Holistic approaches to modelling crop productivity
Outline

1. Quantifying uncertainty
2. Assessing adaptation options
   • Biophysical
   • Socioeconomic
3. Conclusions and future directions
The need for systematic quantification of uncertainty

(a) Maize, mid- to high-latitude

(b) Maize, low latitude

(c) Wheat, mid- to high-latitude

(d) Wheat, low latitude

IPCC, 2007
Response of crops to warming from an ensemble of 53 climates and 36 crop responses

May-Nov mean global temperature

Local temperature during crop growth
Response of crops to warming:
Single-climate multi-crop model ensemble

Challinor et al. (2009a)
Need to improve treatment of uncertainties

Brings together the UK climate modelling, statistical modelling, and impacts communities to work closely together for the first time to:

• Increase the utility of climate prediction: develop risk-based prediction systems for decision making
• Advance the science of uncertainty: integrated assessments of the cascade of uncertainty from climate to impacts (not just feeding climate ensembles through impact models)
• Develop new methodologies for assessing the information content of climate-model projections

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<th>WP1 Design</th>
<th>WP2 Evaluation</th>
<th>WP3 Engagement</th>
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<td>WP4 Implementation</td>
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<td>WP5 Crops</td>
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<td>WP6 Marine Environment</td>
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<td>WP7 Extremes</td>
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</table>
Adaptation

Our assessments need to

1. Quantify uncertainty
2. Include both biophysical and socio-economic mechanisms, and their interactions
• Opened 26$^{th}$ Feb 2008
• $> 4 \times 10^6$ samples
• -18 °C
• “Climate change proof”
Genotypic adaptation to high temperature stress

Hadley Centre PRECIS model, A2 (high emission) scenario 2071-2100
Number of years when the total number of pods setting is below 50%.

Challinor et al (2007b)
Quantifying uncertainty in genotypic adaptation

17 climates (QUMP) x 8 crop simulations for transient A1B in NE China
Integrating natural and social science approaches to modelling adaptation

Spatial scale

Country + Regional Field

Centuries

Decade(s)

Seasons

Large-area crop models combined with climate / climate change simulations

Statistical methods to ID socio-economic characteristics

Participatory methods at the field scale to ID strategies
Assessing socio-economic adaptation options

Invest in other agr activities
Double cropping
Fertiliser, Machinery
Rural population
Infrastructure
Electricity

Vulnerable
Agr production capital, Invest in agr, GDP share of agr

Wheat
Increasing impact
Increasing exposure
Assessing socio-economic adaptation options
Conclusions
Modelling strategies

“Assessing climate impacts and adaptation options requires judicious use of finite computational resources as well as appropriate degrees of integration and specialisation in the climate impacts research community”

Challinor et al (2009c)
Modelling strategies

Techniques to link climate models with crop models

Test system with observed data

Seasonal forecasting (ensembles / satellite)

Climate change (ensembles)

Adaptation

Socio-economics (influences on yields and adaptation)

Sustainable food systems

Combining different models, data
- Ozone: crop-climate-chemistry
- Agricultural and social systems
- Mycotoxins
Future directions

• Include both biophysical and socio-economic mechanisms, and their interactions

• Local vulnerability depends on land use policies and their effects → extend vulnerability index approach to include other drivers

• Land use perspective: demand for food, energy, carbon storage, biodiversity etc; often in competition
  – Enables study of food production (c.f. yield)
## The need for systematic quantification of uncertainty

<table>
<thead>
<tr>
<th>Condition</th>
<th>Crop</th>
<th>Impact</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x CO\textsubscript{2} N. America</td>
<td>Wheat</td>
<td>-100 to +234%</td>
<td>Reilly and Schimmelpfennig, 1999</td>
</tr>
<tr>
<td>2080s Africa</td>
<td>Cereals</td>
<td>-10 to +3%</td>
<td>Parry et al., 1999</td>
</tr>
<tr>
<td>+4°C local $\Delta T$ ‘low latitude’</td>
<td>Wheat</td>
<td>-60 to +30%</td>
<td>IPCC AR4, chap. 5 (Easterling et al., 2007)</td>
</tr>
<tr>
<td>+4°C local $\Delta T$ ‘mid- to high-latitude’</td>
<td>Wheat</td>
<td>-30 to +40%</td>
<td>IPCC AR4, chap. 5 (Easterling et al., 2007)</td>
</tr>
</tbody>
</table>

See Challinor et al. (2007a)
## Studies

<table>
<thead>
<tr>
<th>Description</th>
<th>Climates</th>
<th>Crop responses</th>
<th>Mean temperture</th>
</tr>
</thead>
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<tr>
<td>All-India A2 scenario with regional climate model (RCM)</td>
<td>1</td>
<td>18</td>
<td>Both &gt; and &lt; Topt</td>
</tr>
<tr>
<td>Study of climate and crop modelling uncertainty at one location in India under doubled CO2 (QUMP53)</td>
<td>53</td>
<td>36</td>
<td>&lt;Topt [97%]</td>
</tr>
<tr>
<td>A1B scenario in north-east China (QUMP17)</td>
<td>17</td>
<td>8</td>
<td>&gt;Topt</td>
</tr>
<tr>
<td>Analysis of adaptation to mean temperature in the USA, using a database of 16,000 wheat trials</td>
<td>-</td>
<td>-</td>
<td>&lt;Topt</td>
</tr>
</tbody>
</table>
Quantifying uncertainty in crop and climate responses

17 climates (QUMP) x 8 crop simulations for transient A1B in NE China