Assessing impacts of selective logging on water, energy, and carbon fluxes in Amazon forests using the Functionally Assembled Terrestrial Ecosystem Simulator (FATES)

Yi Xu\textsuperscript{1,2}, Maoyi Huang\textsuperscript{1}, Michael Keller\textsuperscript{3}, Marcos Longo\textsuperscript{4}, Ryan Knox\textsuperscript{5}, Charles Koven\textsuperscript{5}, Rosie Fisher\textsuperscript{6}

\textsuperscript{1}Pacific Northwest National Laboratory, \\
\textsuperscript{2}Nanjing Normal University, \\
\textsuperscript{3}USDA Forest Service, \\
\textsuperscript{4}EMBRAPA Brazilian Agricultural Research Corporation, \\
\textsuperscript{5}Lawrence Berkeley National Laboratory, \\
\textsuperscript{6}National Center for Atmospheric Research

2017 CESM Land Modeling Working Group Meeting, 28 February to 2 March 2017
Motivation and Objective

- Forest degradation as a result of logging, fire, and fragmentation not only alters carbon stocks and fluxes in tropical forests, but also impacts the exchanges of water and energy fluxes between the land and atmosphere;

- Such impacts are poorly quantified to date due to difficulties in accessing and maintaining observational infrastructures, and the lack of proper modeling tools;

- To develop a modeling tool to quantify the complex interactions among forest degradation, ecosystem recovery, climate, and environmental factors.
Functionally Assembled Terrestrial Ecosystem Simulator (FATES) in CLM

- Previously known as CLM(ED) (Fisher et al., 2015, GMD)
  - See details in presentation by C. Koven/R. Fisher
- Landscape structured according to disturbance history
- Height resolved competition between plants for light
- Plant distribution emerges from plant functional properties
A selective logging module in CLM(FATES)

- Size-dependent mortality rates associated with selective logging
  - Mortality due to timber harvest directly
  - Mortality due to collateral damage
  - Mortality due to mechanical damage for infrastructure construction

- Removal of aboveground biomass of logged trees
  - Logs are transported off-site

- Conversion of live biomass to Coarse Woody Debris (CWD) following logging
  - CWD are updated accordingly.
Site description

- Meteorological forcing and fluxes from eddy covariance towers at two sites located in the Tapajos National forest near Santarem:
  - KM67, Old-growth forest (in use), 2001-2006
  - KM83, Selectively logged forest, 2001-2003

- Soil texture
  - KM67, 2% sand + 8% silt + 90% clay
  - KM83, 18% sand + 2% silt + 80% clay

- Plot-level measurements are available from the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)
Numerical experiments

- km 67 (intact site),
  - Simulation 2001-2006, 400-year spin-up
- km 83 (logged site, time of logging: 1 Sept 2001)
  - Simulation 2001-2003, 400-year spin-up

<table>
<thead>
<tr>
<th>Parameters perturbed</th>
<th>km 67</th>
<th>km 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>( SLA_0 ) (m² gC⁻¹)</td>
<td>0.012</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>0.018</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>0.025</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>0.035</td>
<td>0.035</td>
</tr>
<tr>
<td>( V_{cmax25} ) (μmol m⁻² s⁻¹)</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mortality</th>
<th>km 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct (DBH&gt;35cm)</td>
<td>15%</td>
</tr>
<tr>
<td>Collateral</td>
<td>~5% (all sizes)</td>
</tr>
<tr>
<td>Mechanical</td>
<td>~5% (all sizes)</td>
</tr>
</tbody>
</table>
Sensitivity to logging intensities

“Best” parameter set from previous experiment
- SLA$_0$ = 0.035, Vcmax = 60

Recovery following different logging intensities
- Biomass and LAI
- Forest structure and composition

<table>
<thead>
<tr>
<th>Mortality</th>
<th>KM 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td></td>
</tr>
<tr>
<td>10% (DBH&gt;35cm)</td>
<td>15% (DBH&gt;35cm)</td>
</tr>
<tr>
<td>Direct</td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>3.3%</td>
</tr>
<tr>
<td>Collateral</td>
<td>3.3%</td>
</tr>
</tbody>
</table>
Energy and water budgets

**KM 67**

- **Net radiation**
- **Sensible heat flux**
- **Latent heat flux**
- **Soil water in top 10cm**

**KM 83**

- **Net radiation**
- **Sensible heat flux**
- **Latent heat flux**
- **Soil water in top 10cm**

Logging date: 09/01/2001
Carbon Budget

**KM 67**

- **Net ecosystem exchange of carbon**
- **Net primary production**
- **Above ground biomass**

**KM 83**

- **Net ecosystem exchange of carbon**
- **Net primary production**
- **Above ground biomass**

Logging date: 09/01/2001
Recovery of biomass and LAI following logging

![Graph showing recovery of biomass and LAI over years for different logging rates.](image)
Sensitivity of ecosystem demography to logging intensities at km83
Summary and future work

- CLM(FATES) is able to reproduce latent heat and net ecosystem exchange reasonably well, although sensible heat is significantly overestimated.

- A selective logging module has been implemented into FATES and can be used for site-level applications, but further developments are needed for applications at larger scales.

- Model simulations are highly sensitive to parameter values. A global sensitivity analysis on key parameters in FATES will be conducted.

- The degraded forest is able to recover its biomass in 20 years, but the recovery of forest structure and composition takes much longer based on the numerical experiments.
Acknowledgement

▶ The Next-Generation Ecosystem Experiments – Tropics funded through the Terrestrial Ecosystem Science (TES) program within US Department of Energy’s Office of Biological and Environmental Research (BER)