Exposure and Vulnerability to Energy, Water, and Land Hotspots under Different Climate Futures

A Spatially-Explicit, Global Assessment of Vulnerable Populations and Hydroclimatic Impacts


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Most of the material in these slides is undergoing peer review for publishing. Please do not publish or distribute publicly.
Multi-sectoral risk

- Many studies on climate impacts
- Increased attention on multiple sectors

Risk aggregation in climate impacts research

1. Temporal: “compound events” ... two or more simultaneous events, e.g. drought + heatwave, with impacts often more severe than their sum
2. Spatial: “hotspots”... locations exposed to risks in multiple sectors, although not necessarily at the same time
Global mapping of multi-sector climate and vulnerability hotspots

Multiple indicators (14) across 3 sectors

Hotspots of significant nexus vulnerabilities and impacts

Byers et al. (2017, in review)
Projecting Subnational Income and Inequality

BRT Machine Learning

NLP Projection

\[ \min_{r, \tau} \left( \sum_{j \in J} n_j \Omega \left( \frac{1}{4} I^r_i, I^r_i, T^r_i \right) - \sum_{j \in J} n_j \Omega \left( \frac{1}{4} I^r_i, i^r_j, t^r_j \right) \right)^2 \]

\[ \text{s.t. } \sum_{j \in J} n_j \Omega \left( \frac{1}{4} I^r_i, i^r_j, t^r_j \right) = N^r_i \]

\[ i^r_j - i^{r-1}_j \leq 1.65 \frac{I^r_i - I^{r-1}_i}{\Delta \tau} \]

\[ 1 - \frac{i^r_j}{i^{r-1}_j} \leq 0.05 \Delta \tau \]

\[ 1 - \sum_{j \in J} n_j i^r_j - \sum_{j \in J} n_j \ln i^r_j \leq 0.05 \]

\[ \forall j \in J \]

\[ i^r_j \in [t_{\text{min}}, t_{\text{max}}] \]

\[ i^r_j \in [0, \infty) \]

Indicators

Urban and Rural Income and Inequality

Scenarios

All 5 SSPs

Resolution

Global, States, 0.125 Grids

Gidden et al. (2017, in review)
Populations Vulnerable to Poverty

Gidden et al. (2017, in review)
## Multi-sector risk indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td></td>
<td></td>
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<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>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>Heat event exposure</td>
<td>Total days experienced as 3-day events above hist. p95 for wet bulb temperature</td>
<td>5 GCMs, 4 GHMs</td>
</tr>
<tr>
<td>Cooling demand</td>
<td>Measure absolute change in cooling degree days &gt;26°C.</td>
<td>5 GCMs</td>
</tr>
<tr>
<td><strong>Hydroclimate risk to power production</strong></td>
<td>Thermal and hydropower capacity impacted by changes in low flows, peak flows and variability</td>
<td>5 GCMs, 4 GHMs</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>Environmental flow exploitation index</td>
<td>Agriculturally driven exploitation of environmental flows</td>
<td>GLOBIOM + LPJmL</td>
</tr>
<tr>
<td>Habitat degradation</td>
<td>Change from non-agricultural 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>
w1: Water stress index

w2: Non-renew GW abstr.

w3: Drought intensity

w6: Inter-annual variability

Water impacts: 2.0° SSP2
Energy impacts: 2.0° SSP2
Global hotspot exposure

Byers et al. (2017, in review)
Hot and vulnerable

3.0 °C

Byers et al. (2017, in review)

MSR >4.0, income < $10 /day
Regionalised impacts – SSP2, 2050

- Northern hemisphere regions have better than average impacts
- Most Asian and southern regions are on/worse than average

Byers et al. (2017, in review)
Impacted Populations

Exposed

Exposed & Vulnerable

Byers et al. (2017, in review)

Sustainability  
Middle of the road  
Rocky road
Conclusions and findings

- More than double exposure between 1.5-3.0°C
- Asia already faces severe exposure and vulnerability at 1.5°C
- African exposure emerges intensely at 2-3°C
- As many E&V in SSP3 as today, but more concentrated in Asia and Africa
- Difference in SSPs results in order of magnitude reductions in E&V
Thank you very much for your attention!


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Backup Slides
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

Original indicator

 SSP2 2050

- 3.0°C
- 2.0°C
- 1.5°C

% Population exposure

Multi-sector impact score

Indicator value

Indicator score