Multi-sector climate impacts assessment for water, energy and land

Edward Byers, Matthew Gidden, Peter Burek, David LeClere, Amanda Palazzo, Simon Parkinson, Joeri Rogelj, Yusuke Satoh, Yoshi Wada, Petr Havlik, Volker Krey, Simon Langan, Barbara Willaarts, Keywan Riahi

International Institute for Applied Systems Analysis, Laxenburg, Austria

edward.byers@iiasa.ac.at

ISIMIP workshop 2017

9th October 2017
Global mapping of multi-sector climate and vulnerability hotspots

Multiple Indicators (~12) across 3 sectors

Regions with multi-sector climate hotspots and vulnerable populations

Combined indicators
Downscaling future scenarios of socioeconomic change

- **Shared Socioeconomic Pathways (SSPs)**

  - SSP 1: (Low Challenges) Sustainability Taking the Green Road
  - SSP 2: (Intermediate Challenges) Middle of the Road
  - SSP 3: (High Challenges) Regional Rivalry A Rocky Road
  - SSP 5: (Mt. Challenges Dominate) Fossil-fueled Development Taking the Highway

- **Population**
- **Urbanization**
- **GDP**
- **GINI (inequality)**
- **Income**

Who is vulnerable to poverty (<$10/day)?

- O’Neill et al. (2014)
- Jones & O’Neill (2016)
- Dellink et al. (2017)
- Gridded to 0.125° (1/8th °)

Gidden et al. (…)

**2010**

**2050 SSP1**

**2050 SSP3**
<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Models &amp; data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water stress index</td>
<td>Water stress index: as a proportion of human demands divided by renewable surface water resources</td>
<td>5 GCMs, 3 GHMs</td>
</tr>
<tr>
<td>Non-renewable GW abstraction index</td>
<td>Fraction of groundwater abstraction that is non-renewable</td>
<td>HadGEM2-ES + PCR-GLOBWB</td>
</tr>
<tr>
<td>Drought intensity</td>
<td>% change in drought intensity (deficit / duration)</td>
<td>5 GCMs, 4 GHMs</td>
</tr>
<tr>
<td>Peak flows risk</td>
<td>High fraction of ensemble agreement where substantial change in flood risk (doubling) is expected</td>
<td>5 GCMs, 4 GHMs</td>
</tr>
<tr>
<td>Seasonality</td>
<td>% change for the index of mean seasonality</td>
<td>5 GCMs, 4 GHMs</td>
</tr>
<tr>
<td>Inter-annual variability</td>
<td>% change for the index of mean inter-annual variability</td>
<td>5 GCMs, 4 GHMs</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to clean cooking</td>
<td>Fraction of population with access to clean cooking</td>
<td>MESSAGE + SSPs</td>
</tr>
<tr>
<td>Heatwave event exposure</td>
<td>Total days experienced as 5-day events above hist. p99 for locations where Tmean p99&gt;26°C.</td>
<td>5 GCMs</td>
</tr>
<tr>
<td>Cooling demand growth</td>
<td>Measure absolute change in CDD&gt;26°C.</td>
<td>5 GCMs</td>
</tr>
<tr>
<td>Hydroclimate risk to power production</td>
<td>Combined thermal and hydropower capacity impacted by changes in low flows, peak flows, drought intensity and variability</td>
<td>5 GCMs, 4 GHMs, Platts, Raptis</td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop yield</td>
<td>Mean change in crop yield as basket of staple crops</td>
<td>GLOBIOM</td>
</tr>
<tr>
<td>Water exploitation index</td>
<td>Identify major changes of agriculturally driven water exploitation</td>
<td>GLOBIOM + LPJmL</td>
</tr>
<tr>
<td>Habitat degradation</td>
<td>Change from non-ag to agricultural land use</td>
<td>GLOBIOM</td>
</tr>
<tr>
<td>Nitrogen leaching</td>
<td>Measurement of excess nitrogen leaching due to intensive agriculture</td>
<td>GLOBIOM</td>
</tr>
</tbody>
</table>
Climate change index scoring under uncertainty

Continuous scale (0 to 3) with intermediate ranges determined

0. Negligible risk
1. Low risk
2. Moderate risk
3. High risk

2.0°C climate example: Drought intensity change
Heating & cooling

**COOLING ENERGY DEMANDS**
- Poorer tropics see **increase** in cooling demands

**HEATING ENERGY DEMANDS**
- Rich sees **reduction** in heating demands

**OVERALL**
- Energy savings for the “Rich North”
- Energy increases for the “Poor South”
Example: South Asia heatwave events on population

In a 30-year period, how many “very hot” (>p95) 5-day events can be expected?

![Image of climate heatwave events]

![Histogram showing population impacted by climate change]

- Hist
- 1.5°C
- 2.0°C
- 3.0°C

Additional population impacted by climate

- SSP3
- SSP1
Example: hydroclimate impacts on steam turbine and hydro power plants

### Powerplant database

<table>
<thead>
<tr>
<th>Category</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel types</td>
<td>coal, bio, gas, hydro, sun</td>
</tr>
<tr>
<td>Unit types</td>
<td>CCGT, ST, CT, IC, HY</td>
</tr>
<tr>
<td>Cooling systems</td>
<td>ot_fresh, cl_fresh, air</td>
</tr>
<tr>
<td>Status</td>
<td>Operational, Planned, Retired</td>
</tr>
</tbody>
</table>

### EXAMPLE Impact datasets

#### % Change in Q90 for 2.0°C

- **Global steam turbine capacity**
  
  - **Steam turbine capacity impacted by % change in Q90 discharge at 2.0°C:** World
  
  - **- water**
  
  - **+ water**
Sectoral aggregation

Combine average scores with ‘hotspot points’

- Scores are averaged within sectors and indicators can be weighted
- Hotspots:
  - Min. score 2 if 2 sectors > 2.5
  - Min. score 2 in 1 sector == 3.0

Byers et al. (…)

Water impacts: 2.0° SSP2

Land sector impacts: 2.0° SSP2

Energy sector impacts: 2.0° SSP2
Hotspot areas

- Growing in area
- Growing in intensity

Byers et al. (…)

---

**ssp2 2050**

- 3.0°C
- 2.0°C
- 1.5°C

**Multi-sector impact score**

% Population exposure

**1p5-hist**

**2p0-hist**

**3p0-hist**

MSI threshold: 2.0
Exposure & vulnerability

<table>
<thead>
<tr>
<th>2050</th>
<th>1.5°C / SSP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>8.5 bi</td>
</tr>
<tr>
<td>E</td>
<td>2.3 bi</td>
</tr>
<tr>
<td>V</td>
<td>1.1 bi</td>
</tr>
<tr>
<td>E&amp;V</td>
<td>0.3 bi</td>
</tr>
</tbody>
</table>

Byers et al. (…)

![Graphs showing temperature and vulnerability by region for different scenarios.

*SSP1 2050 1.5°*
8.5bi total, 2.3bi exp, 0.3bi E&V

*SSP2 2050 2.0°*
9.2bi total, 4.9bi exp, 0.72bi E&V

*SSP3 2050 3.0°*
10.0bi total, 7.2bi exp, 1.83bi E&V
Conclusions

Energy

- Energy sector is challenging because it spans from clean cooking access to high-tech infrastructure
- Projections of future capacity are still needed
- Temperature-related impacts are substantial for both H&C and heat-related stress

Overall

- Overall exposure depends most on GMT
- Reducing inequality and poverty is key to reducing the Exposed & Vulnerable population, regardless of GMT
Additional slides
SSP1 & SSP3 compared in 2050

High urban population
More wealthy
Access to cooling

High rural population
Low cooling access and vulnerable
Cooling Demand in Top 150 Cities

Historical

Change in CDD in a 3°C climate