Climate Change and Agriculture

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Intergovernmental Panel on Climate Change
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OUTLINE

• What we currently know about climate change and its implications for world food supply

• Ten lessons to help us respond

• Conclusions: challenges for the CGIAR
Agriculture: a driver of GHG and a key area of impacts

• Agriculture contributes 20% of GHG emissions globally, today.
• By 2020 this will be 15% or less; and by 2050 10% or less.

• Agriculture as a source of greenhouse gases IS NOT the main issue.
• Protecting agriculture from climate change IS the main issue
Change in annual temperatures for the 2050s

The change in annual temperatures for the 2050s compared with the present day, when the climate model is driven with an increase in greenhouse gas concentrations equivalent to about a 1% increase per year in CO₂. The picture shows the average of four model runs with different starting conditions.

The Met.Office Hadley Centre for Climate Prediction and Research
Observed change in annual precipitation for the 2050s

The change in annual precipitation for the 2050s compared with the present day, when the climate model is driven with an increase in greenhouse gas concentrations equivalent to about a 1% increase per year in CO₂. The picture shows the average of four model runs with different starting conditions.

The Met.Office Hadley Centre for Climate Prediction and Research
Annual runoff: A measure of water supply (2080s)

Percentage change in 30-year average annual runoff by the 2080s.

University of Southampton
Projected increase in intensity of Indian monsoon, c. 2050 (HadRM2)

Change in Annual number of rainy days

Change in rainfall per rainy day
Other projected changes of climate (by 2100)

- Sea levels will rise 0.1 to 0.8 metres
- More tropical cyclones
- More frequent very hot days
- And… we can see some of these changes already, occurring now.
Crop yield change: 2010, 2050, 2080

Percentage change in average crop yields for the climate change scenario (Hadley model). Effects of CO₂ are taken into account. Crops modelled are: wheat, maize and rice.
Projected global cereal production for reference case and the climate change scenario.

Percentage change in global cereal prices under the climate change scenario (0 = reference case).

Additional people at risk of hunger (0 = reference case, i.e. about 300 million in 2000, FAO).
Response 1: Mitigation.

Emissions and concentrations of CO₂ from unmitigated and stabilising emission scenarios

- Unmitigated emissions
- 750 ppm stabilisation
- 550 ppm stabilisation
Changes in crop yield from the present day to the 2080s

Potential change in cereal yields (%)

- 10 – 5
- 5 – 2.5
- 2.5 – 0
- 0 – -2.5
- -2.5 – -5
- -5 – -10
- -10 – -20
- No data

Unmitigated emissions

Stabilisation of CO₂ at 750 ppm

Stabilisation of CO₂ at 550 ppm
Response 2: Sustainable Development
The effect of development pathways
example: IPCC’s SRES scenarios

A1 = World of Global Markets: high growth, high tech, low pop,
A2 = World of Regional Enterprise: high pop, high growth (but inequitable) [current pathway]
B1 = World of Global Sustainability: low pop, moderate growth, global envtl agreements.
B2 = World of Local Stewardship: low pop, moderate growth, local envt management.
Future reference case estimates of the numbers of people at risk of hunger, for the four SRES marker scenarios (no climate change).
Response 3: ADAPT

• Successful adaptation needs clear picture of future agro-climate, at regional level
• So, what lessons have we learned about this, so far:
Climate Change and Agriculture
‘Lessons’ Learned

Annual Temperature Trends 1973-2002

Cynthia Rosenzweig
NASA Goddard Institute for Space Studies
Columbia University
Impacts of Climate Change on Multiple Cropping Production Potential of Rain-fed Cereals

Climate change impacts are visualized using a normalized difference index. It is calculated by dividing the difference in cereal production capacity between future and current production potential by their sum.
Climate change impacts are visualized using a normalized difference index. It is calculated by dividing the difference in cereal production capacity between future and current production potential by their sum.
Effects are Negative in Long Term
Percent Change in Food Production Potential

WORLD

PRODUCTION potential assuming LOW range end of CO2 concentration

PRODUCTION potential assuming HIGH range end of CO2 concentration

AREA EXTENT assuming LOW range end of CO2 concentration

AREA EXTENT potential assuming HIGH range end of CO2 concentration

0-10 = Severity of climate change (~time)
Developed and Developing Countries Diverge in Vulnerability

Both Impacts and Adaptive Capacity
IPCC, 2001

Multitudes of global and regional studies on rural groups, agricultural systems
Water Resources are Key

Possible decadal surprises

Change in seasonality

Environmental Stress Demand:Supply Ratio

Strzepek et al., 1999
Pests May Surprise!

Overwintering range of potato leafhopper under two doubled $CO_2$ climate change scenarios. (Stinner et al., 1989)

Range of expansion of soybean sudden death syndrome (Fusarium solani f.sp. glycines) in North America. (X.B. Yang).

Approximate distribution of European corn borer annual generations in the U.S. and Canada. (Mason, 1996)
Risk of Current Climate Variability is a Pathway to Climate Change

Seasonal-to-interannual*
Decadal-to-century**

*Focus on
Extreme events
Regional Stakeholders
Short-term Decisions
Adaptation

**Focus on
Mean changes
National Policymakers
Long-term Decisions
Adaptation & Mitigation

Need new models to integrate the two time-scales . . .

Ing. Juan Notaro, Uruguayan Minister of Agriculture in 1999/2000

"... The results of your work during the recent drought were useful for making both operational and political decisions.”
Farmers* need to Adapt** and Mitigate at the Same Time

* Agricultural stakeholders  **To both climate variability and change.

Responses
Adaptation is Important, But Not Always Possible, Complete, or Cheap

Two examples for the CCGS 2030s Scenario

Spring wheat

Strategy: Early planting
Results: Successful heat stress avoidance

Winter wheat

Strategy: Change of cultivar
Results: Unable to reverse damage due to low precipitation

CC = Canadian Climate Centre GCM
U.S. National Assessment; Tubiello et al., 2002
Climate Change and Adaptation Affects C-Sequestration

Simulation Results (40 years)

Corn Field, North Platte, NE

Barriers and bridges projects to adoption of C-sequestration techniques by farmers
Take changing climate and climate variability into account

How does C-sequestration help farmers adapt to climate extremes?

Change in Soil C, T C ha\(^{-1}\) yr\(^{-1}\)

Legend:
- Current Climate
- Climate Change, CCCM
- Climate Change, HAD

- Irrigation
- N Fertilization
Climate Change is Already Happening

1973-2002 Annual Temperature Trends
Interpolated
<-1.2C to >1.2C
Conclusions : 1

• Climate change is likely **globally** to: reduce potential agricultural output in the longer term, and increase risk of hunger.
• Adverse effects, **regionally and near-term**, are especially marked in tropics and sub-tropics (e.g., especially in Africa).
Conclusions : 2

• Most serious effects, sub-nationally, will probably be at the social and economic margins (where adaptive capacity is low).

• Stabilisation at 750 ppm does not avoid most serious effects. Stabilisation at 550 ppm does, but cost will be great (= c.20 times Kyoto reductions).

• Therefore, successful mitigation will need to be part of a ‘Sustainable Development’ pathway.
Conclusions: 3

- A **combination** of adaptation and mitigation is necessary.
- Invest in adaptation, to increase resilience to climate change: a) technology (e.g., crop breeding for new climates; rural electrification), b) management (e.g., farming systems that use water more efficiently), c) institutions (e.g., market and tariff structure).
- Many adaptations can be ‘win-win’ (e.g., drought-proofing for present weather can increase resilience to effects of a long-term drying trend).
Conclusions : 4

• Need to foster adaptation in most vulnerable regions: the poorest, small island, low-lying coasts, and semi-arid tropics/sub-tropics

• Should we concentrate more on non-optimising objectives? eg reduce risk, minimise yield reductions in drought years, develop resilient (rather than maximising) crop varieties and crop mixes.

• Regardless…Adaptation is needed now.
Examples of adaptation

- **New crop varieties**: eg drought resistant (by traditional plant breeding, or genetic modification);
- **Irrigation**: needs rural electrification (especially in Africa= a Millenium Development Goal)
- **Shift of cropping zones**: eg northwards in N. Hemisphere (but limited by soils)
- **Reform global food system**: [today, enough food is produced for all, but still 500m are hungry]
Changes in Drought Severity.

HadCM3 A2 scenario (Burke and Brown, 2006)
Additional number of people at risk of hunger in Africa under the climate change scenario (0 = Projected reference case).

Projections for cereal production in Africa under the reference case and the climate change scenario.
Changes in runoff from the present day to the 2080s

- Unmitigated emissions
- Stabilisation of CO₂ at 750 ppm
- Stabilisation of CO₂ at 550 ppm

University of Southampton

Change in annual runoff (%)

-75 -50 -25 -5 to 5 25 50 75
Millions at Risk in the 2080s

- Additional millions at risk of hunger, malaria, and coastal flooding
- Risk of water shortage
- Risk of malaria
- Risk of hunger
- Risk of coastal flooding

Legend:
- Blue: Risk of water shortage
- Green: Risk of malaria
- Red: Risk of hunger
- Purple: Risk of coastal flooding

Temperature Increase vs. Additional millions at risk of increased water shortage.
Future reference case estimates of cereal production under the four SRES marker scenarios (no climate change).
Future reference case global cereal prices, relative to 1990 prices, for the four SRES marker scenarios (no climate change).
A2 in 2050s  B2

- Pop 11.3 billion
- GDP 82 tr $
- primary energy 970 GJ/yr
- carbon 16 GtC/yr

- Pop 9.3 billion
- GDP 110 tr $
- primary energy 870 GJ/yr
- carbon 11 GtC/yr
Development Path Matters

Aggregated developing-developed country differences (%) in average crop yield changes from baseline for the HadCM2 and HadCM3 scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>HadCM3—2080s</th>
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<tbody>
<tr>
<td></td>
<td>A1FI</td>
</tr>
<tr>
<td>CO₂ (ppm)</td>
<td>810</td>
</tr>
<tr>
<td>World</td>
<td>−5</td>
</tr>
<tr>
<td>Developed</td>
<td>3</td>
</tr>
<tr>
<td>Developing</td>
<td>−7</td>
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<tr>
<td>Difference (%)</td>
<td></td>
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<tr>
<td>Developed–developing</td>
<td>10.4</td>
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</tbody>
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Potential change (%) in national cereal yields for the 2050s (compared with 1990) under the HadCM3 A1FI with CO₂ effects

Parry et al. 2004