Ozone: an invisible threat to food security

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Ozone production and trend

Effect of ozone on plants

Representative Concentration Pathway (RCPs) of tropospheric ozone trajectories

- RCP 2.6
- RCP 4.5
- RCP 6.0
- RCP 8.5

Ozone ppbv

Pollutants “bake” together in direct sunlight forming ozone.

Ozone production and trend

JULES-crop SoyFACE project Calibration Key Findings
Spatial and temporal scale of tropospheric ozone

Hadley Centre Global Environmental Model 2-Earth System

1950-2005 Historical ozone distribution
Biochemical effect of ozone on plant

Castagna et al. (2009)

- Maximum RuBP saturated rate of carboxylation (Vc max)
- Leaf Area Index
- Gross Primary Productivity
- Stomata conductance

Fitzgerald Booker
Diagram: Ainsworth et al. (2012). *The effects of tropospheric ozone on NPP and implications for Climate Change*
JULES-Crop

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Key Findings
Cropland and pasture represent 12% and 26% of land surface.

5 normal plant functional types

C3 and C4 crops

Different day sensitivity and growth rate.

Simulate farm-level productivity

4 Crop functional types

Variables associated with climate change e.g. drought, flood, rising temperature
SoyFACE project

- O$_3$ Free Air CO$_2$ Enrichment (FACE-O$_3$) on soybean at Illinois, USA
- Chamber environment modifies plant response and underestimate the yield losses.
- SoyFACE allows controlled CO$_2$ and O$_3$ enrichment to simulate different RCPs in 2100.
- 20m diameter
- Fumigate 9 hours per day
- Stop fumigation if the leaves are wet
## Vc max calibration

<table>
<thead>
<tr>
<th>Sources</th>
<th>Description</th>
<th>Vc max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kattge et al. (TRY database, accessed on 12/05/2015)</td>
<td>Average of all literatures with soybean Vc max</td>
<td>121.89</td>
<td>μ mol m(^{-2}) s (^{-1})</td>
</tr>
<tr>
<td>Betzelberger et al.</td>
<td>SoyFACE measurement</td>
<td>120</td>
<td>μ mol m(^{-2}) s (^{-1})</td>
</tr>
<tr>
<td>JULES C3 grass</td>
<td>Used as soybean by default</td>
<td>58.4</td>
<td>μ mol m(^{-2}) s (^{-1})</td>
</tr>
</tbody>
</table>
## Soybean parameters calibration

<table>
<thead>
<tr>
<th>JULES Parameters</th>
<th>Default</th>
<th>Tuned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top leaf nitrogen concentration</strong> (kg N/kg C)</td>
<td>0.073</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Scale factor of top leaf nitrogen to V_{c_{max}}</strong></td>
<td>0.0008</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Ratio of root N to leaf N</strong></td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Ratio of stem N to leaf N</strong></td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Fractional reduction of photosynthesis by O_{3}</strong> (sensitivity) (mmol m^{-2})</td>
<td>1.40</td>
<td>0.825</td>
</tr>
<tr>
<td><strong>Threshold of ozone flux</strong> (mmol m^{-2} s^{-1})</td>
<td>5.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Soybean parameters calibration

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Ozone - yield response calibration

Soybean carbon yield in 2009

- Observation (Carbon content is 50% of dry biomass)
- Ozone: 4, 0.625, n=130
- Standard JULES Crop

Relative AOT 40
Historical soybean yield change

Global soybean yield anomalies from 1960

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Historical maize yield change

Global maize yield anomalies from 1960

- standard CruNCEP
- CruNCEP + CO2 + O3
- detrended observation
- CruNCEP + CO2
- Observation
- detrended output
- CruNCEP + O3

Ozone production and trend
Spatial distribution of ozone
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Key Findings
Global economic impact of O$_3$ and CO$_2$

Impact of Ozone and CO2 on crop yield in 1995-2005

Average annual change of economic value

Economic value of crop is taken from FAO statistic using data from 1991-2005. Harvested area from FAO was multiplied with the model yield output.
Yield gap

1. Potential yield (JULES-crop with irrigation)
2. Climatic Potential Yield (JULES-crop)
3. Limit by: Water (Irrigation)
4. Limit by: Ozone
5. 75% Potential
6. Average Farm Yield (FAO observed yield)

Key Findings:
- Reduce by: Pest, Nutrient, Disease, Weeds, Pollution, Management
Future soybean yield

RCP 8.5

RCP 2.6

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