Evaluating the need for integrated Land Use and Land Cover Change (LULCC) analysis

Difference in 2004 forest area between the year-2000 referenced and the chronological LULCC

Alan V. Di Vittorio
Lawrence Berkeley National Laboratory

Jiafu Mao and Xiaoying Shi
Oak Ridge National Laboratory

Annual CESM Working Group Meeting
9 February 2016
$\sim 18$ ppmv CO$_2$ bias in 2004

$\sim 395$

$\sim 377$
More forest increases veg C gain by ~54 Pg and decreases CO$_2$ gain by ~15 ppmv over 90 years.
• What is the contribution of LULCC uncertainty to simulated carbon cycle uncertainty?

• How does the LULCC-driven carbon uncertainty compare to the effects of CO₂ concentration, nitrogen deposition, and climate?

• How can we improve LULCC to reduce atmospheric CO₂ bias and improve carbon cycle projections?
iESM-CLM simulations: 1850 - 2004

- Identical CMIP5 land use inputs

<table>
<thead>
<tr>
<th>Case</th>
<th>LULCC Reference</th>
<th>LULCC assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>No LULCC</td>
<td>Constant 1850</td>
<td>No conversion</td>
</tr>
<tr>
<td>Default*</td>
<td>Year 2000</td>
<td>Proportional to PFTs</td>
</tr>
<tr>
<td>Max forest</td>
<td>Previous year</td>
<td>$\Delta$ Pasture/crop maximizes forest area</td>
</tr>
<tr>
<td>Pasture rule*</td>
<td>Previous year</td>
<td>+ Pasture replaces grass/shrub PFTs first</td>
</tr>
<tr>
<td>Proportional*</td>
<td>Previous year</td>
<td>Proportional to PFTs; accounts for pasture</td>
</tr>
<tr>
<td>Crop rule</td>
<td>Previous year</td>
<td>+ Crop replaces tree PFTs first</td>
</tr>
<tr>
<td>Min Forest</td>
<td>Previous year</td>
<td>$\Delta$ Pasture/crop minimizes forest area</td>
</tr>
<tr>
<td>Prop constant CO$_2$</td>
<td>Previous year</td>
<td>Proportional to PFTs</td>
</tr>
<tr>
<td>Prop const CO$_2$/clim</td>
<td>Previous year</td>
<td>Proportional to PFTs</td>
</tr>
<tr>
<td>Prop const N dep</td>
<td>Previous year</td>
<td>Proportional to PFTs</td>
</tr>
</tbody>
</table>

- Atmosphere: CRU-NCEP, transient CO$_2$, N deposition, and aerosols
5.1 Million km$^2$ range in forest area by 2005
Unique spatial distributions of land cover

Difference in forest area (% of land area)

1 Jan. 2005

Default - Proportional (+2.1 M km²)

Max forest - Proportional (+2.3 M km²)
Net LULCC emissions (Pg C per year)

Cumulative:
Prop - Default = 35 Pg C

Cumulative:
Min For - Max For = 59 Pg C

Cumulative:
Const CO2/clim - Prop = 53 Pg C

Cumulative:
Const Ndep - Prop = 27 Pg C
LULCC effects on total ecosystem carbon (Pg C)

Change in TOTECOSYSC due to land use

- Default
- Max Forest
- Pasture rule
- Proportional
- Crop rule
- Min Forest

28 Pg C ~ 7 ppmv
33 Pg C ~ 10 ppmv

Atmospheric effects on change in TOTECOSYSC due to land use

- Proportional
- Proportional, Constant N dep
- Proportional, Constant CO2/climate
- Proportional, Constant CO2

24 Pg C
41 Pg C
11 Pg C
Summary

• Chronological LULCC raises CO$_2$ bias by $\sim 7$ ppmv

• Max vs Min forest could span $\sim 10$ ppmv CO$_2$

• 33 Pg eco C range is 63% of the 52 Pg C CO$_2$ fertilization effect

• Eco C range is 80% of the 41 Pg C CO$_2$+climate effect

• Climate has little effect on LULCC emissions

• Forest PFT area is likely too high

• Potential for integrated LULCC analysis to reduce atmospheric CO$_2$ bias and improve projections
Summary

- Chronological LULCC raises CO$_2$ bias by $\sim$7 ppmv
- Max vs Min forest could span $\sim$10 ppmv CO$_2$
  - 33 Pg eco C range is 63% of the 52 Pg C CO$_2$ fertilization effect
  - Eco C range is 80% of the 41 Pg C CO$_2$+climate effect
- Climate has little effect on LULCC emissions
- Forest PFT area is likely too high
- Potential for integrated LULCC analysis to reduce atmospheric CO$_2$ bias and improve projections
Summary

• Chronological LULCC raises CO$_2$ bias by ~7 ppmv.

• Max vs Min forest could span ~10 ppmv CO$_2$.

• 33 Pg eco C range is 63% of the 52 Pg C CO$_2$ fertilization effect.

• Eco C range is 80% of the 41 Pg C CO$_2$+climate effect.

• Climate has little effect on LULCC emissions.

• Forest PFT area is likely too high.

• Potential for integrated LULCC analysis to reduce atmospheric CO$_2$ bias and improve projections.
Summary

• Chronological LULCC raises CO₂ bias by ~7 ppmv

• Max vs Min forest could span ~10 ppmv CO₂
• 33 Pg eco C range is 63% of the 52 Pg C CO₂ fertilization effect
• Eco C range is 80% of the 41 Pg C CO₂+climate effect

• Climate has little effect on LULCC emissions

• Forest PFT area is likely too high

• Potential for integrated LULCC analysis to reduce atmospheric CO₂ bias and improve projections
Summary

- Chronological LULCC raises CO$_2$ bias by $\sim$7 ppmv.
- Max vs Min forest could span $\sim$10 ppmv CO$_2$.
- 33 Pg eco C range is 63% of the 52 Pg C CO$_2$ fertilization effect.
- Eco C range is 80% of the 41 Pg C CO$_2$+climate effect.
- Climate has little effect on LULCC emissions.
- Forest PFT area is likely too high.
- Potential for integrated LULCC analysis to reduce atmospheric CO$_2$ bias and improve projections.
Questions?

This work is supported by the Director, Office of Science, Office of Biological and Environmental Research of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231 as part of the Integrated Assessment Research Program.

Difference in 2004 forest area between the Max forest case and the Proportional case
TOTECOSYSC(PgC) for model year 1850-2004