Ensembles of crop yield at seasonal and multi-decadal timescales

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1. Seasonal forecasting of crop yield
   - Bias correction, calibration and multi-model ensembles
   - Inverted ROC curves
   - ‘Applications’ as a measure of skill

2. Climate change
   - Relevance to seasonal forecasting
   - An ensemble of crop yield simulations for doubled CO2
Combining crop and climate models

- **Country +**
- **district**
- **field**

Spatio-temporal scales:
- **annual +**
- **seasonal**
- **monthly**
- **daily**

 Processes:
- **Climate forecast**
- **Downscaling**
- **Weather generators**
- **Meta-model**
- **Large-area model**
- **‘Traditional’ CM**

Yield under future climates
Seasonal forecasting of crop yield using the DEMETER hindcasts

- Multi-model ensemble: 7 (models) * 9 ensemble members

- Run each seasonal hindcast realisation through GLAM to create an ensemble of crop yields

- Try various bias-correction and calibration options

Probabilistic forecasting of crop failure: ROC curves

Failure: Y<500kg/ha (Rao et al. 2000)

- NCAL and BIC are most skillful
- BIC tends to perform less well than NCAL; some failures never simulated by BIC

Inverted ROC curves

- Cannot directly compare the predictability of Y<500 with Y<400, as they occur with different frequencies (Lalaurette, 2004)
- =>IROC: as ROC, but false alarm ratio on the x-axis.
- As with the ROC curve, skill is greater when the area under the curve is greater.

Yield is another metric of SF skill

Non-linearity between climate and derived variables

Changes in rainfall will change the mean and the variability of yield, as well as the nature of the relationship between yield and rainfall.
Menu

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Seasonal forecasting as a testbed for climate change

SF is relevant to climate change studies:

- Evaluating applications models
- Some commonality/similarity in methods
  - Quantification of uncertainty (e.g. multi-model ensembles)
  - Communication of uncertainty and probabilities
  - Down/up scaling
Seasonal forecasting in a changing climate

What is the relevance of climate change for SF?

• ‘Taking the shorter route’
• But climate change is not just a 2100+ problem
  – We need to capture changes in interannual variability associated with climate change
  – Means are also important
    o Signal already seen in agricultural yield; CO2 and warming roughly cancel (Lobel and Field, 2007)
    o Adaptation will mean likely changes in crop variety
• Opportunities associated with climate change (cf Oxfam)
• As ‘climate change processes’ become increasingly important
  – $2\times$CO2 to look at processes (and projections of impacts)
  – Shorter timescales, where uncertainty is less, to look at prediction
An ensemble of crop yield simulations for doubled CO$_2$

- Run GLAM 2.0 using
  - One baseline climate scenario (PRECIS)
  - 28 parameter sets, varying the response of leaves, biomass and transpiration to elevated CO2
- Compare simulated yields, water-use and LAI to FACE and controlled environment data
  - 18 ensemble members produced realistic results
- Run future climate scenario (A2 2071-2100) with only those 18 members and examine output
- Identify key processes and associated uncertainties
- Sensitivity tests on DSSAT and Qnut models to assess level of consensus on these processes and uncertainties
Quantifying uncertainty for prediction and adaptation

One possible adaptation
Standard wisdom:
“Droughted plants take better advantage of high CO₂ because they are at a point in the photosynthesis curve that is more CO2-sensitive.” (TAR WGII)

What do: • Models • FACE say?

Long, et al., 2004
Interaction between water stress and assimilation

$y$: yield change for well-watered crop (%) minus yield change for stressed crop (%)

$x$-axis shows, roughly, increasing level of organisation from left to right
Key result

Effect of elevated CO$_2$ on stressed versus irrigated crops:

• Leaf-level: greater benefit for stressed crops

• Canopy-level: greater benefit for irrigated crops?
  – But FACE inconclusive

• Implications for rainfed vs irrigated agriculture
Conclusions

Need to account for:

• The emerging impacts of climate change
  – CO2 fertilisation and interaction with water stress
  – Changes in mean temperature
  – Incidence of heat stress events

• The effect of adaptation, and other social and management factors

• Errors in observations and simulations – Bayesian framework?
Conclusions

To do this we need:

• Robust process-based applications models
  – Note usefulness of upscaled applications models, especially as computer power and resolution increase
• Data for calibration and evaluation of application models
• Consensus on calibration techniques for application models?
  – Probably quite application/model dependent, so we should avoid being too prescriptive.
  – e.g. GLAM has a simple process-based calibration parameter that can correct some bias in mean rainfall