Model intercomparison of idealized global deforestation experiments

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Experimental set up:
- Branching off PI-control; coupled land-atmosphere-ocean; CO₂ and land-use fixed in 1850
- **20 million km² of forest linearly removed over 50 years** (historically: ~10 mio km²)
- Only from 30% most forested grid cells (→ same pattern across models)
- Replacement by natural grass land; removal of above-ground carbon
- Dynamic vegetation switched off
- At least 30 years of stabilization → ≥ 80 yrs
Novelty

- Straightforward implementation ➔ comparability of models
- Robust detection: strong deforestation signal (> historical or RCP) ➔ Similar to 1%/yr CO$_2$ experiments
- Transient simulations ➔ signal over time
- Biogeophysical and carbon cycle effects in one run

Model

<table>
<thead>
<tr>
<th>Model</th>
<th>MPI-ESM1.2-LR</th>
<th>IPSL-CM6A-LR</th>
<th>CESM2</th>
<th>BCC-CSM2-MR</th>
<th>CNRM-ESM2-1</th>
<th>CanESM5</th>
<th>MIROC-ES2L</th>
<th>EC-Earth3-Veg</th>
<th>UKESM1-0-LL</th>
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</thead>
<tbody>
<tr>
<td>years</td>
<td>150</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>90</td>
<td>150</td>
<td>80</td>
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<td>realizations</td>
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<td>3</td>
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</tbody>
</table>
Deforested fraction

Predominantly tropical deforestation; second peak in boreal region

Initial forest area: 36 - 66 $10^6$ km$^2$

<table>
<thead>
<tr>
<th>Model</th>
<th>Initial forest cover [Mkm$^2$]</th>
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<tbody>
<tr>
<td>MPI</td>
<td>48.15</td>
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<tr>
<td>IPSL</td>
<td>56.25</td>
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<td>CESM</td>
<td>46.98*</td>
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<td>CNRM</td>
<td>66.39*</td>
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<td>BCC</td>
<td>35.96*</td>
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<td>CanESM</td>
<td>56.48</td>
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<td>UKESM</td>
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<td>EC-Earth</td>
<td>37.75</td>
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<td>MIROC</td>
<td>40.86</td>
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<td>Model mean</td>
<td>48.26</td>
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</table>
Temperature response to deforestation (last 30 years)

Generally, no surprises:
- Extratropical cooling due to albedo increase
- Tropical warming due to a reduction in evapo-transpiration

Unexpected:
- Cooling in UKESM and EC-Earth, also over land in tropics

Only statistically significant changes are shown.

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Temperature sensitivity to deforestation: $\Delta T/\Delta F$

Changes in Tas per unit of tree fraction ($\Delta T/\Delta F$): if universal, could be used for any landuse change scenario

A complication: Mixed local and non-local effects

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Zonal changes in temperature & zero latitude

Model | Zero lat
--- | ---
MPI | 17.7°N
IPSL | 11.4°N
CESM | 26.9°N
BCC | 34.2°N

Zero Latitude: Latitude of ΔT sign changes in Northern Hemisphere
Precipitation response to deforestation

Reduction of hydrological cycle in tropics: transpiration of grasses < forests in tropics (exc. BCC and EC-Earth)

Only statistically significant changes are shown

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Biogeophysical effects in time (30-yr mov. average)

Different amplitude of cooling response, linear trend
When do changes emerge (ensemble mode)?

Time/fraction of emergence: When is the signal > noise?

(mean of trends) > (1 \(\sigma\) of trends)

- “Time of emergence”: within 50 years over the strongly deforested tropical regions
- The signal propagates from the centre of deforestation to the edges
- The “fraction of emergence” is more similar among the models than the “time of emergence”
Carbon cycle response

- MPI: continued decline due to changed litter input
- IPSL: almost only governed by cVeg
- CESM: stabilization due to productive grasses
- CNRM: Soil C increase
- BCC: strongest C decrease
- multi-model mean of land carbon decrease: 274 ± 113 PgC

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Relative changes in carbon density

Removed carbon:
Proportional to vegetation and soil carbon density
Summary & Conclusions

• The pre-industrial forest area ranges between 36 and 66 million km$^2$ with multi-model mean of 48.3±9.9 million km$^2$, close to historical reconstructions

• Most of the deforested area is in tropics, with a second peak in the boreal region. The effect on global annual near-surface temperature ranges from no significant change to a cooling by 0.55°C, with multi-model mean of -0.22±0.21°C

• Four models simulate temperature increase over deforested land in tropics and a cooling over deforested boreal land. In these models, the latitude of changing the sign of temperature response ranges from 11 to 34°N, with a multi-model mean of 23°N

• For those models that provided several ensemble members (MPI, IPSL and CESM2), the near-surface temperature changes emerge within 50 years over the tropical regions of strongest deforestation. The signal propagates from the centre of deforestation to the edges, indicating the influence of non-local effects

• The biogeochemical effect of multi-model mean of land carbon reduction by 274±113 PgC calculated offline would be a warming by 0.52±0.22°C, suggesting that the net effect of deforestation is a warming

• Sensitivities such as $\Delta T/\Delta F$, $\Delta c_{\text{Land}}/\Delta F$ in idealized runs could be compared with variable landuse scenarios in the CMIP6 runs, providing a basis for understanding “realistic” CMIP6 simulations