade in food likely to grow in importance
    - Within and between regions

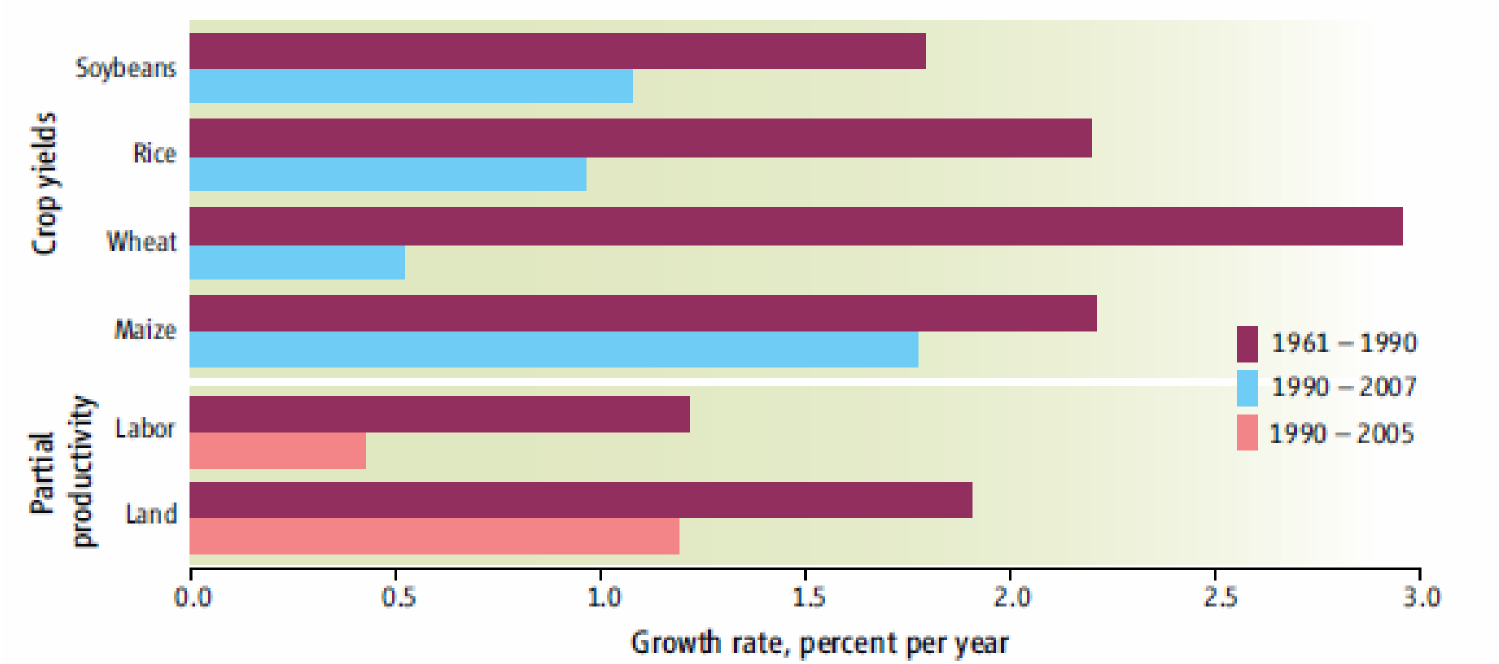


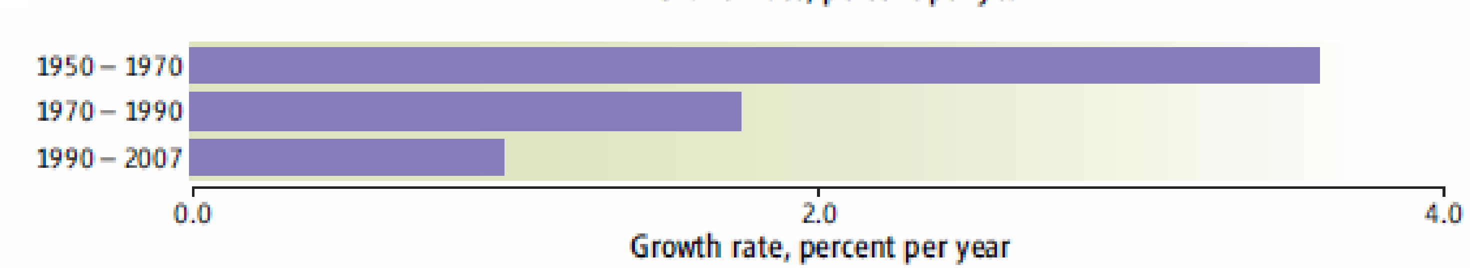


Slowdown in productivity growth in the world's major crops

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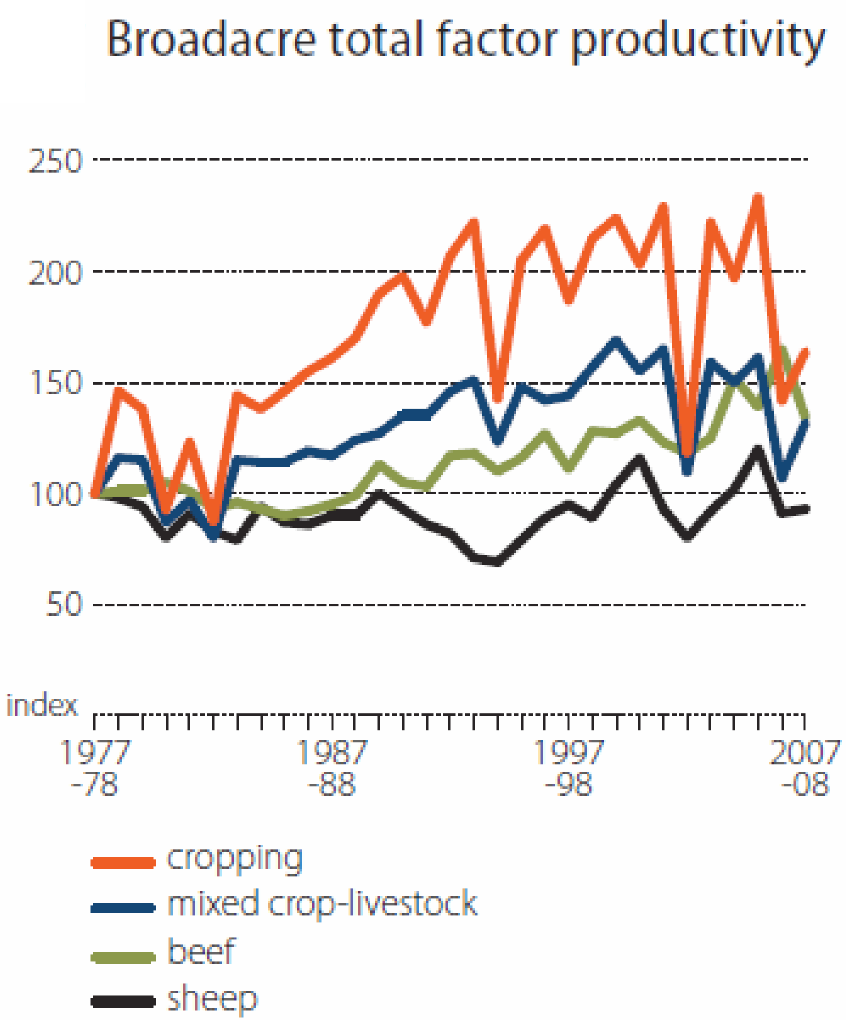
Total factor productivity growth in Australia's cropping industries (ABARE)



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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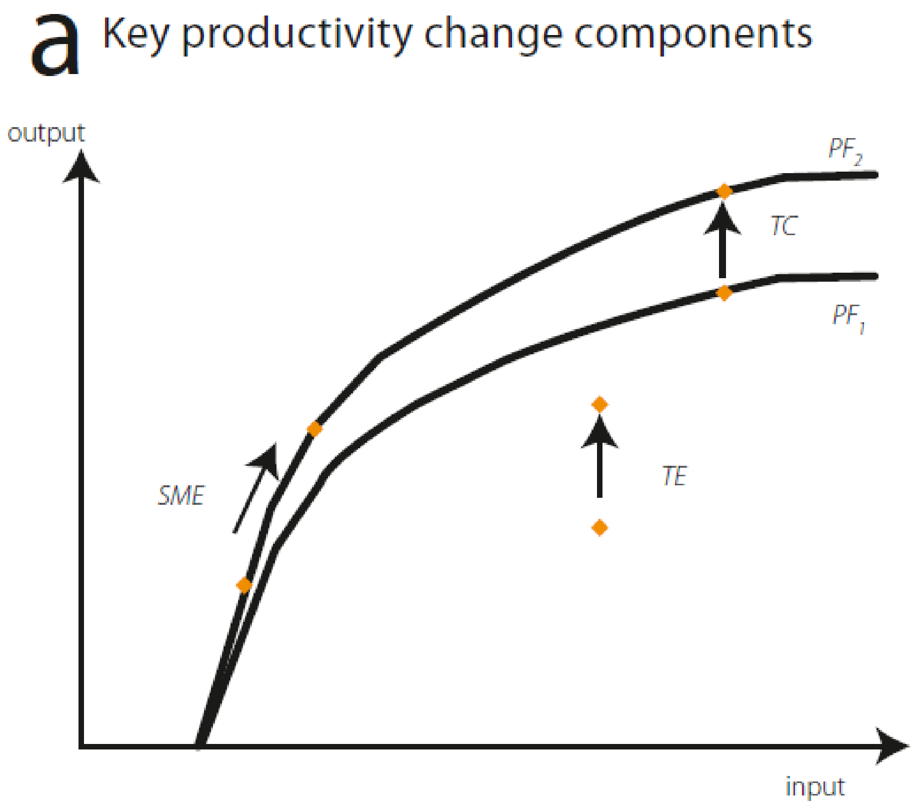
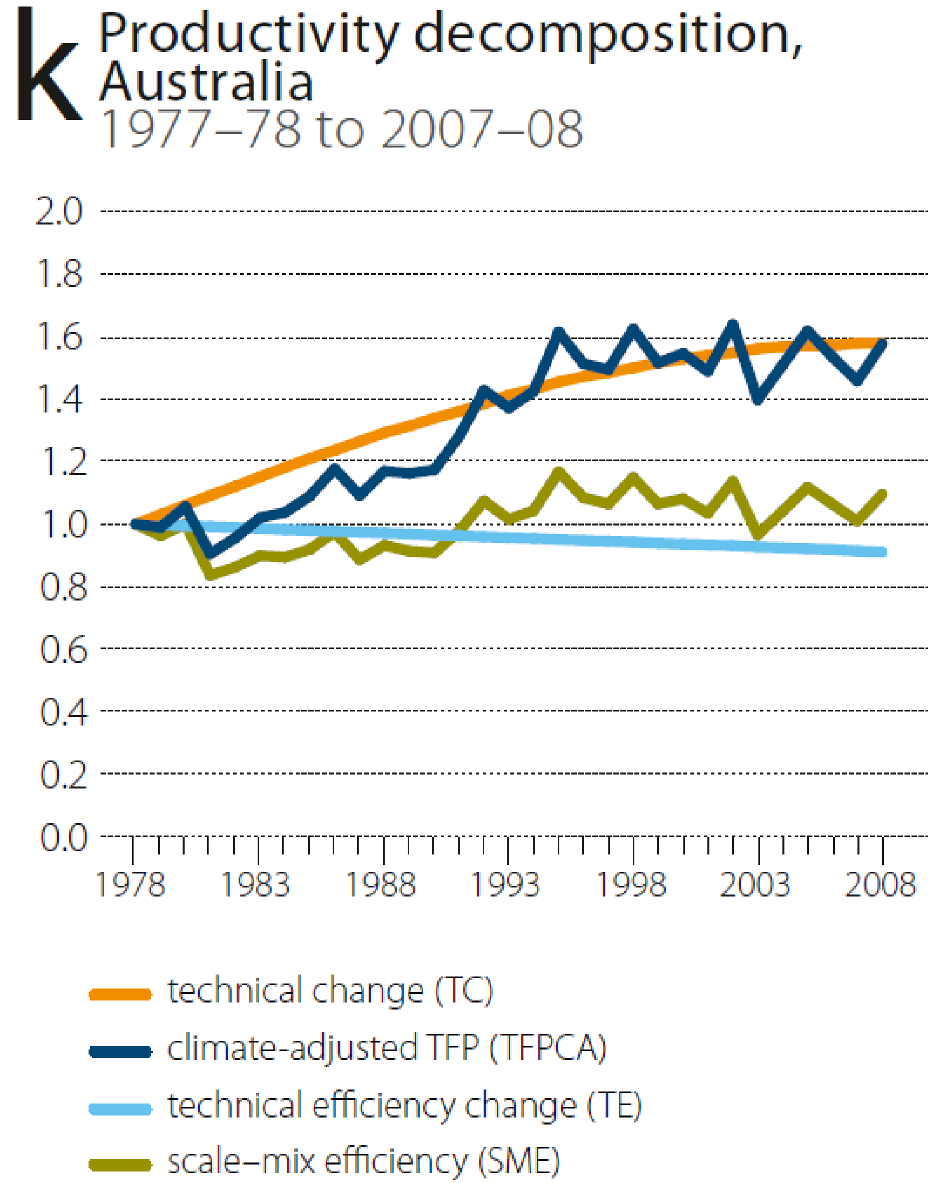
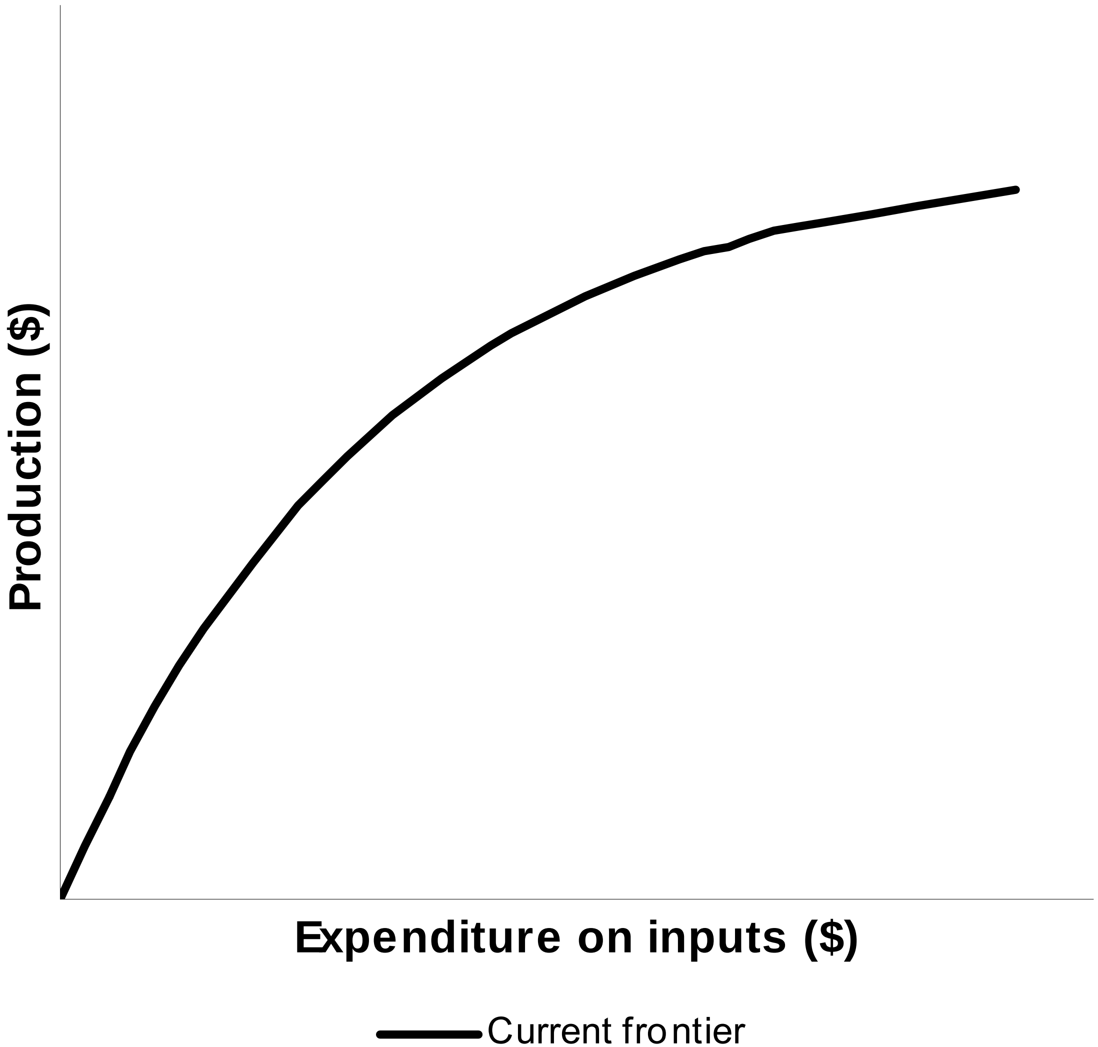
Econometric assessment of productivity

Hughes et al. 2011. ABARES





Investment framework
Production v's investment ($)



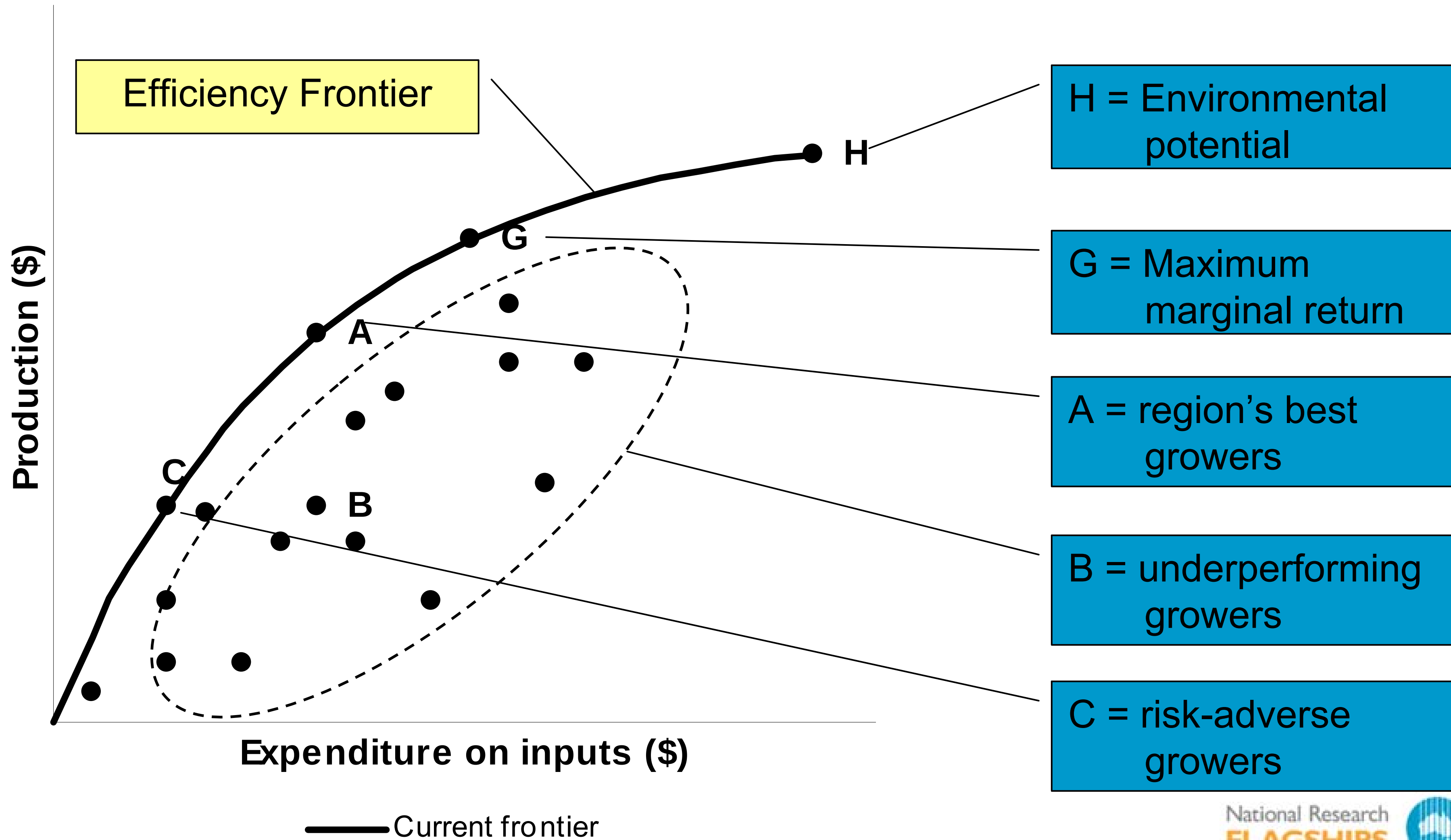
Production – input responses

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

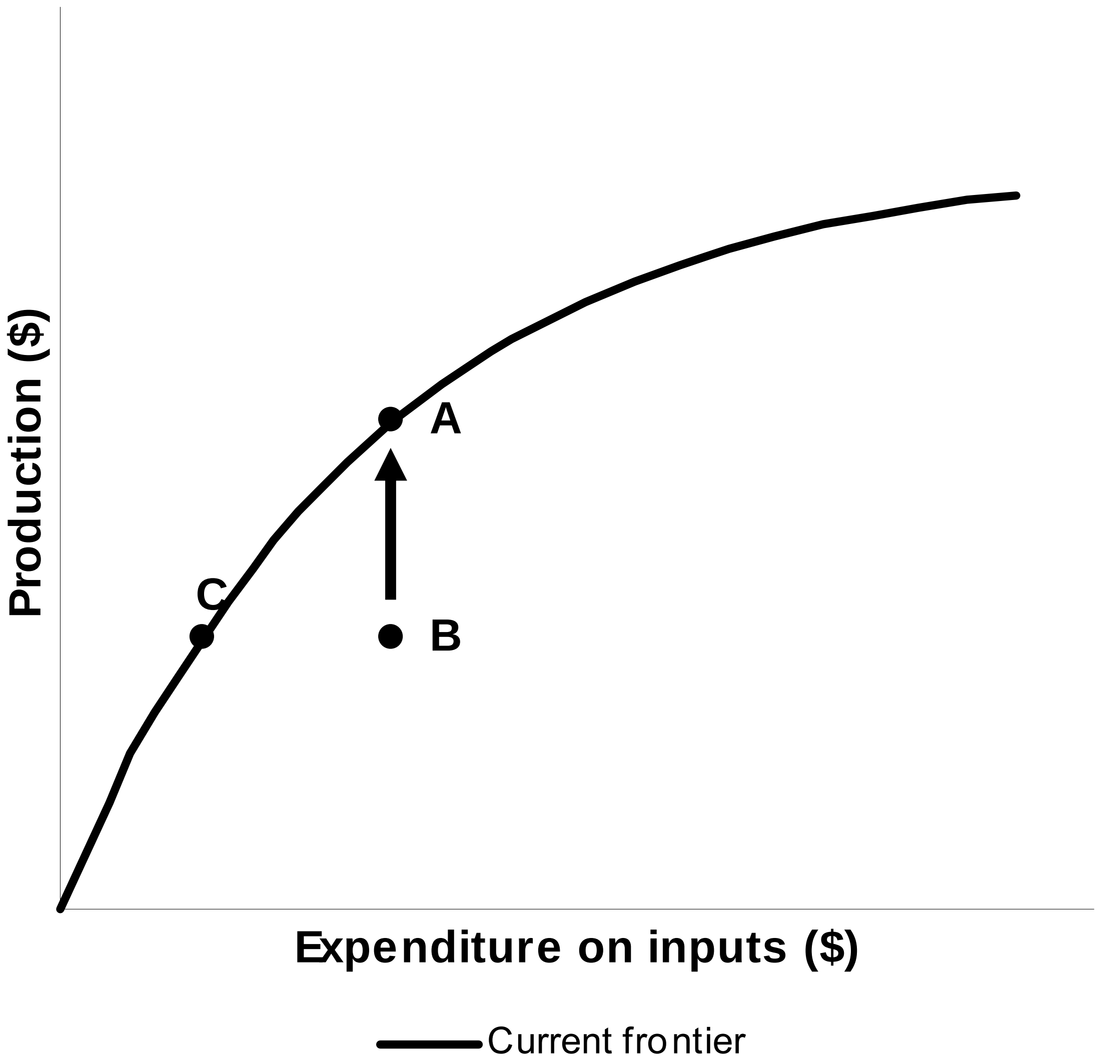
Developed by CSIRO & GRDC

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

Investment framework
map current grower performance



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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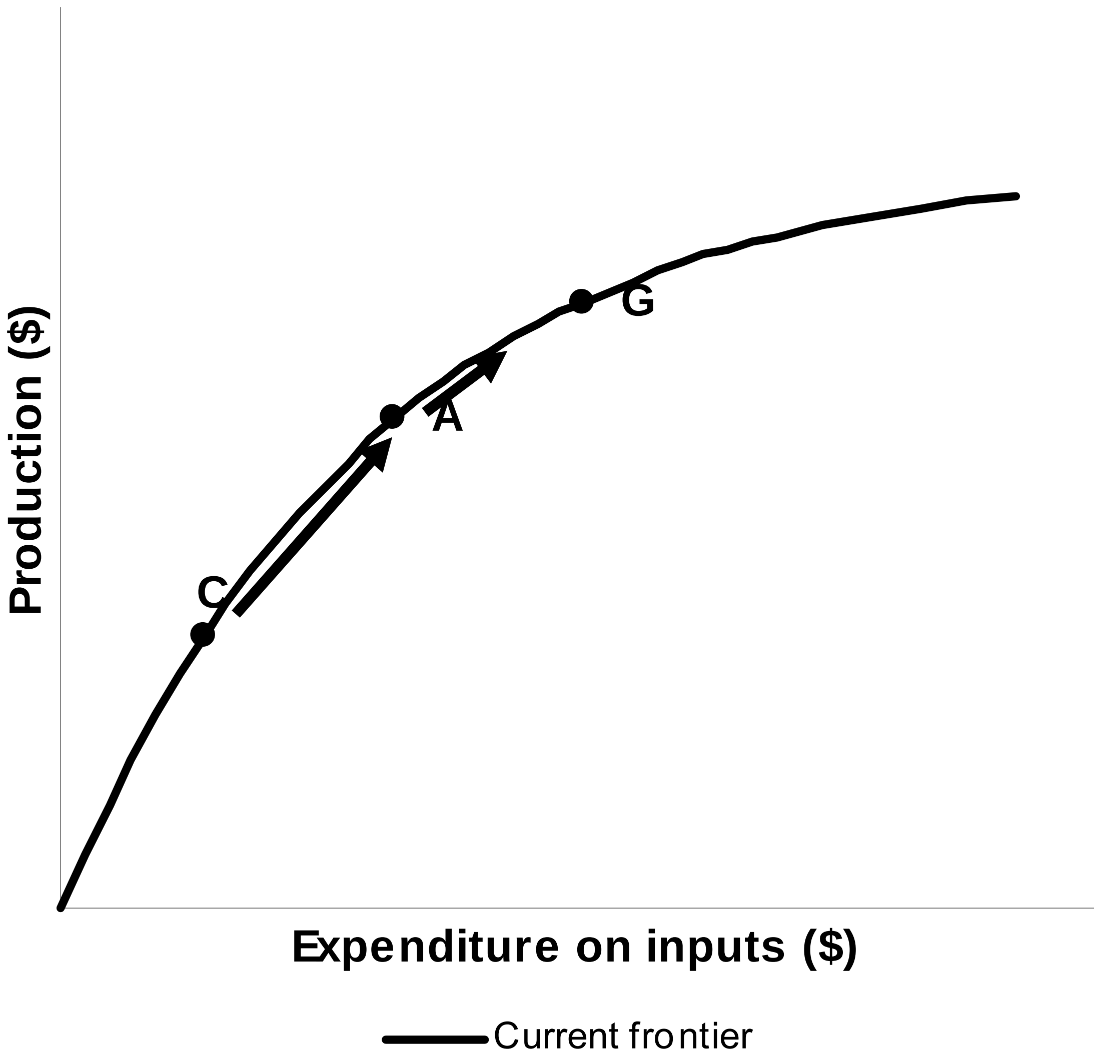
Pathway 2: Encourage growers to adopt risk management practices



- 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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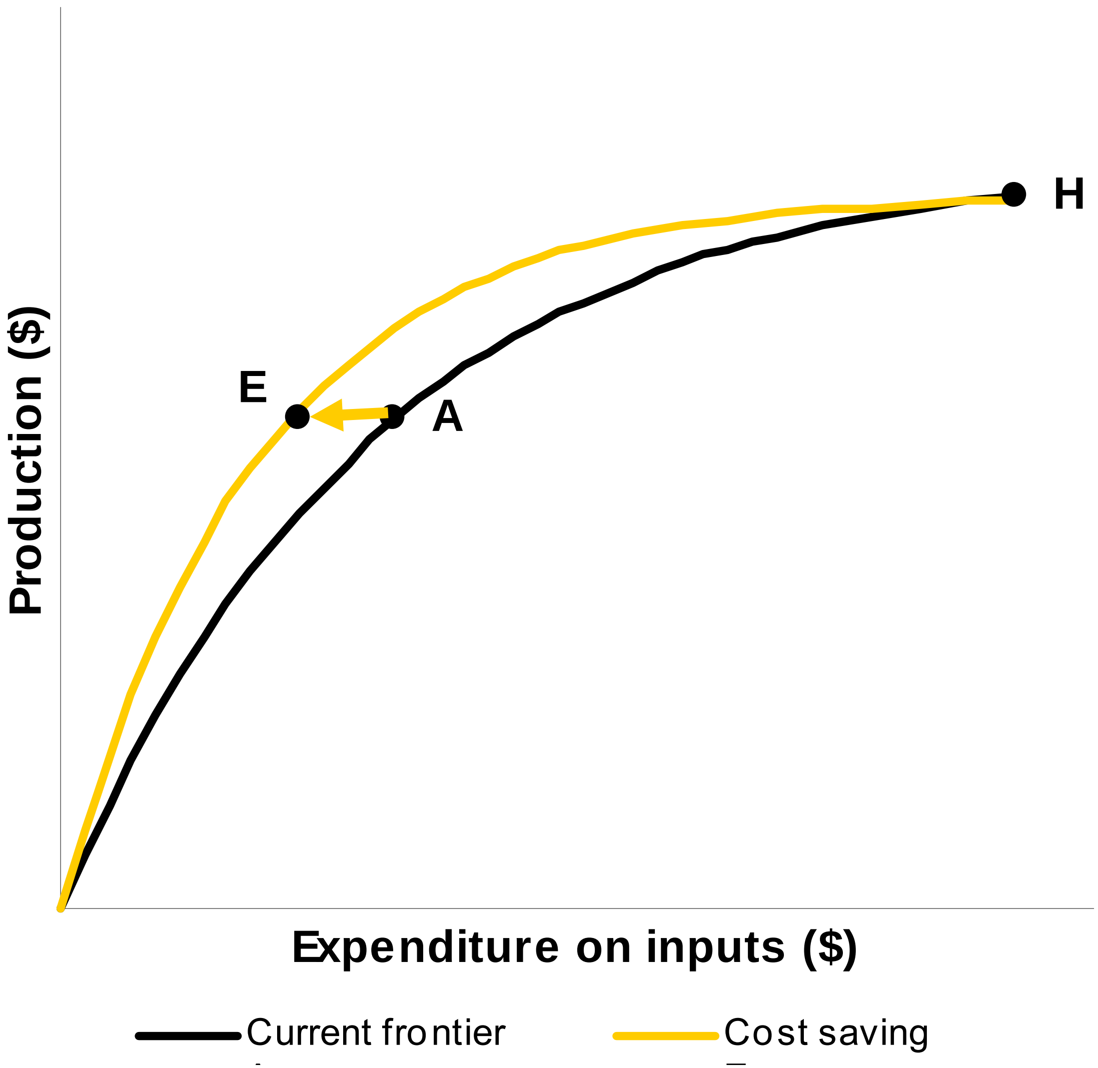
Pathway 3: Increase efficiencies of resource use



- 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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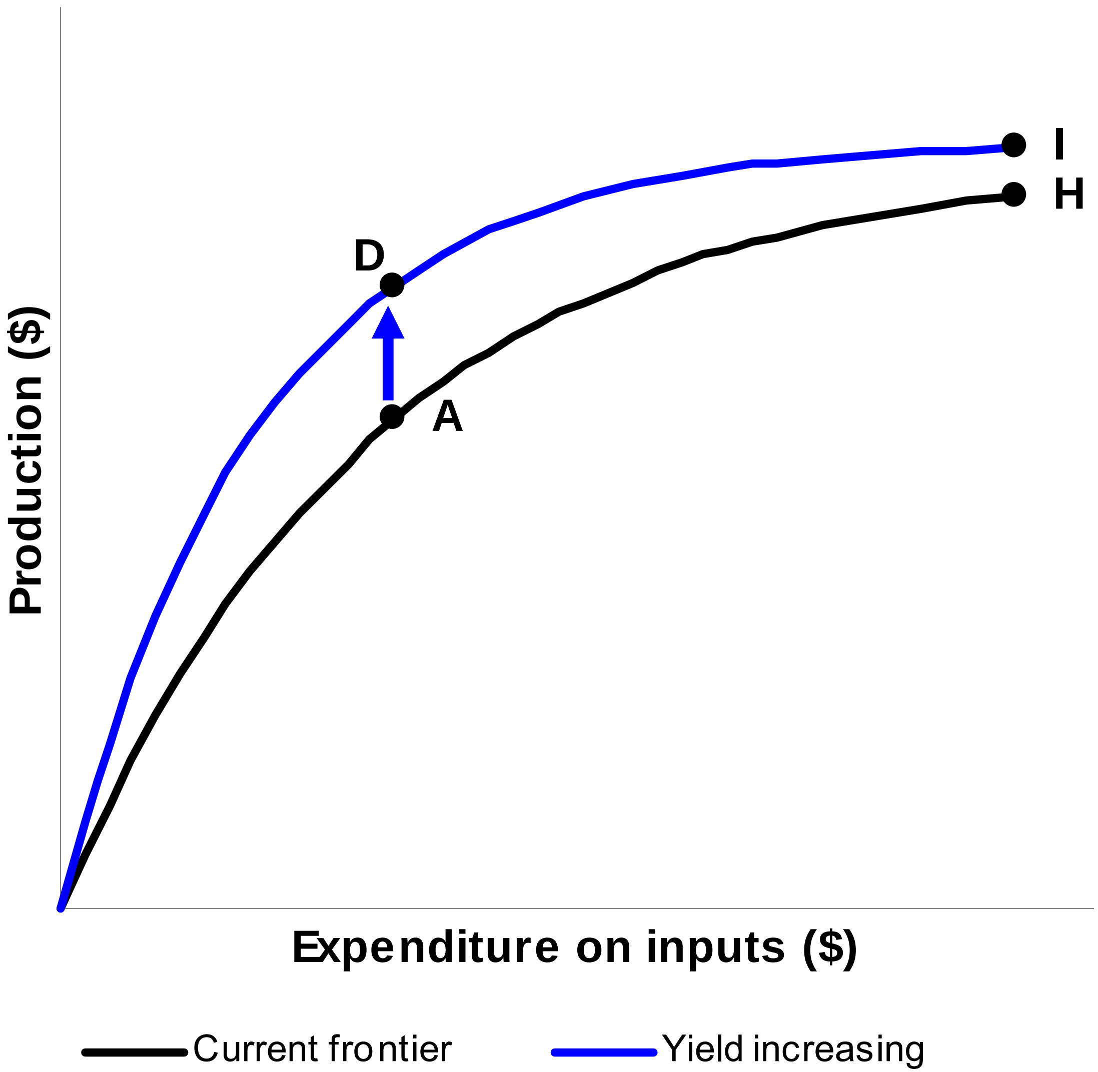
Pathway 4: Create new production frontiers



- 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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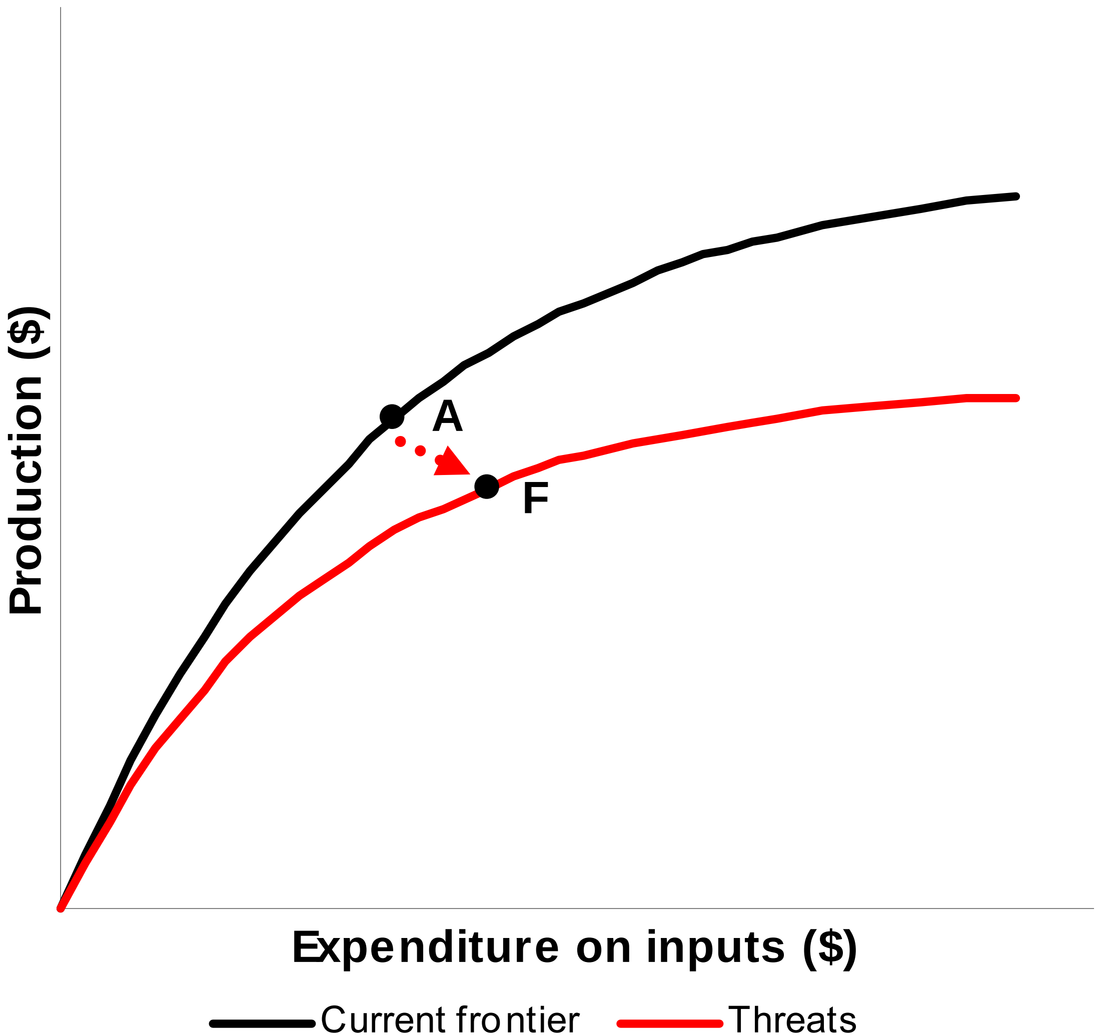
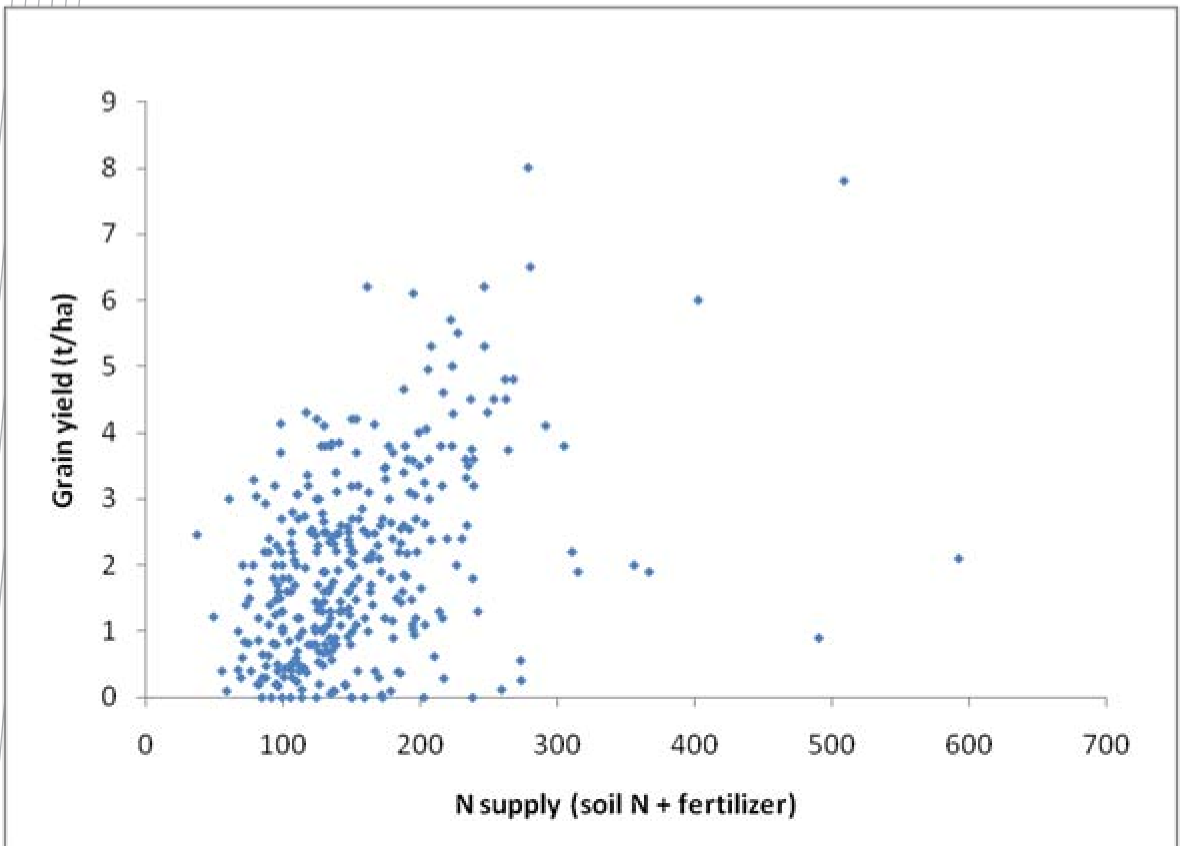
Pathway 5: Maintain current production potential



- 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

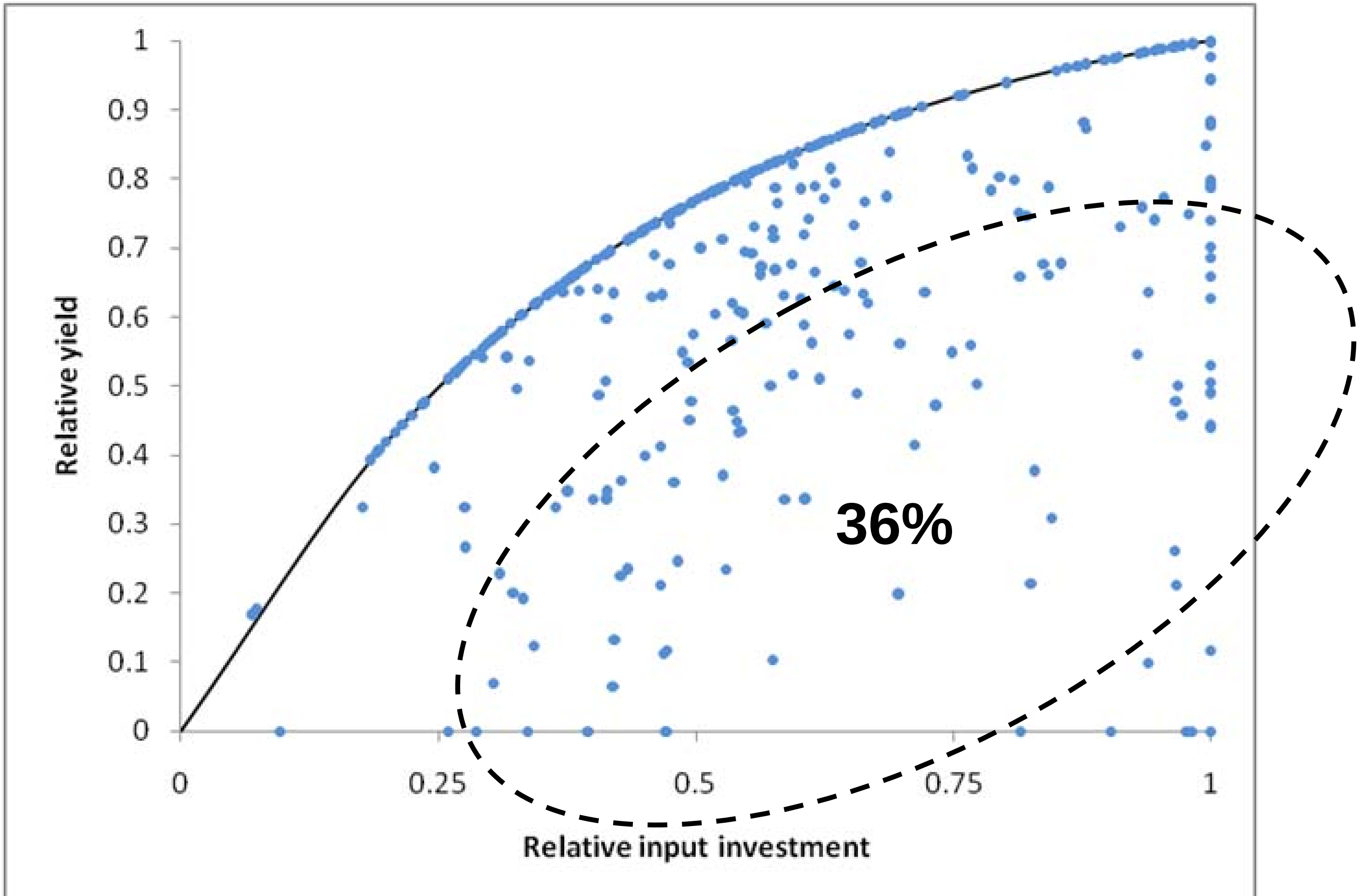
Performance of Yield Prophet farmers

www.yieldprophet.com.au

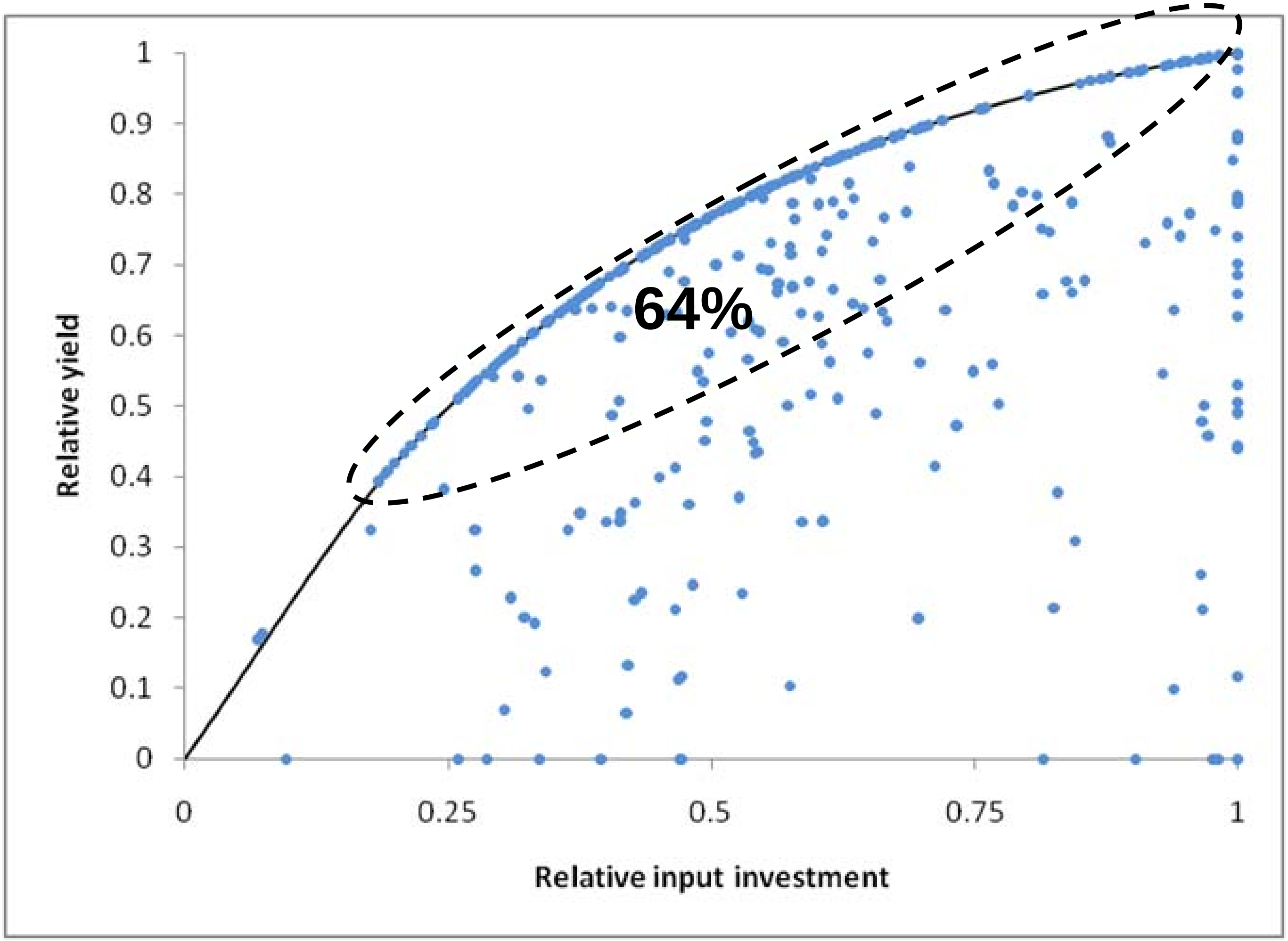


- Internet-based subscriber system to predict current wheat yields and management response using APSIM
- Observed data for 334 commercial wheat crops monitored nationally between 2004-07

Increase production through improved practices



New technologies needed to improve performance



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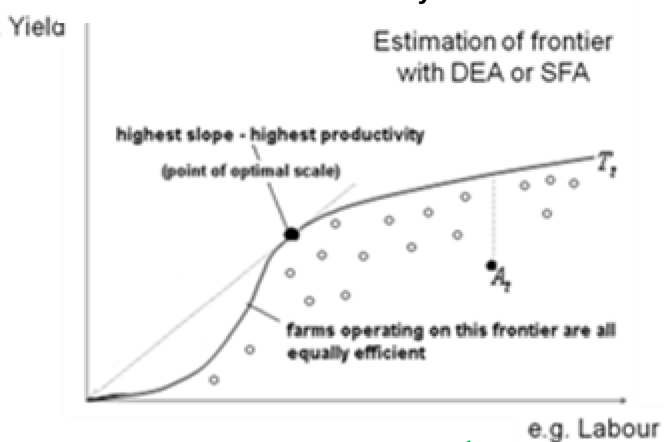
CSIRO-GRDC case study

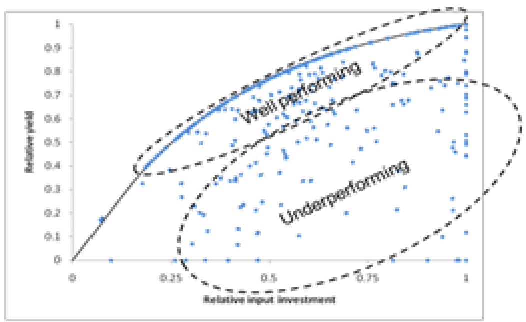
CFI survey data

Farms	47	Crops	282
Paddocks	94	Fallow	318
Seasons	7	Total	600

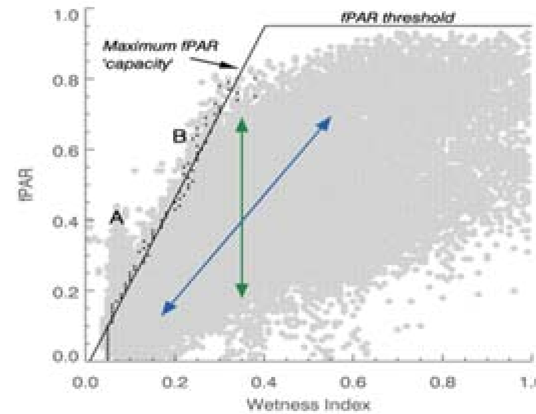
Econometric decomposition of Total Factor Productivity



APSIM simulation of crop performance



Remote sensed assessment of crop performance

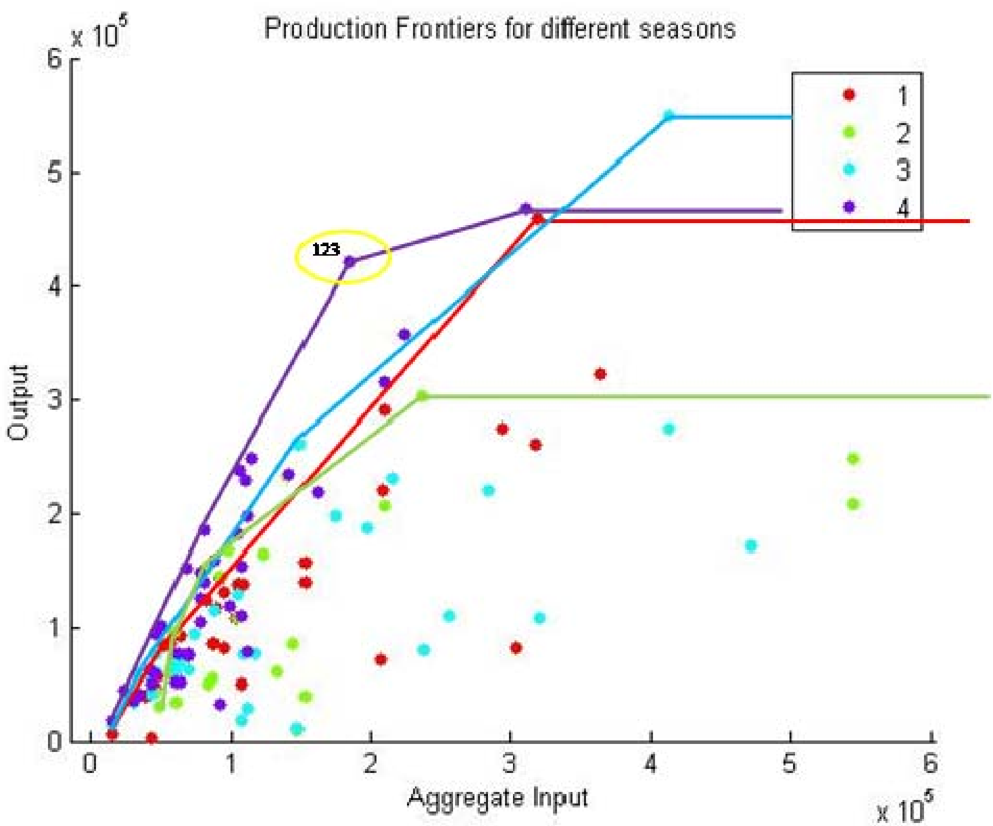


Benchmarked performance of cropping systems in the western region of NSW & Qld

- Proportion of surveyed crops to achieved their potential yields (APSIM)
- Influence of technology availability and adoption, intensity of land use, land use change, land degradation, seasonal conditions, human skills/know-how (Econometrics)

•Extrapolation to regional performance (Remote sensing)

Econometric analysis – benchmark against other crops and years

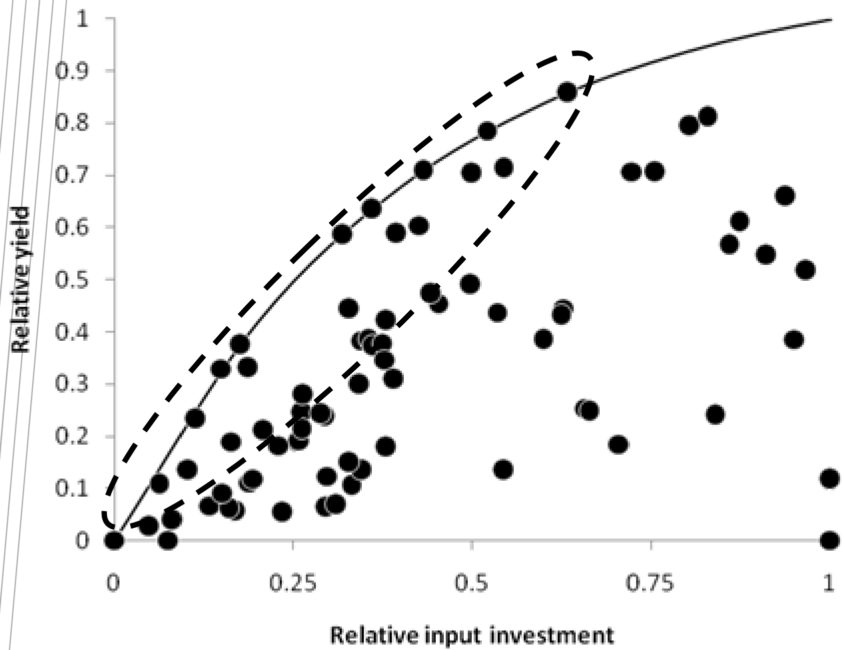


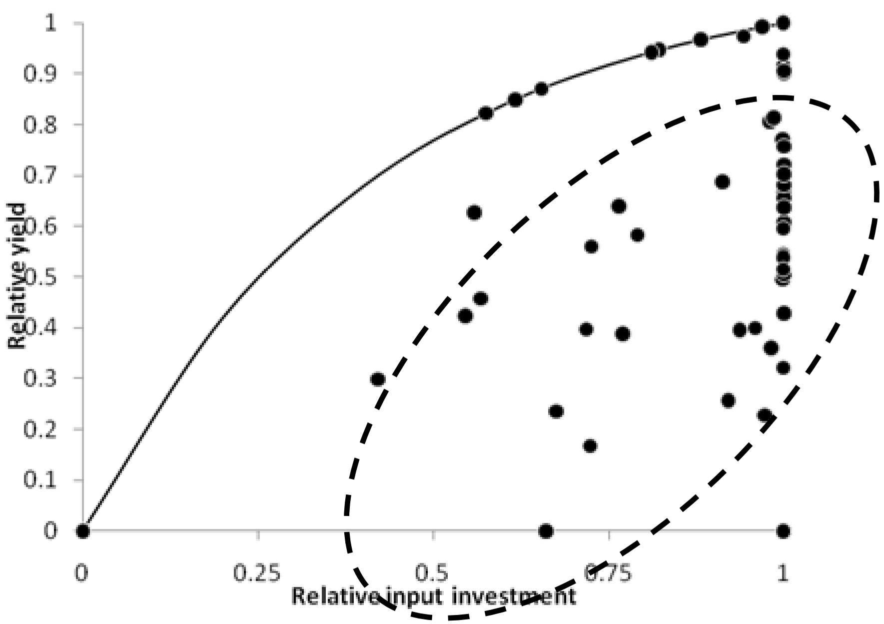
- No technical change observed
- High level of scale efficiency
  - scale change will not be a likely contributor to productivity growth in the short run.
- Average score of around 75% for technical efficiency.
  - A possible big contributor to productivity and output growth in the near future.

Marinoni et al., 2011

Production Frontiers - benchmark against potential & attainable yields (APSIM)

- **Individual crops**
  - Generally low input investment per crop
  - Some crops close to efficiency frontier
  - Technical change required for many growers
- **Crop rotations over 7 seasons**
  - Generally high input over rotation
  - Most rotations were inefficient
  - Low cropping intensity (low risk) the source of inefficiency





Hochman et al., 2011

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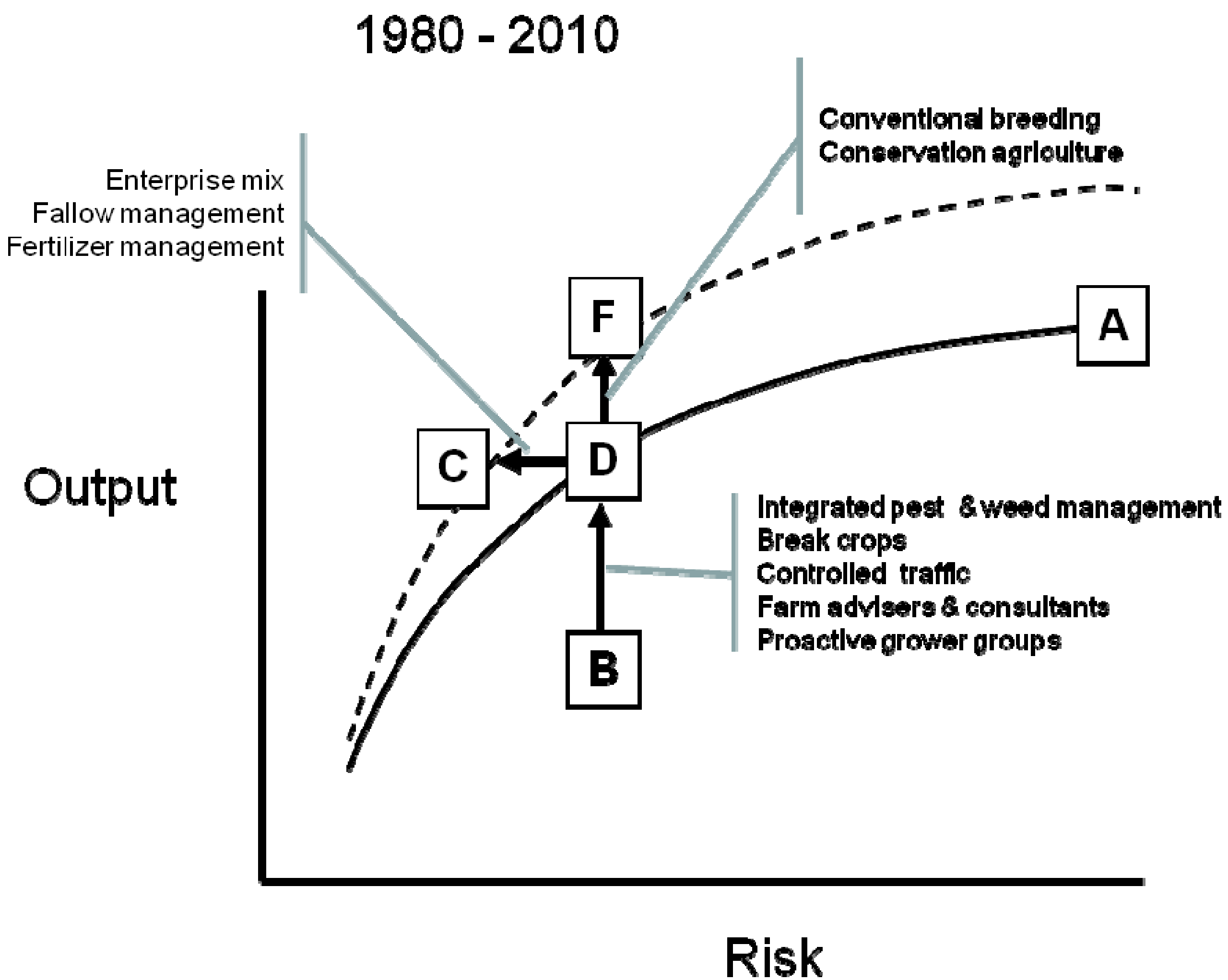
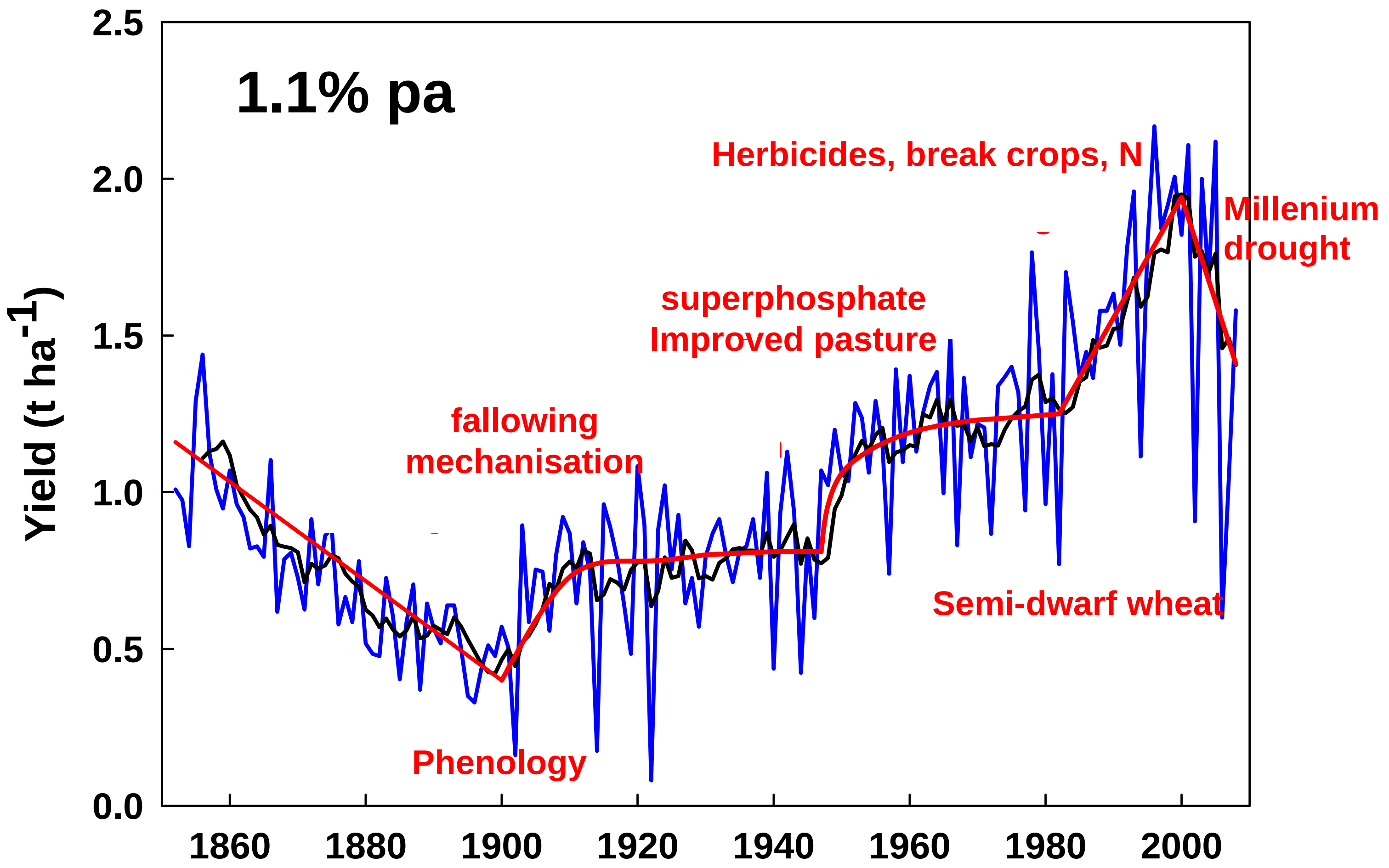
Past technologies



Australian national wheat yield trends



Angus (2009); Fischer (2009)

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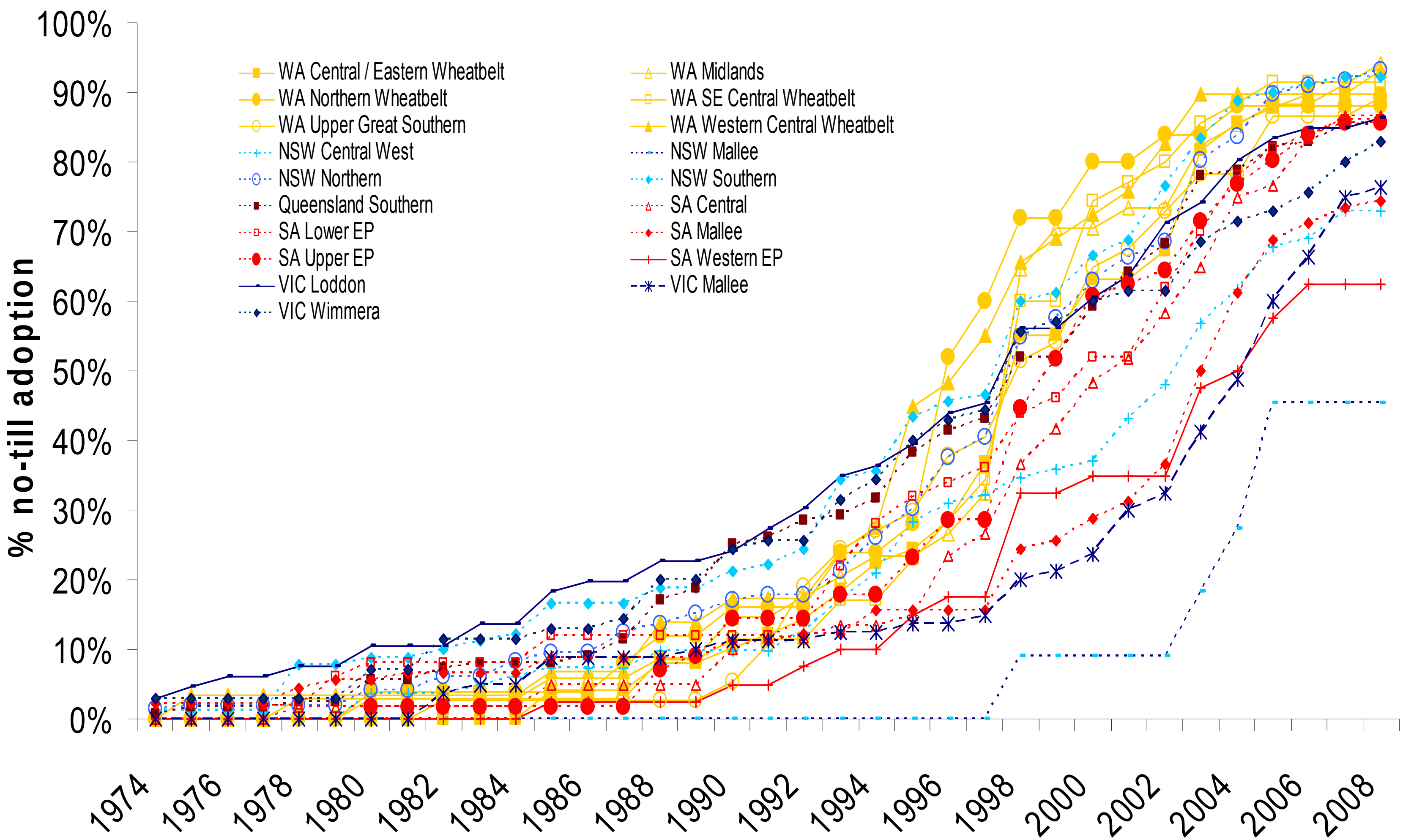
No-till adoption across Australian cropping regions



Llewellyn et al 2009

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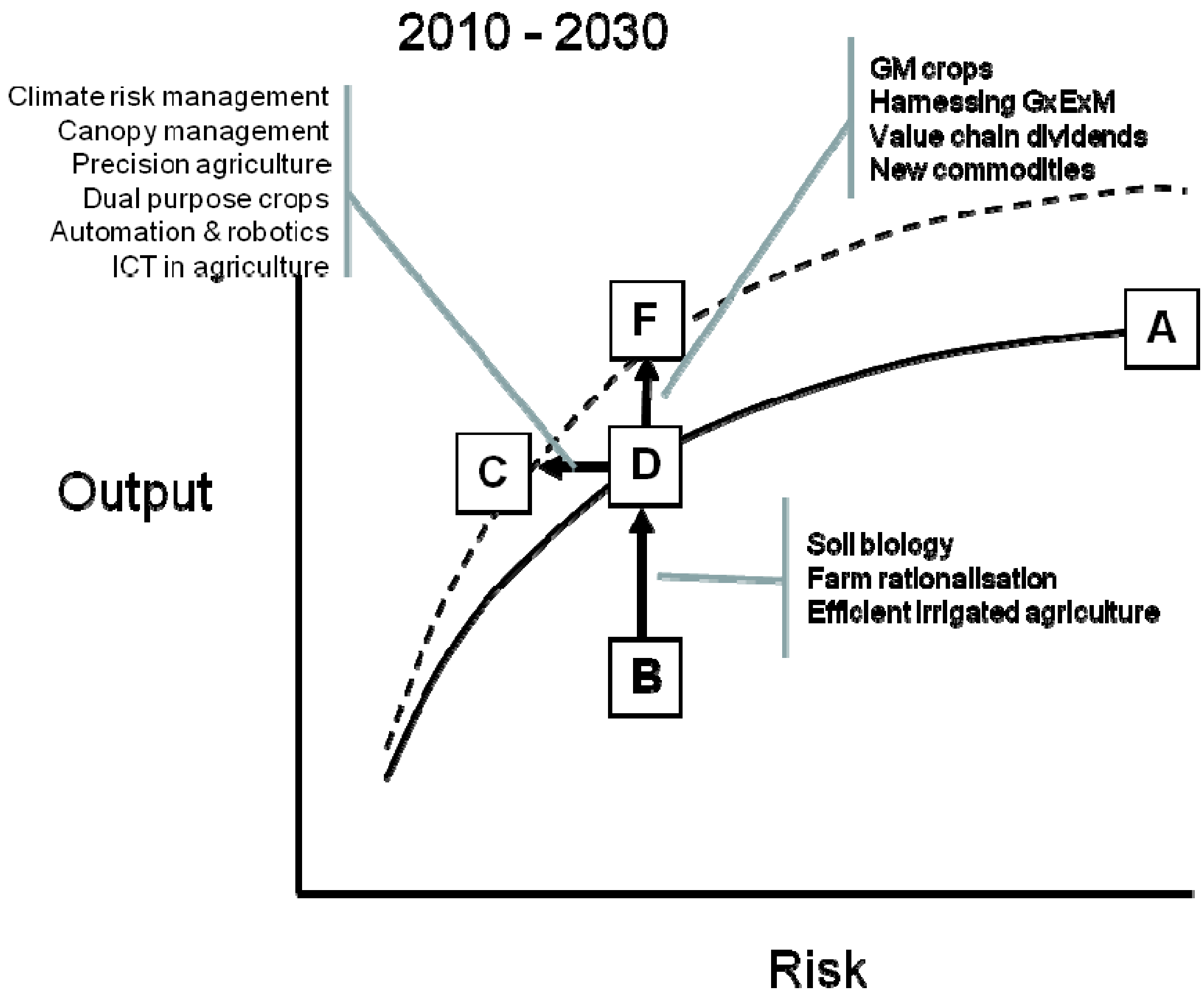
Future technologies



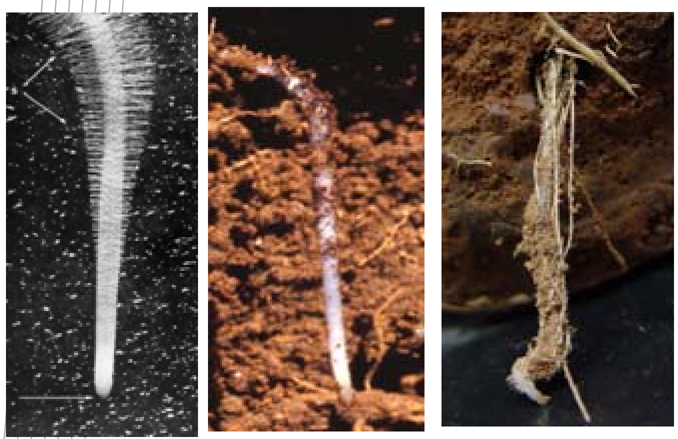
Genomics as a basis to increase yield

- International effort to decode the cattle and sheep genomes.
- New tools to select more efficient and better adapted animals.
- Fertility is a focus
- Industry poised for increase in productivity from the rate of genetic improvement now possible.

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

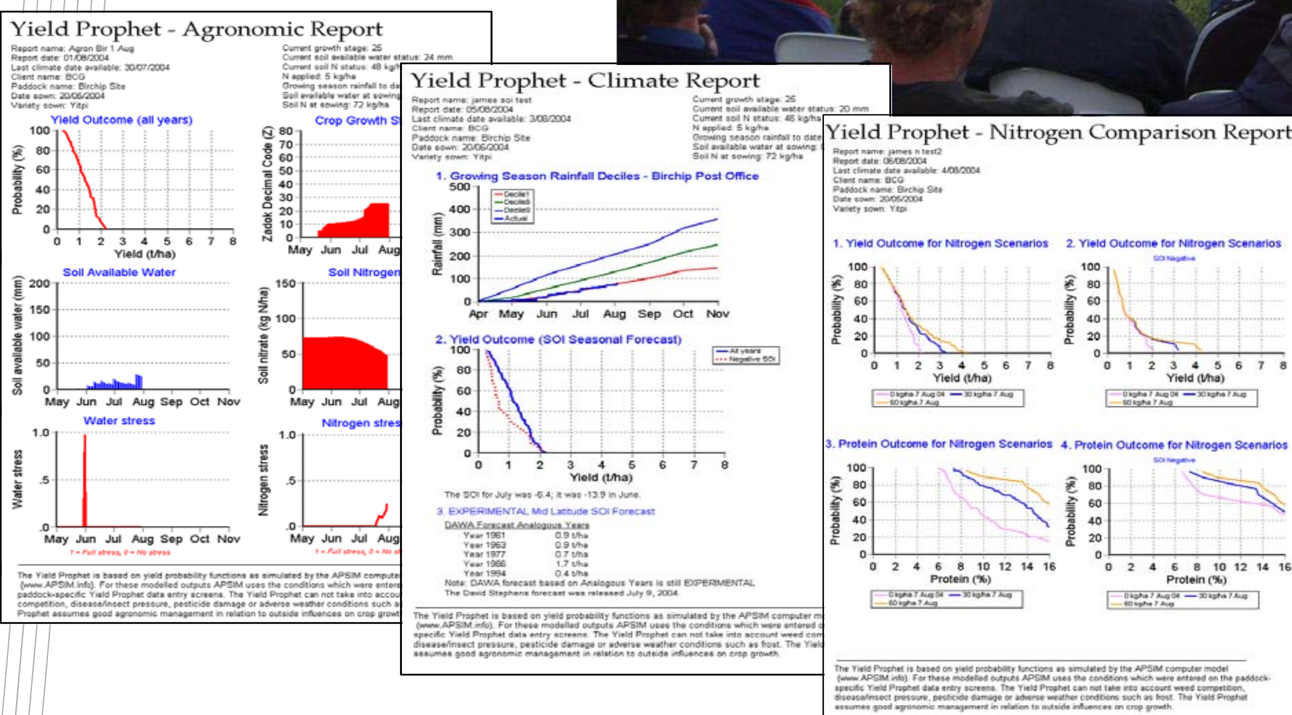
Adoption of PA by Australian grain growers

- 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

Climate risk management

www.yieldprophet.com.au



Birchip Cropping Group

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Robotics eg.weed control

- Current methods of weed control:
  - Use existing (normally large) tractors
  - Need a person to drive the tractor
  - Use chemicals
  - Use diesel to fuel the tractor

- Prospects for new method of controlling weeds using small mobile robots
- Small, lightweight
- Battery powered
- Move slowly which means mechanical weed control can be considered
- Dock with a base station to swap batteries
- Base station is solar powered and mobile (back-up diesel generator)

Nutrient use efficiency

Phosphate solubilisation and plant-growth promotion by Penicillium-based rhizosphere inoculants

As at May 2010 (the start of the sowing season), new P-solubilising inoculant products for crops,'**TagTeam**' & '**JumpStart**', which contain a CSIRO *Penicillium* strain had been applied to over 17,500 hectares of crop.

Penicillium gaestrivorus
P-solubiliser

New crop "rhizosphere inoculants"

Science behind the innovation………

- **Taxonomy, genetic differentiation & stability of microbial strain**
- **Ecology: inoculant persistence & impacts on microbial communities**
- **Mechanisms by which growth promotion & P-availability are improved**
- **Mechanisms of pathogen inhibition (*i.e.* anti-fungal metabolites)**

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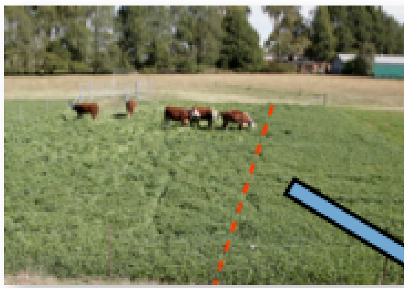
ICT in Agriculture – “virtual fencing”

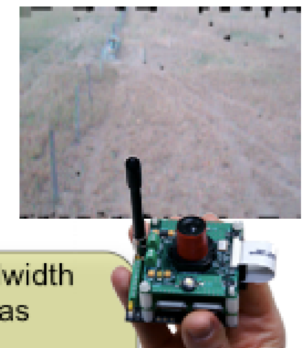
Sensor networks:

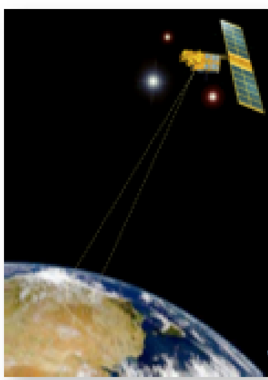
- Gather information about an environment or system at a level of spatial and temporal detail not previously available



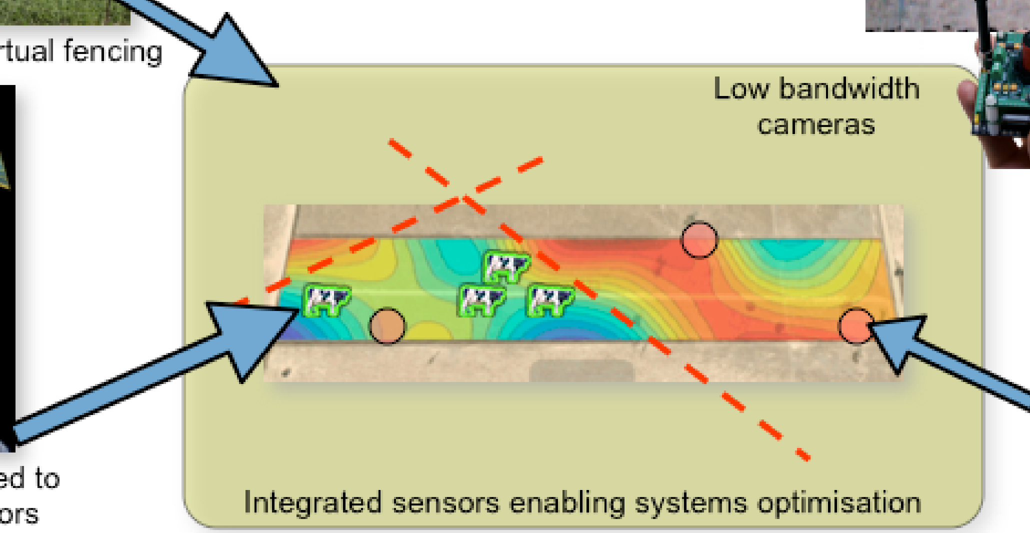
System control e.g. virtual fencing

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



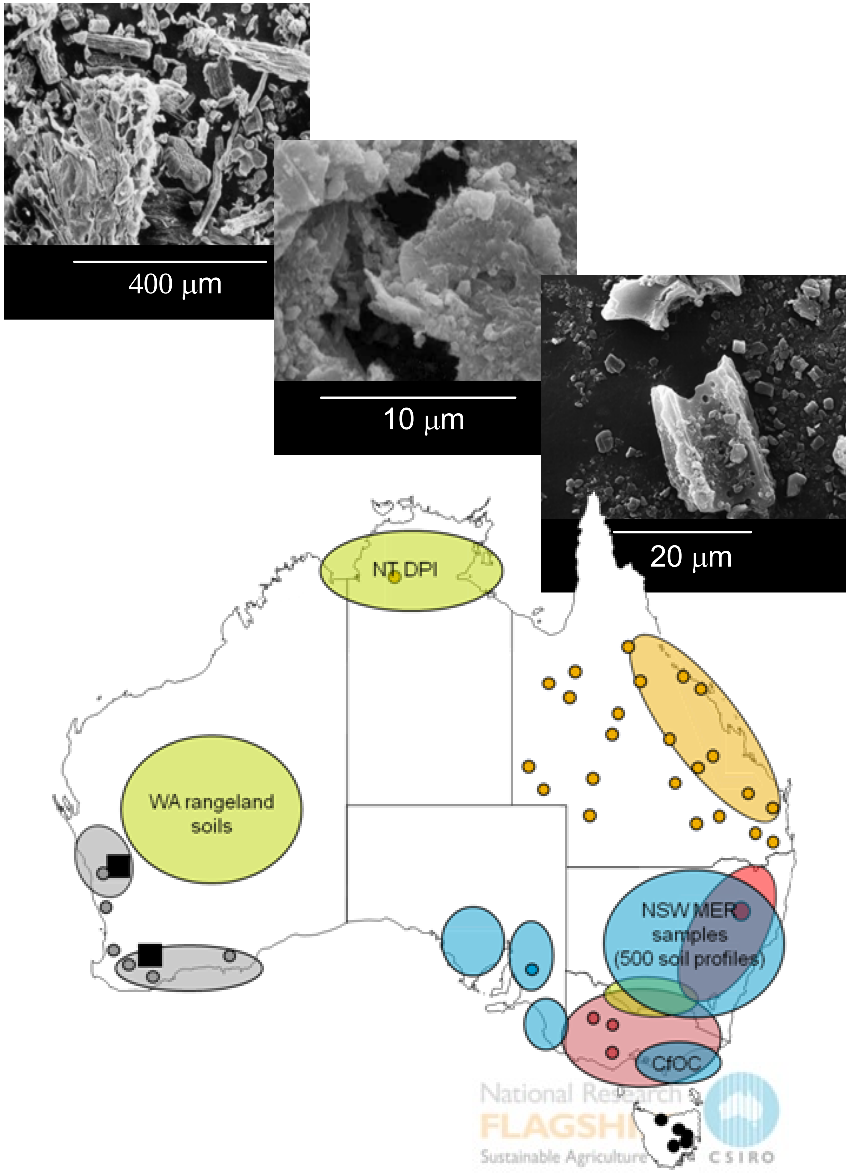


Remote sensing linked to ground based sensors



Soil carbon – measuring & managing

- Regional assessment of the impact of agricultural management strategies on soil carbon content and composition
- Use of a consistent approach across Australia
- Derivation of baseline data for predicting the outcome of management scenario
- Definition of the contributions to soil carbon made by perennial pastures
- Development of rapid measurement techniques for soil carbon and bulk density



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

Peter Carberry
Deputy Director
Sustainable Agriculture Flagship

Phone: +61 7 46881377
Email: peter.carberry@csiro.au
Web: www.csiro.au

www.csiro.au

Thank you

Performance of Australian farmers

	pre-2000 1977–78 to 1999–2000	post-2000 1999–2000 to 2007–08	total 1977–78 to 2007–08
Cropping specialists and mixed cropping–livestock farms			
Australia			
Technical change (TC)	1.95%	0.40%	1.53%
Technical efficiency change (TE)	–0.30%	–0.34%	–0.31%
Scale–mix efficiency (SME)	0.35%	0.17%	0.31%
Climate-adjusted TFP (TFPCA)	2.00%	0.24%	1.53%
Southern			
Technical change (TC)	1.95%	0.45%	1.55%
Technical efficiency change (TE)	–0.34%	–0.35%	–0.34%
Scale–mix efficiency (SME)	[illegible]	[illegible]	[illegible]
Northern			
Technical change (TC)	1.70%	0.31%	1.32%
Technical efficiency change (TE)	–0.22%	–0.26%	–0.23%
Scale–mix efficiency (SME)	0.45%	0.37%	0.43%
Climate-adjusted TFP (TFPCA)	1.93%	0.42%	1.53%

(TC)	2.25%	0.37%	1.74%
cy change (TE)	–0.30%	–0.34%	–0.31%
ncy (SME)	0.22%	1.30%	0.50%
TFP (TFPCA)	2.17%	1.32%	1.94%