On the sustainability and effects of irrigation for massive production of bioenergy crops

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Outline

• Updates of the global water resources model H08
  1. Model development
  2. Global impact assessment
  3. Regional impact assessment
  4. Integrated assessment

• Bioenergy crop production and irrigation
1. Model development

Substantially updated for more “realistic” expressions of water flows

The original H08 model

- Water abstraction from river
- Consumption based

The new H08 model

- +Water abstraction from groundwater, canals, & desalination
- Withdrawal based

Hanasaki et al. 2016, HESS
Hanasaki et al. (under review; discussion paper available here)
Where do people take water from?

Legend: fraction of water source

East Asia (surface water dominated)

Sahara (groundwater+desalination)

Hanasaki et al. (under review; discussion paper available [here](#))
See also [H08 web site](#)
2. Global impact assessment > ISIMIP

Inter Sectoral Impact Model Intercomparison Project Phase 2b (IPCC SR1.5)

Multi sectoral impact analyses using multiple impact models (>20)

Lange et al. (in prep)
See also project website
2. Global impact assessment > ISIMIP

What is the 1.5 degrees warmer world?

GMT

“Transient” 1.5 deg C (most of the studies)

“Stabilized” 1.5 deg C

Extended future

1.5deg

Pre-industrial

1900
2000
2100

Evapotranspiration

Precipitation

Surface temperature

Total discharge

Snow water equivalent

Linear regression:
- Global

Percentage of cell-boxes:
- 100%
- 75%
- 50%
- 25%
3. Regional impact assessment

Many excellent students have applied H08 to multiple regions:

- Chao Phraya River (Thailand)
  - Mateo et al. 2014, WRR; Hanasaki et al., 2014; HRL
  - +Adaptation
  - Takata et al. in prep

- Ganges Brahmaputra Megna
  - Masood et al. 2015, HESS

- Korean Peninsula
  - Yoo, 2016, Master thesis

- Kyushu Island (Japan)
  - Maji, 2017, Master thesis; Hanasaki et al. subm

Forthcoming: China, India, Panama and Philippines
4. Integrated assessment

Linking AIM/CGE and H08 for energy-water nexus studies

AIM/CGE (emission, mitigation)

- Socio-economic constraints
- Physical constraints

H08 (impacts, adaptation)

17 regions, 43 sectors, annual interval
50km-grid, 3 sectors, daily interval

Challenge: Fill the gaps

Water use
- Environmental
- Domestic
- Agricultural

Food
- Bioenergy
- Manufacturing
- Electricity

Thermal-power
Hydro-power

FY2015
FY2016
FY2017
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Background

BECCS to achieve 2 (1.5) degrees target

2 degrees scenarios (negative emission)

GHG emission paths

BECCS needed to achieve the 2 degrees target

<table>
<thead>
<tr>
<th></th>
<th>C sequestration GtCeq/yr</th>
<th>Land (Mha)</th>
<th>Energy (EJ/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BECCS</td>
<td>3.3</td>
<td>380-700</td>
<td>170</td>
</tr>
<tr>
<td>Present level</td>
<td>Total emission ~10</td>
<td>Total cropland ~1500</td>
<td>Primary energy ~500</td>
</tr>
</tbody>
</table>

Source: Smith et al. 2016
## Scenarios

### How to produce bioenergy crop?

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>S1 (rainfed)</th>
<th>S2 (irrigation)</th>
<th>S3 (sustainable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>2000</td>
<td>2100</td>
<td>2100</td>
<td>2100</td>
</tr>
<tr>
<td>Total cropland [Mha]</td>
<td>1570</td>
<td>2120</td>
<td>2120</td>
<td>2120</td>
</tr>
<tr>
<td>Bioenergy cropland [Mha]</td>
<td>0*</td>
<td>500</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Irrigation for bioenergy crop</td>
<td>No</td>
<td>No</td>
<td>Yes, even if unsustainable</td>
<td>Yes, if sustainable</td>
</tr>
</tbody>
</table>

Yamagata et al. submitted; Hanasaki et al. in prep
## Results

Tradeoffs among water, food, and energy.

<table>
<thead>
<tr>
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<th>S2 (irrigation)</th>
<th>S3 (sustainable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total irrigation use [km3/yr]</td>
<td>1420</td>
<td>1480</td>
<td>3490</td>
<td>2220</td>
</tr>
<tr>
<td>Nonsustainable irrigation use</td>
<td>660</td>
<td>720</td>
<td>1910</td>
<td>920</td>
</tr>
<tr>
<td>Food production [Mt/yr]</td>
<td>7500</td>
<td>7110</td>
<td>8150</td>
<td>7110</td>
</tr>
<tr>
<td>BECCS [GtC/yr]</td>
<td>0</td>
<td>4.03</td>
<td>2.88</td>
<td>3.01</td>
</tr>
</tbody>
</table>

Yamagata et al. submitted; Hanasaki et al. in prep
Why S3 was not effective?

Where irrigation is needed, there is no water available!!
Summary

- Research updates
  - The new model
  - Global impact studies (ISIMIP) → Julien Boulange
  - Regional impact studies → Kumiko Takata
  - Energy-Water nexus studies
    - Hydropower, Cooling water → Zhou Qian
    - Bioenergy and irrigation

- Bioenergy and irrigation
  - Irrigation enhances bioenergy production
  - Water availability matters. Don’t be too much optimistic!