

# Agriculture and climate change

## Adaptation and mitigation: An economic perspective

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# Outline

- 1 Climate change and agriculture: some facts
- 2 Impacts of climate change on agriculture
- 3 Potential contribution of agriculture to GHG mitigation
- 4 Concluding remarks

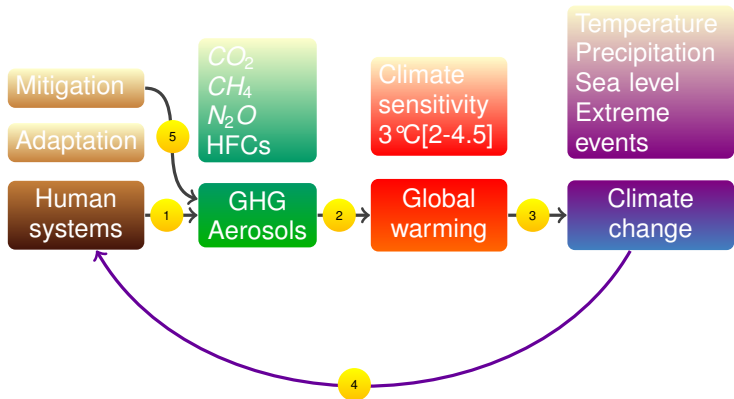
## Why economists should care

*Greenhouse gas (GHG) emissions are externalities and represent the biggest market failure the world has seen. We all produce emissions, people around the world are already suffering from past emissions, and current emissions will have potentially catastrophic impacts in the future. (Nicholas Stern, 2008)*

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# Mechanisms of anthropogenic climate change



## Warming scenarios

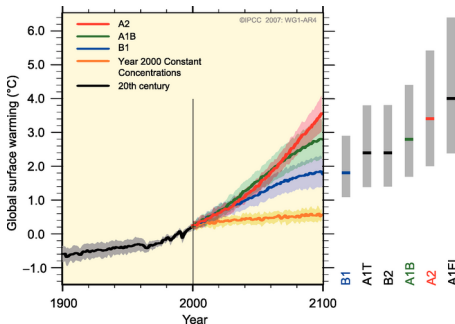
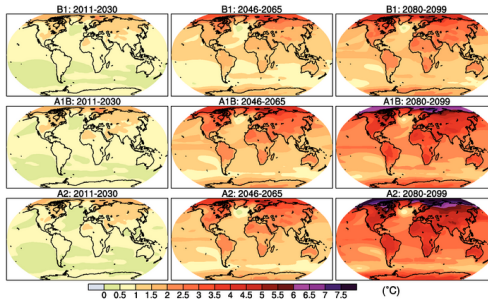


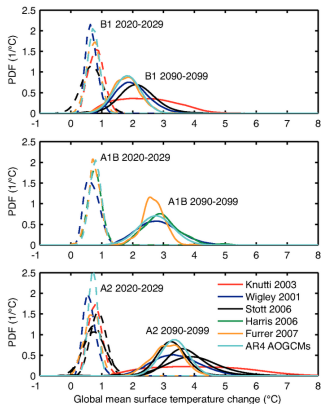
Figure: Multi-model global average of surface warming relative to 1980-1999. Right: 2090-2099 average. *Source: IPCC, 2007.*

# Warming scenarios



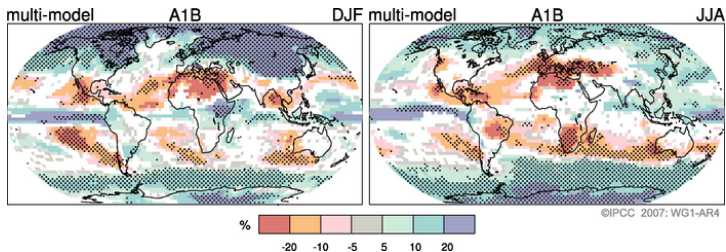
**Figure:** Multi-model mean of annual mean surface warming relative to 1980-1999. *Source:* IPCC, 2007.

## Uncertainty within and across studies



**Figure:** Probability density functions from different studies for global mean temperature change. *Source:* IPCC, 2007.

# Changes in precipitation



**Figure:** Relative changes in precipitation for the period 2090-2099, relative to 1980-1999, from December to February (left) and from June to August (right). *Source:* IPCC, 2007.

## Extreme weather events

*Over the 21<sup>st</sup> century, it is very likely (>90%) that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. (IPCC, 2007)*

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## Main anticipated impacts

- *Ecosystems*: change in ecosystem structure and function, species geographical ranges
- *Food production*: crop productivity increases at mid-high latitudes for moderate mean temperature increases, decreases at lower latitudes even for small temperature increases; globally, increase in food production with 1-3°C
- *Coasts*: increased flood risk in low-lying areas
- *Water resources*: glacier and snow cover loss, changes in runoff; overall negative impact on freshwater systems
- Agriculture will be one of the most hardly hit economic sectors because weather is a direct input into production

## Impacts in Europe

*In northern areas climate change may produce positive effects on agriculture through introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation. [...] In southern areas the disadvantages will predominate. The possible increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops. [Olesen and Bindi, 2002]*

## Channels of impact on agriculture

- Change in growing degree-days (GDD)
- Increased occurrence of high temperatures ( $>34^{\circ}\text{C}$ )
- Change in growing season
- Change in soil moisture
- $\text{CO}_2$  fertilization; increased water efficiency
- Catastrophic events that destroy crops
- Change in access to water in irrigated areas

# Approaches

- Agronomic approach  
[Adams et al., 1990, Adams, 1989, Easterling et al., 1992, Parry et al., 1999, Robertson et al., 2012]
- Ricardian approach  
[Mendelsohn et al., 1994, Schlenker et al., 2005, Schlenker et al., 2006, Van Passel et al., 2012]
- Profit panel approach [Deschênes and Greenstone, 2007]
- Statistical yield approach [Schlenker and Roberts, 2009, Guiteras, 2009, Ortiz-Bobea, 2012]

# Agronomic approach

- Relies on process-based crop simulation models
- May simulate adaptation strategies
  - change in planting dates
  - change in fertilizer
  - change in irrigation
  - adoption of better suited varieties
  - changes in crop mix
- But do not reflect “revealed preference”
- Even when integrated into larger trade models, farm response not fully optimized  
[Adams et al., 1990, Parry et al., 1999]
- Normative models

# Ricardian or “hedonic” approach

## [Mendelsohn et al., 1994, Schlenker et al., 2006]

- Cross-sectional regression of land values on historical climatic variables, with controls (soil, socio-economic)
- Farmland values reflect the capitalized value of climate suitability to agricultural production
- Approach implicitly accounts for adaptation
- Main criticism: omitted variable bias, notably irrigation
- Does not reveal pathways of adaptation
- Most recent estimates:
  - US: 10-25% loss in farmland value in the near-medium term, 27-69% in long run
  - Europe: 8-44% loss in farmland value by 2100

# Profit panel approach

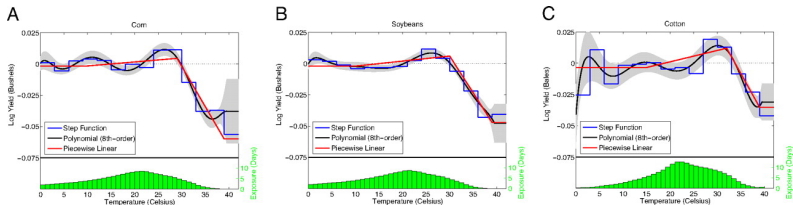
## [Deschênes and Greenstone, 2007]

- Relies on year-to-year weather variation to identify effects of CC on farm profits
- Eliminates bias due to time-invariant omitted variables
- Uses short run weather changes, not climate trends
- Possibility of bias due to time-varying omitted variables (e.g., storage)
- Likely overestimates damages because ignores long run adaptation mechanisms
- Most recent estimates: -4% in US farm profits for the period 2070-2099

# Statistical yield models

- More closely related to agronomic literature
- Summary representation of biophysical processes and farmer adaptation *via* panel data analysis
- Action now is on how to integrate weather variables (nonlinear effects):
  - GDD, HDD [Roberts et al., 2012]
  - Temperature bins [Schlenker and Roberts, 2009]
  - Role of soil moisture [Ortiz-Bobea, 2012]
  - Change in planting date [Ortiz-Bobea and Just, 2012]

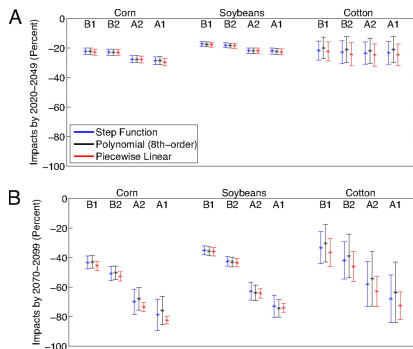
# Statistical yield models



**Figure:** Nonlinear effects of temperature on crop yields. *Source:* Schlenker and Roberts, *PNAS* 2009.

For corn, substituting a full day (24h) at 29°C with a full day at 40°C would result in a 7% yield decline

# Results



**Figure:** Predicted climate-change impacts on crop yields under the Hadley III climate model. *Source:* Schlenker and Roberts, *PNAS* 2009.

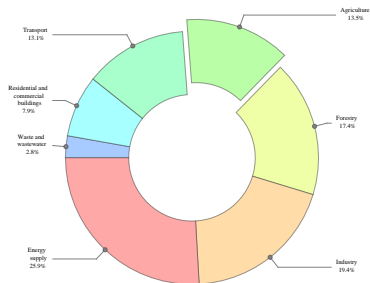
## Further results

- Recent estimates of yield effects for the US largely depend on climate scenario
- Crop yields are sensitive to high temperatures in rain-fed environments  
[Schlenker and Roberts, 2009, Roberts et al., 2012]
- Estimates for India indicate moderate yield losses in near-term [Guiteras, 2009]
- Taking account of soil moisture reduces the predicted effects of extreme temperature on yields by 30%  
[Ortiz-Bobea, 2012]
- Allowing for shifts in planting dates could further reduce impacts by 30-70% [Ortiz-Bobea and Just, 2012]

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# Anthropogenic sources of GHG



**Figure:** Global share of different sectors in total anthropogenic GHG emissions in 2004. *Source:* IPCC, 2007.

# Agriculture's contribution to GHG reductions

- Agriculture contributes a non-negligible share of total GHG emissions, mainly  $CH_4$  and  $N_2O$
- Agriculture has an important mitigation potential, mainly through carbon sequestration in SOM (C “sink”)
- [Smith et al., 2008]:
  - biophysical potential: 5500-6000 Mt  $CO_2$ -eq year<sup>-1</sup>
  - economic potential at \$20 t  $CO_2$ -eq<sup>-1</sup>: 1500-1600 Mt  $CO_2$ -eq year<sup>-1</sup>, or 5% of annual emissions in the 1990s
- Channels of C sequestration: agronomic and livestock practices, rice management, agroforestry...
- Potential policy avenues: supply of carbon offsets to other sectors

# Supply of GHG reductions

- Econometric approach likely not a realistic option due to lack of empirical data
- Economists instead have relied on optimization models
- Agriculture and forestry activities in the US [McCarl and Schneider, 2001] (normative approach)
- Changes in cropping patterns, input intensity and tillage in CA [Garnache and Mérel, 2012] (positive approach)

## Some results for California cropping systems

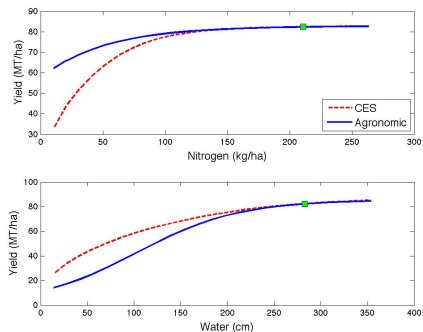


Figure: Calibration of crop yield responses (Tomato)

# GHG emissions and crop management

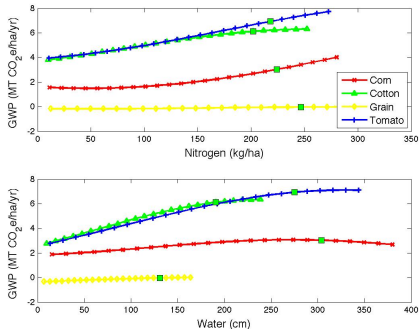


Figure: GWP as a function of nitrogen and water applications

## Supply curve of GHG offsets

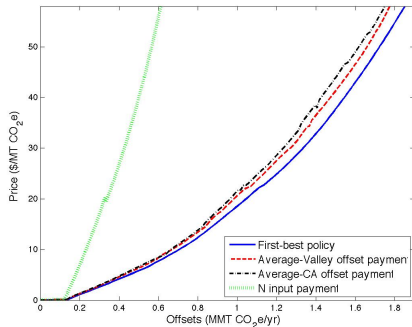


Figure: CA supply curve of GHG offsets (N and water only)

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## Concluding remarks

- Vibrant economic literature on climate change and agriculture
- An array of approaches have been implemented to predict effects of climate change on agriculture
- Most seminal studies have used data from the US, a large player in the world food system
- Even when focussing on the US, the conclusions of the literature are not clear-cut
- Partly due to different approaches, partly due to uncertainties regarding climate

## Concluding remarks

*Agriculture is the sector that has been most extensively studied in attempts to predict the economic impact of global climate change. [...] Despite the existence of a large and growing literature, economists do not appear to have reached a consensus on the potential magnitude of the impact, or even on its sign. [Fisher et al., 2012]*

*Much uncertainty remains [...] about the likely economic impacts of climate change, and so further research is necessary.  
[Deschênes and Greenstone, 2012]*

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