Multiple drivers of change – a challenge for cropping systems designers and managers

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For the next few decades we can foresee many challenges for agricultural sciences – what is its role?

It is not a matter of predicting the future, but of being prepared for it.

*Pericles*
Rice production in 2007:

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>Asia</th>
<th>C &amp; S America</th>
<th>USA</th>
<th>Africa</th>
<th>Europe</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt</td>
<td>650</td>
<td>590</td>
<td>23.9</td>
<td>9.0</td>
<td>23.5</td>
<td>3.5</td>
<td>0.2</td>
</tr>
<tr>
<td>%</td>
<td>100</td>
<td>90.8</td>
<td>3.7</td>
<td>1.4</td>
<td>3.6</td>
<td>0.5</td>
<td>0.0</td>
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</tbody>
</table>

- Rice is the staple food crop for about 3 billion people.
- Rice feeds roughly half the planet’s population.
- 750 million of the world’s poorest people depend on rice.
- Demand for rice is increasing strongly while resources are becoming increasingly limited.
- 91% of all rice produced comes from Asia.
Global and regional rice production since 1961

- Since 1960 strong, near-linear trend in rice production ➔ 3-fold increase in annual global production volume, made possible by the green revolution.
- The 2002/2003 El Niño event lead to the largest annual production decline ever (29 Mt or 5% less than in 2001).
- Mounting concern that future production increases are very limited, especially in Asia.

Drivers of change

- World Water Week 2009 in Stockholm showed that demand for food and animal feed will double during the next 50 years with little scope for expanding arable land.
- In most places there are now clear limits on the amount of additional land and water that can be used for agriculture.
Population Division of the Department of Economic and Social Affairs of the UN

Drivers of change

World population

- Total population
- Urban population
- Rural population

Population (billions)

1940 1960 1980 2000 2020 2040 2060

Population Division of the Department of Economic and Social Affairs of the UN
Urbanisation will compete with agriculture for

- Water
- Land
- Energy
- Labour

Largely because of this scarcity we are struggling to repeat the successes of the green revolution.

Scarce resources already lead to buzzwords like:

‘we need to produce more with less!’
Resource scarcity increases the urgency for improved eco-efficiencies (EF) at all levels

- '...encompasses both the ecological and economic dimensions of sustainable agriculture. Social and institutional dimensions of sustainability, while not explicitly captured in EF measures, remain critical barriers and opportunities on the pathway towards more eco-efficient agriculture...' (Keating et al., 2010)

- EF are seen as 'achieving more with less', but the concept requires consideration of all production factors and their co-dependencies / co-limitations

- EF are achieved through substitution of production factors
A risk management framework Agricultural input / output relations as efficiency frontiers

Keating et al., 2010, Crop Science, 50, 109-119.
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Pathways for productivity improvement

(i) Using enabling technologies to maintain current productivity but reduce risk (A to B)

(ii) Addressing system inefficiencies at “constant risk” (A to C)

(iii) Moving along the new efficiency frontier (C to D)

(iv) Lifting productivity to a new level through transformational technologies (C to F)

Variance in economic returns as a measure of risk

Using efficiency frontiers as risk management tools

Keating et al., 2010, Crop Science, 50, 109-119.
<table>
<thead>
<tr>
<th>Enabling Technologies</th>
<th>Transformational Technologies</th>
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<tbody>
<tr>
<td>knowledge embedded within</td>
<td>knowledge intensive</td>
</tr>
<tr>
<td>provides control over environment</td>
<td>improves understanding functions</td>
</tr>
<tr>
<td>derived from traditional, reductionist science with clear problem statements, rarely contested at that level</td>
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‘mineral fertiliser’ ‘conservation agriculture’
Enabling and transformational technologies

**Enabling Technologies**
knowledge embedded within the systems

- mineral fertiliser, new varieties
- models that optimises N applications
- irrigation systems
- farm machinery
- GM technology

**Transformational Technologies**
knowledge intensive systems

- conservation agriculture
- models that improve breeding programs
- aerobic rice systems
- precision farming
- GM crops within cropping systems

*‘Good’ modelling can bridge the gap … sometimes*
Enabling Technologies

- knowledge embedded within
- provides control over environment
- derived from traditional, reductionist science with clear problem statements, rarely contested at that level
- non-contextual in time & space
- mono-causal perspective
- single effects
- addressing technical problems
- silver bullets

Transformational Technologies

- knowledge intensive
- improves understanding functions
- accounts for norms & values, leads to different problem definitions with the result that every answer can be contested
- highly contextual in time & space
- multi-causal perspective
- interactions
- addressing societal problems
- co-innovations
Connecting enabling and transformational technologies

From ‘knowledge-embedded technologies’ to ‘knowledge intensive technologies’

Two different pathways for acquiring scientific knowledge (Pielke, 2010):

- **knowledge embedded technologies** provide increased control over the environment (e.g. dams to regulate river flows); and
- **knowledge intensive technologies** improve the understanding of how the world functions and helps with ‘wicked problem solving’

Need to combine reductionist, value-neutral science with value-specific transdisciplinary science
Can science help cropping systems designers & managers?

- A wide range of technologies exist - from targeted breeding, improved management practices to novel irrigation techniques.
- In contrast to the green revolution there are no obvious technological ‘winners’ –improvements in ‘systems services’ have to come from a combination of context-specific innovations.
- Co-dependencies of limiting factors (e.g. nutrients, water, market access, infrastructure, governance) need to be considered at local scales.
- Imperative: effective connection between global & national policies and local agency
- Requires attention to scale and different perspectives between the ‘macro’ and the ‘micro’ level.
- ‘Good’ modelling can act as a bridge between enabling and transformational technologies (providing tractable ‘in silico’ solutions to be evaluated by multiple stakeholders across scales before ‘in vivo’ implementation)
Producing ‘more with less’ is an unhelpful oversimplification of the real issues (needs to avoid buzzword).

We need two types of science for problem solving:
- disciplinary based science that delivers knowledge technologies
- transdisciplinary science that tells us how to apply these technologies

Scientists and civil society need to agree about the problems and how science can contribute to solving them.

Both sides need to accept the two modes of inquiry as legitimate and scientific.

We need to be clear about what type of technology we want to apply – an EF framework can help.
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