The global and regional health impacts of future food production under climate change

Marco Springmann, Daniel Mason-D’Croz, Sherman Robinson, Paola Ballon, Tara Garnett, Charles Godfray, Doug Gollin, Mike Rayner, Peter Scarborough
Climate change and health

- Climate change could be the biggest global health threat of the 21st century (UCL-Lancet, 2009).
- Health impacts related to food security may be one of the most important consequences of climate change due to the large number of people affected (IPCC AR4, AR5).
So far: strong focus on undernutrition.

Health impacts according to IPCC (AR5, Chapter 11):

- Risk level with current adaptation (red) and high adaptation (yellow).
However, in 2010, 7x more deaths attributed to dietary risk factors (composition of diet) than to child and maternal undernutrition, up from a ratio of 2 in 1990 (Lim et al., 2012).

General trend away from communicable diseases to non-communicable diseases associated with high body weight and unbalanced diets (Lozano et al., 2012).

Leading risk factors for death in 2010 (GBD, 2013)
This study:

- First analysis of the global health implications of changing diets and weight levels subject to agricultural production under socio-economic developments and climate change.

Methods:

- Coupled modelling framework:
  1. Agricultural economic model
     - Projects changes in agricultural production and consumption subject to socio-economic pathways and climate shocks;
  2. Global health model
     - Estimates health impacts associated with changes in dietary and weight-related risk factors.
Model framework

Model framework

Climate
- General circulation models (GCMs)
- $\Delta$Temp. $\Delta$Prec. ...

Biophysical
- Global gridded crop models (GGCMs)
- $\Delta$Yield (Biophysical)

Economic
- Global economic models
- $\Delta$Area $\Delta$Yield $\Delta$Cons. $\Delta$Trade

Health
- $\Delta$cons(fruits&veg)
- $\Delta$cons(red meat)
- $\Delta$kcal availability $\rightarrow$ $\Delta$weight
- Global health model
- $\Delta$deaths (age, reg, risk fac., cause)
Global health model

Comparative risk framework:

- 6 risk factors: FV and meat (2/3 of dietary risks), weight classes (5 of following 10 risk factors)
- 4 causes of death: CHD, stroke, and cancer (60% of NCD deaths), aggregate of other causes
- Changes in mortality by calculating population attributable fractions (PAFs) to risk exposures
Global health model

Data sources

- Population and mortality data by region and 5-year age group for 2050 from IIASA and UN Population Division.
- Cause-specific mortality rates by using WHO burden of disease data for disaggregating all-cause mortality rates.
- Relative risk parameters from pooled analysis of prospective cohort studies, and from meta-analysis of prospective cohort and case-control studies (WCRF/AICR).
  - Adoption of parameters if there is "substantial amount of consistent evidence for plausible mechanisms."
- Focus on chronic disease risks for adults (aged 20 and older).
- Uncertainty intervals from Monte-Carlo analysis: 1,000 draws of log-normal RR distribution.
Agricultural scenarios

Comparison of two scenarios:
- Reference scenario without climate change
- Climate change scenario
- Year: 2050

Scenario input:
- Middle-of-the-road socio-economic pathway (SSP2)
- High emissions pathways (RCP8.5)
- 3 general circulation models (IPSL, HDGM, MROC)
- 2 crop models (DSSAT, LPJ)
⇒ 6 climate-change scenarios per development pathway
Results: agricultural impacts

- Fruits&Veg: -35.8 g/cap/day; more in WPR, HIC
- Red meat: -3.9 g/cap/day; more in HIC, AMR, WPR, EUR
- kcal available: -289 kcal/cap/day; more in AFR, SEA, WPR
Results: health impacts

Climate-related deaths by risk factor and cause of death:

- FV is primary risk factor globally.
- Weight-related deaths are globally balanced.
Results: health impacts

Climate-related deaths by risk factor and region:

- **FV** leads in HIC, WPR, EUR, EMR.
- **UND** leads in AFR, SEA; **OBS** leads in AMR;
- **OBS > UND** in HIC, EMR, EUR, WPR.
Climate-related deaths per capita:

- Climate-related deaths in 118 out of 155 countries.
- Less deaths due to CC in 37 out of 155 countries (< 1%).
Results: health impacts

Weight-related deaths per capita:

- High number of weight-related deaths per capita in IND, AFR.
- High number of avoided weight-related deaths in countries with positive climate impacts.
High number of diet-related deaths per capita in China.
Results: sensitivity analysis

Alternative socio-economic and emissions pathways:

- Small changes with respect to socio-economic pathways.
- Less climate deaths in mitigation scenarios (up to 70%).
Key findings:

- Modest reductions in per-capita food availability (3%) and consumption (4%, 1%);
- 529,000 climate-related deaths globally
  \[\equiv\] 28% reduction in #avoided deaths due to dietary and weight-related changes between 2010 and 2050.
- \[\Rightarrow\] Climate change could significantly reduce progress towards greater food and nutrition security.
In context:

- Comparison to other health impacts of climate change (WHO, 2014):
Policy implications:

- Climate change mitigation could substantially reduce #climate-related deaths (up to 70%).
- Strengthening public-health programmes aimed at preventing and treating diet and weight-related risk factors could be suitable climate change adaptation strategy:
  - Impacts differentiated by region and risk factor;
  - For example, high burden due to reduction in FV in China; high burden due to increase in UND in India;
  - Opposing risk factors (UND, OBS) suggest broad focus on weight-related risk factors more appropriate than targeting UND and OBS individually.
  - Magnitude of FV impacts suggest importance of dietary composition (nutrition security), in addition to calorie availability (food security).
Caveats:

- **Agricultural modelling framework:**
  - Biophysical yield impacts best for major staples crops; others inferred from biophysical similarities;
  - Economic responses of agricultural commodity markets to climatic shocks are subject to high uncertainty;
  - Impacts of climate change on livestock production could be more responsive if heat and water stress on animals were taken into account.

- **Comparative risk analysis framework:**
  - Weight changes were estimated from historical associations between food availability and mean BMI;
  - Potential for residual confounding of risk factors in observational studies.

- **General:**
  - Global databases (FAO, WHO) are usually subject to significant adjustments;
  - Country-level aggregation hides intra-regional variability.
Contact

Thank you for your attention.

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Back-up slides
International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT):

- Developed in the 1990s by the International Food Policy Research Institute (IFPRI).
- Designed to examine alternative futures for global food supply, demand, trade, prices, and food security.
Overview:

- Currently updated to new model version with 56 commodities, a high spatial resolution (159 countries, 320 food production units), details on physical use of land and water
- Partial equilibrium approach:
  - World food prices are determined annually at levels that clear international commodity markets
  - Food production depends on crop and input prices, productivity growth, area expansion, irrigation and water availability
  - Food demand depends on commodity prices, income, and population growth
- Baseline parameters:
  - Food supply, demand, and trade derived from FAOSTAT
  - Commodity prices and income derived from World Bank data
  - Population statistics from the UN
High spatial resolution:

- 159 Countries
- 154 Water Basins
- 320 Food Production Unit
IMPACT description

Model suite:
- Food model (→ demand, production, prices)
- Spatial Production Allocation Model (SPAM)
- Crop model (DSSAT, LPJ → crop yields)
- Water models (→ water availability and stress)
- Climate change impacts (GCMs → crop models)

→ Good to couple:
Comparison of two scenarios:
- Reference scenario without climate change
- Climate change scenario
- Year: 2050

Scenario input:
- Socioeconomic pathways
- Climate change impacts
Focus on SSP2 (other SSPs in sensitivity analysis).
Climate change impacts

Representative Concentration Pathways (RCPs):

- Focus on highest emissions pathway (RCP8.5) (others in sensitivity analysis).
Climate change impacts

Biophysical climate change impacts:

- Feed RCPs into general circulation models (IPSL, HDGM, GFDL) ($\rightarrow \Delta \text{Temp}, \Delta \text{Prec}$)
- Feed into crop-model suite (DSSAT, LPJ) ($\rightarrow \Delta \text{Yield}$)
- Feed into IMPACT ($\rightarrow \Delta \text{Area}, \Delta \text{Prod}, \Delta \text{Cons}$)

$\Rightarrow$ Output (food consumption and kcal availability) of 6 climate-change scenarios fed into Global Health Model.
Global health model

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Relative-risk parameters:

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>CHD</th>
<th>Stroke</th>
<th>Cancer</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV consumption</td>
<td>0.96 (0.93-0.99)</td>
<td>0.95 (0.92-0.97)</td>
<td>0.93 (0.84-0.99)*</td>
<td>1.00</td>
</tr>
<tr>
<td>meat consumption</td>
<td>1.25 (1.21-1.29)</td>
<td>1.10 (1.05-1.15)</td>
<td>1.01 (1.00-1.05)*</td>
<td>1.00</td>
</tr>
<tr>
<td>underweight</td>
<td>0.67 (0.65-0.70)</td>
<td>1.03 (0.71-1.47)</td>
<td>1.11 (0.94-1.32)</td>
<td>1.75 (1.50-2.05)</td>
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<tr>
<td>normal weight</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>overweight</td>
<td>1.31 (1.24-1.39)</td>
<td>1.07 (0.73-1.59)</td>
<td>1.10 (1.04-1.17)</td>
<td>0.96 (0.89-1.03)</td>
</tr>
<tr>
<td>obese</td>
<td>1.78 (1.64-1.92)</td>
<td>1.55 (1.14-2.11)</td>
<td>1.40 (1.30-1.50)</td>
<td>1.33 (1.22-1.46)</td>
</tr>
</tbody>
</table>

*global average, actual RR is region-specific.

Coupling of Health Model and IMPACT

**Relevant parameters:**
- Change in population (and age distribution)
  → baseline shift in exposure
- Change in food consumption (F-V and meat)
  → direct impact via RRs
- Change in weight (inferred from consumption)
  → direct impact via RRs
Coupling of Health Model and IMPACT

Change in food consumption:

- IMPACT reports food availability.
- Availability ≠ Consumption: due to food loss and waste.
  - Approximate consumption by using FAO data on food loss and waste.

<table>
<thead>
<tr>
<th>Food group</th>
<th>EUR_w</th>
<th>ACO_w</th>
<th>ASA_w</th>
<th>AFR_w</th>
<th>EMR_w</th>
<th>SEA_w</th>
<th>AMR_w</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>cereals</td>
<td>35%</td>
<td>35%</td>
<td>34%</td>
<td>19%</td>
<td>30%</td>
<td>20%</td>
<td>26%</td>
<td>28%</td>
</tr>
<tr>
<td>root tub</td>
<td>52%</td>
<td>60%</td>
<td>48%</td>
<td>44%</td>
<td>33%</td>
<td>41%</td>
<td>39%</td>
<td>45%</td>
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<tr>
<td>oilpuls</td>
<td>20%</td>
<td>21%</td>
<td>18%</td>
<td>28%</td>
<td>29%</td>
<td>27%</td>
<td>19%</td>
<td>23%</td>
</tr>
<tr>
<td>FV</td>
<td>46%</td>
<td>52%</td>
<td>37%</td>
<td>52%</td>
<td>55%</td>
<td>51%</td>
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<tr>
<td>meat</td>
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<td>22%</td>
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<tr>
<td>dairy</td>
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<td>20%</td>
<td>11%</td>
<td>25%</td>
<td>20%</td>
<td>21%</td>
<td>21%</td>
<td>19%</td>
</tr>
</tbody>
</table>
Coupling of Health Model and IMPACT

Method to estimate weight change:

1. Estimate relationship between FAO FBS data and mean BMI using data from 1980-2008;
2. Use kcal data from IMPACT to estimate change in mean BMI, and that to shift BMI distribution.