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The FATES Selective Logging Module

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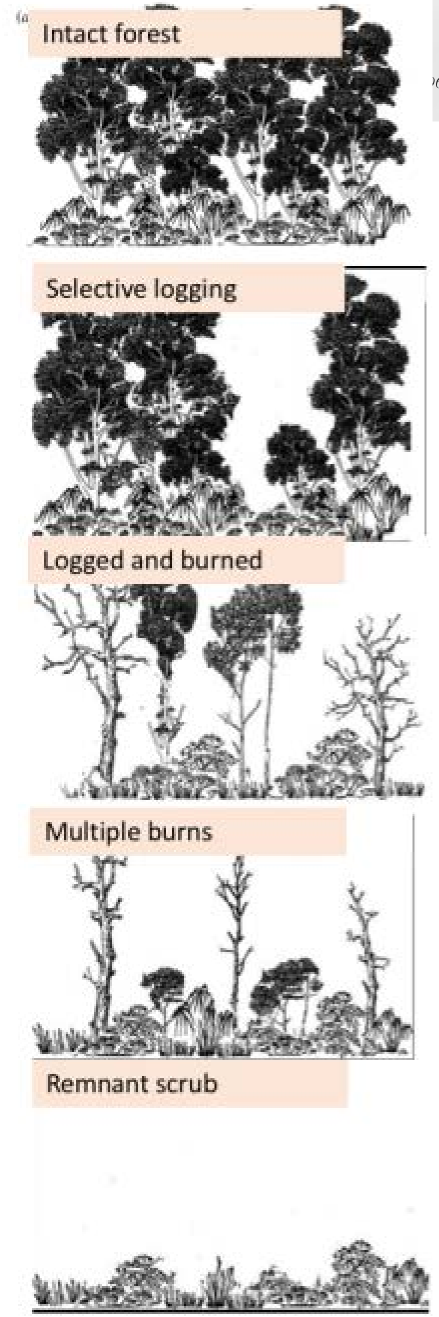
2018 CESM LMWG/SDWG meetings, Mesa Lab, NCAR

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 energy fluxes between the land and atmosphere;

- Such impacts are poorly quantified to date due to of limited field sampling, limits of remote sensing approaches;

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



Degradation in tropical forests (Barlow and C. A. Peres, 2008)

Importance of accounting for forest management in Earth system models

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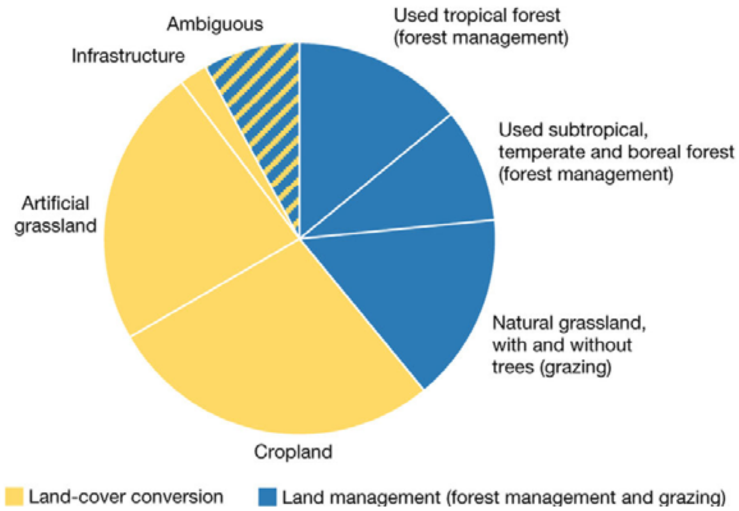
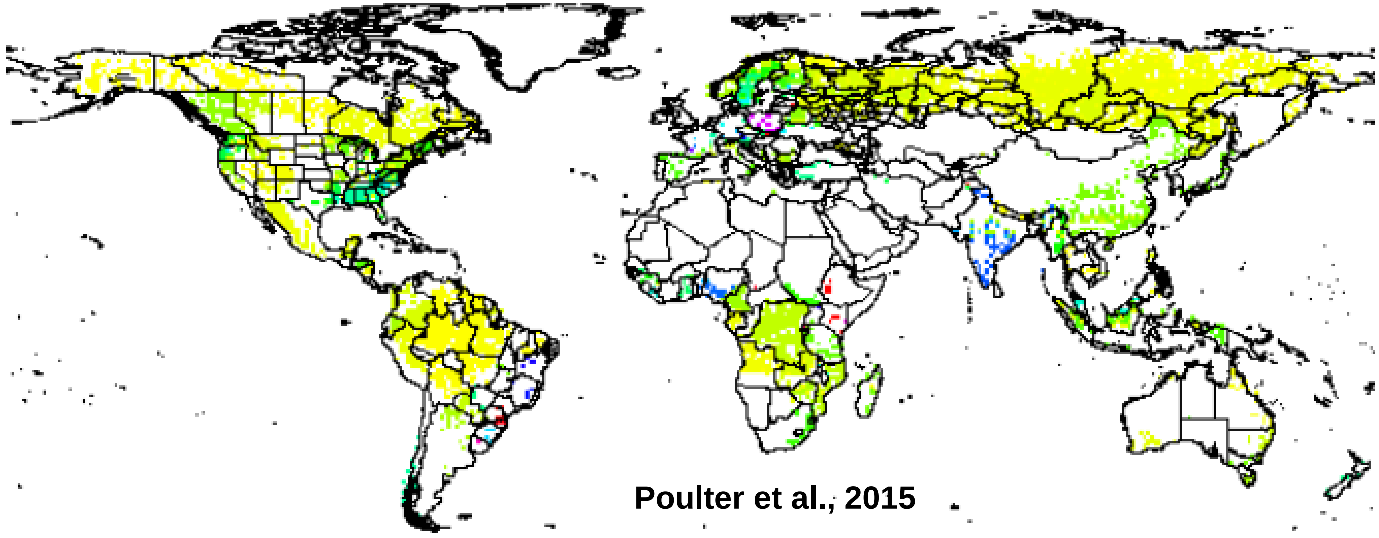


- land-cover conversion (53–58%) and land management (42–47%) contribute almost equally to the overall difference between potential and actual biomass stocks
- Forest management contributes two-thirds and grazing one-third to the management-induced difference in biomass stocks

Erb et al., 2018, Nature

Global wood harvest (industrial roundwood + fuelwood) extent



Poulter et al., 2015

Site Description

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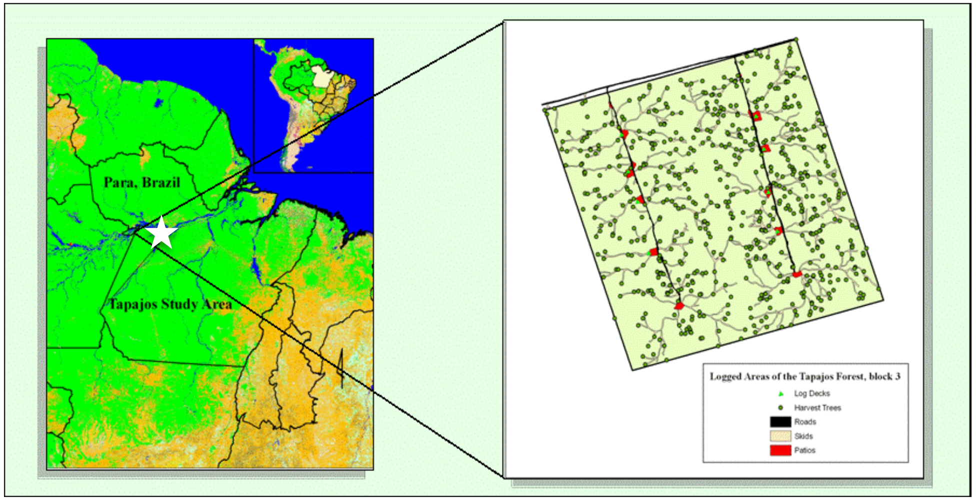


Location of logged areas in Tapajos National Forest and a typical study block showing tree-fall location, skid trail, road, and log deck coverages (Asner et al., 2004);

- Meteorological forcing and fluxes from eddy covariance tower in logged (KM83) forests where plot-level measurements were collected as part of the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA);

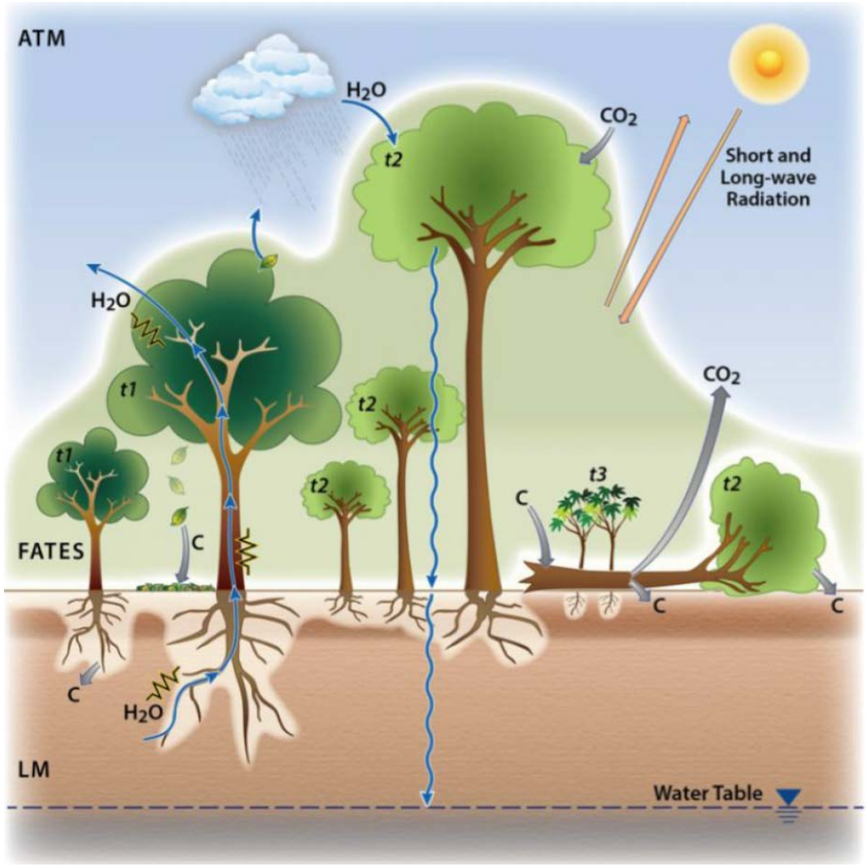
- The site represents the lowest degradation/logging level but is one of the few sites with decade-long observations in the tropics

Landscape Components of Selective Logging

Functionally Assembled Terrestrial Ecosystem Simulator (FATES)

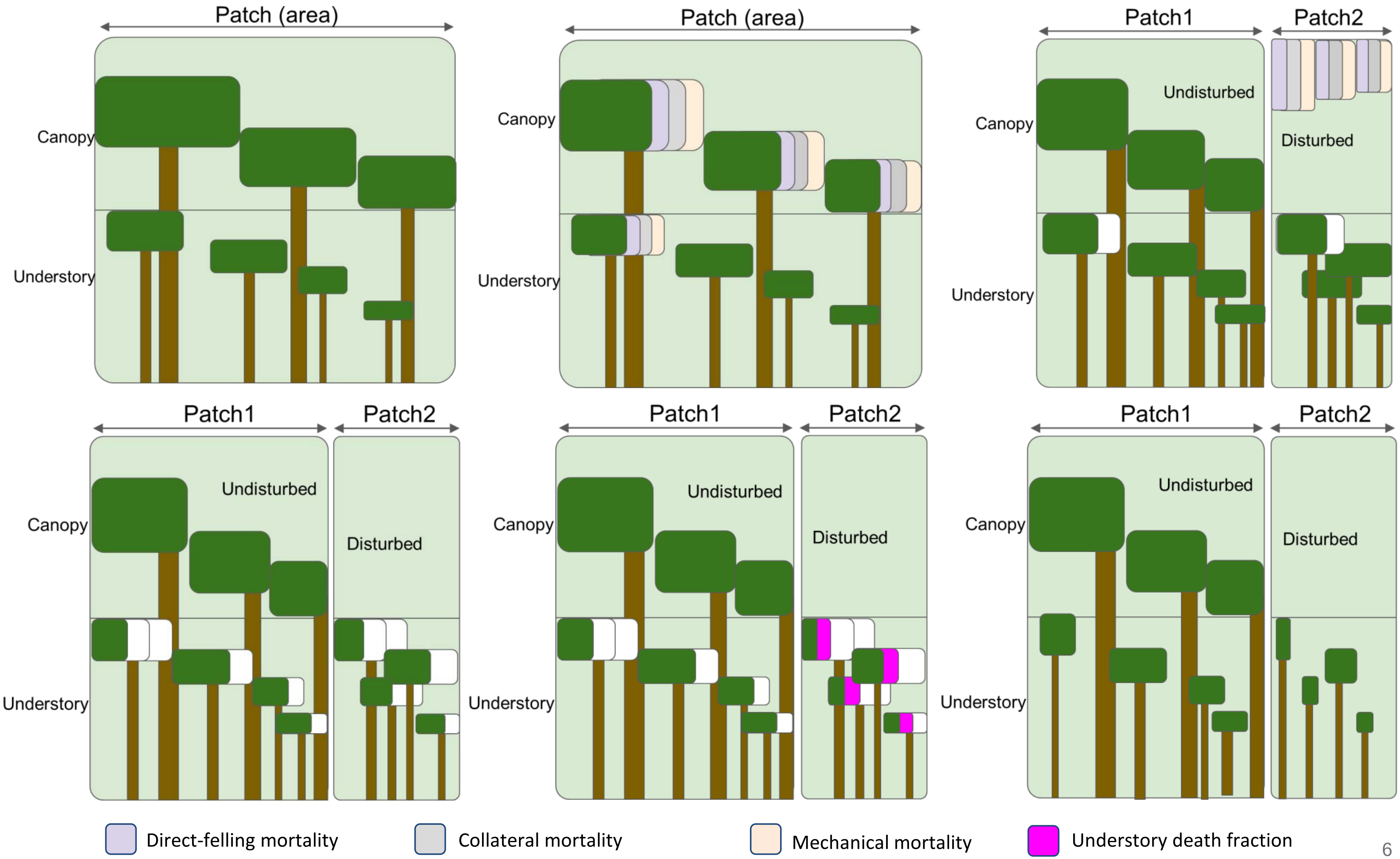
- Landscape structured according to disturbance history
- Height resolved competition between plants for light
- Cohortized representation of tree populations (plant functional types and sizes).

Functionally Assembled Terrestrial Ecosystem Simulator (FATES)

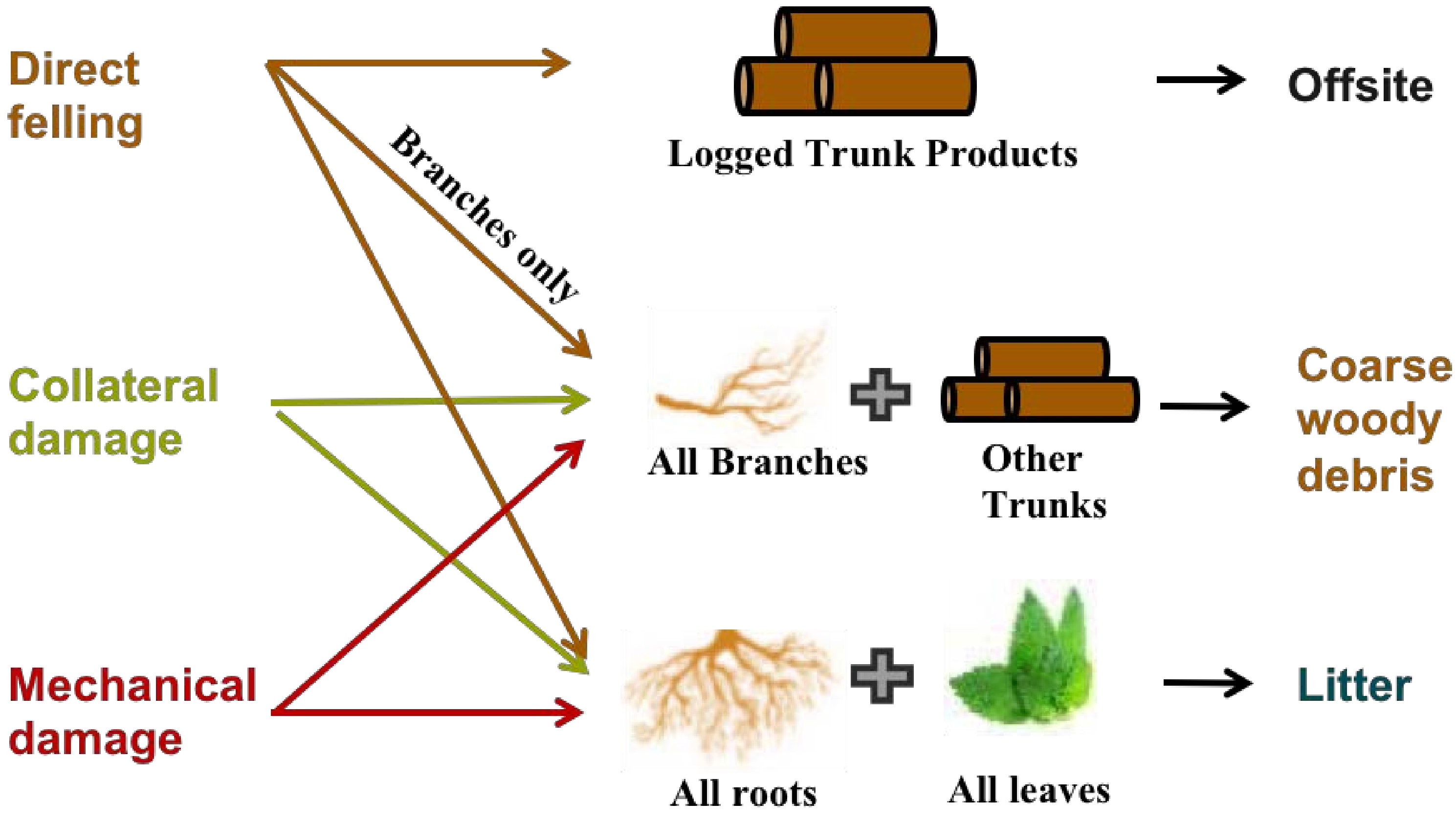


Fisher et al., 2015

Generating a new patch following logging



Flow of necromass following logging



Numerical Experiments

FATES Parameters to distinguish early and late successional PFTs

Parameter names	Units	Early successional PFT	Late successional PFT
Specific leaf area	$m^2\ gC^{-1}$	0.016	0.015
V_{cmax} at 25°C	$\mu mol\ m^{-2}\ s^{-1}$	68	60
Specific wood density	$g\ cm^{-3}$	0.5	0.9
Leaf longevity	yr	0.9	2.6
Background mortality rate	yr^{-1}	0.035	0.014
Leaf C:N	$gC\ gN^{-1}$	20	40
root longevity	yr	0.9	2.6

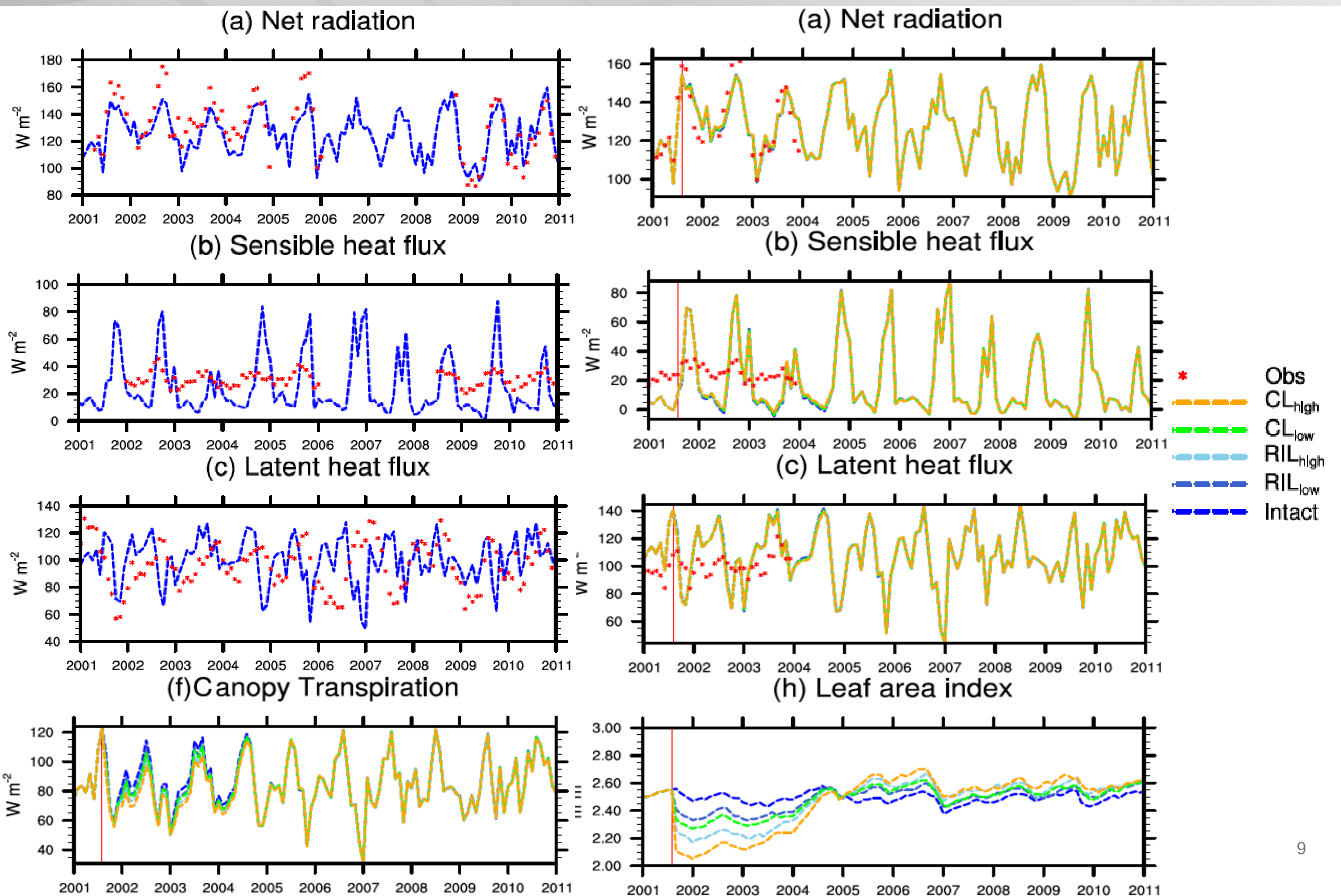
Cohort-level fractional damage fractions in different logging scenarios

Scenarios	Conventional Logging		Reduced Impact Logging	
	High	Low	High (KM83×2)	Low (KM83)
Experiments	CL_{high}	CL_{low}	RIL_{high}	RIL_{low}
Direct felling fraction ($DBH > DBH_{min}$[1])	0.18	0.09	0.18	0.09
Collateral damage fraction ($DBH > DBH_{min}$)	0.036	0.018	0.018	0.009
Infrastructure damage fraction ($DBH < DBH_{max\_infra}$[2])	0.15	0.07	0.04	0.02
Understory death fraction[3]	0.65	0.65	0.65	0.65

[1]DBH_{min} = 50 cm
[2]DBH_{max_infra} = 35 cm
[3]Applied to the new patch generated by direct felling and collateral damage

- ❑ The model was driven by forcing from KM67 for 100 years after a single logging event on 09/01/2001.
- ❑ 800-yr spin-up to stabilize water/carbon pools, as well as size structure/PFT composition.

Simulated energy fluxes



Simulated energy fluxes

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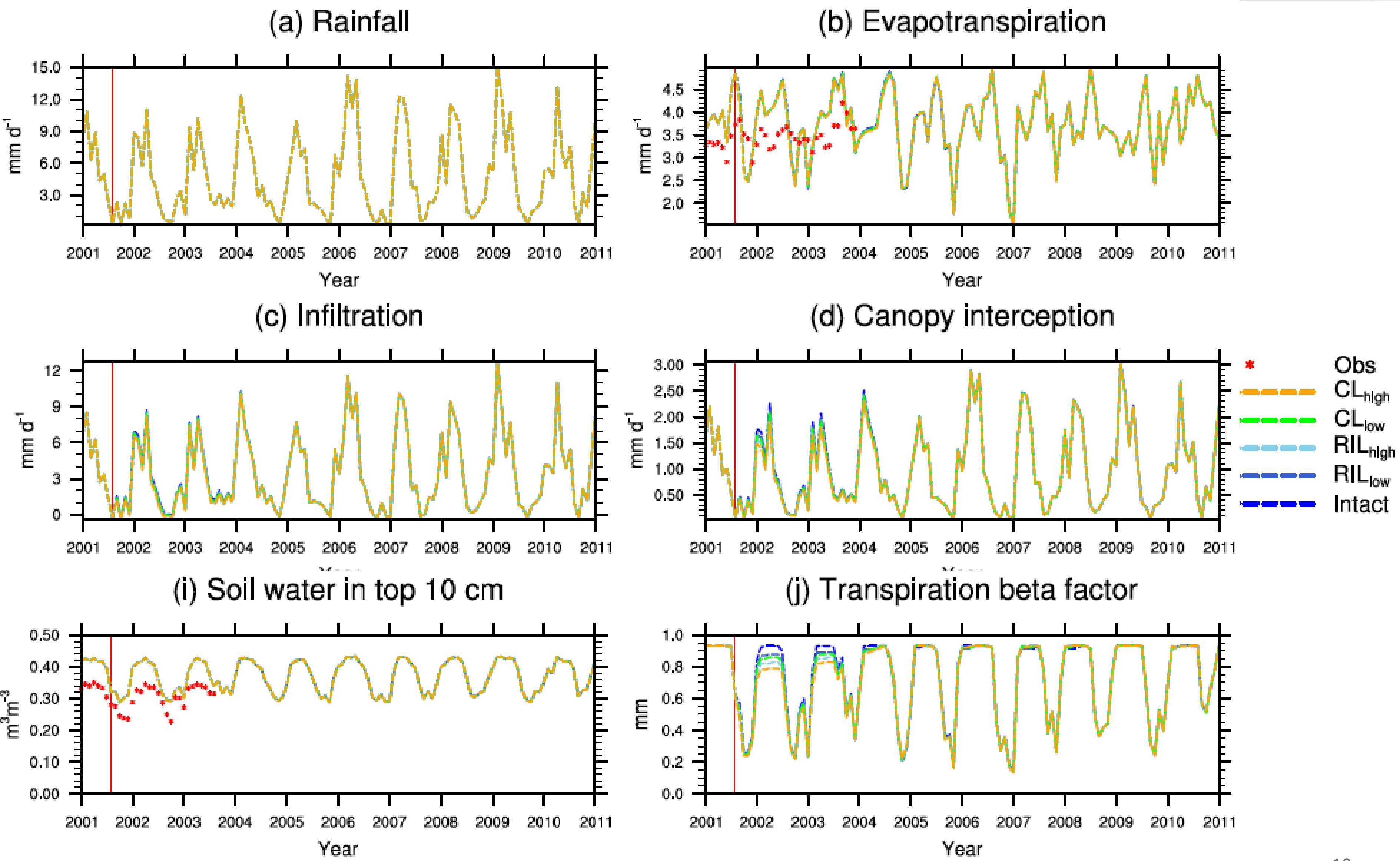
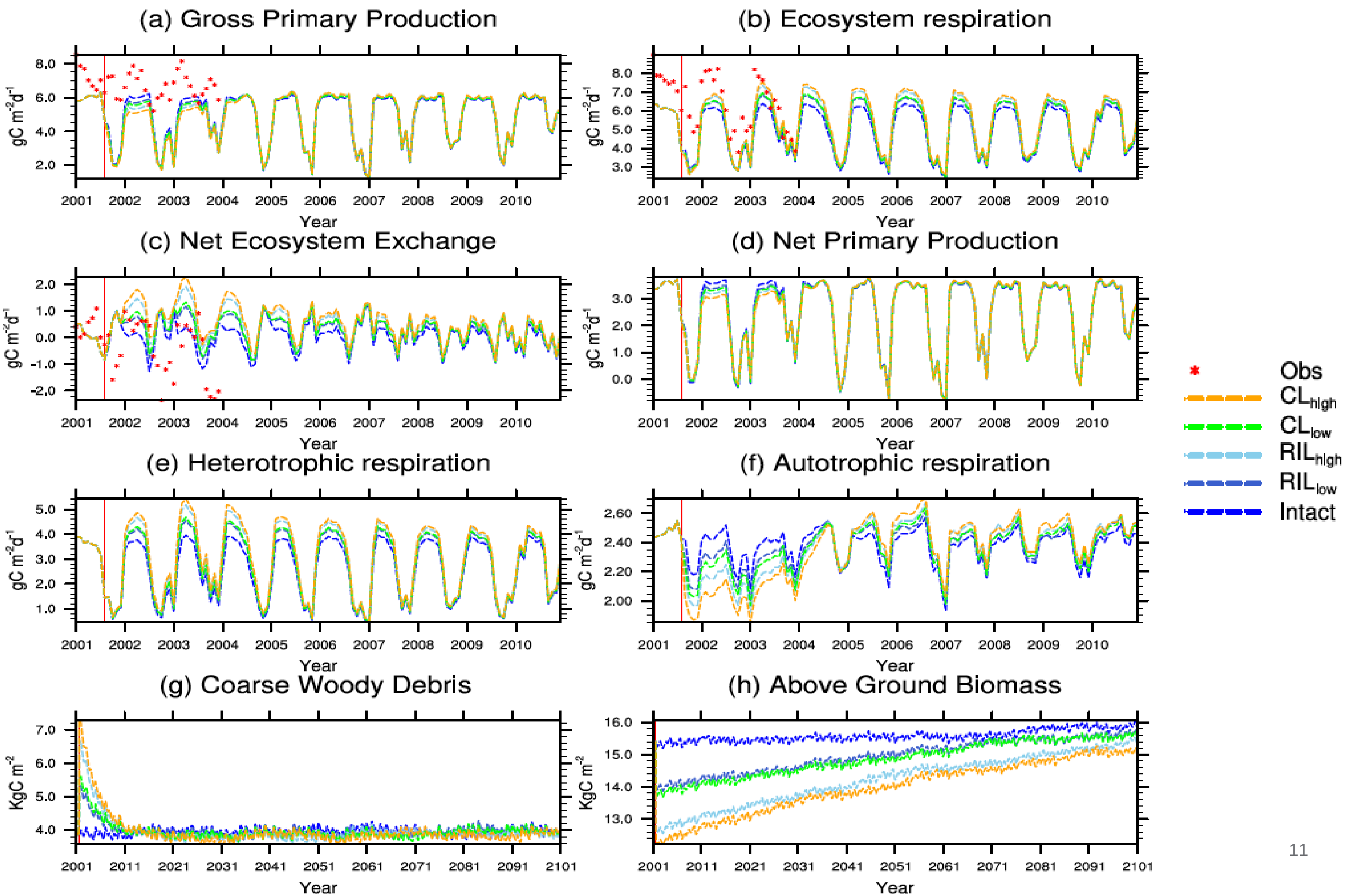


Carbon fluxes and pools



Forest structure and composition

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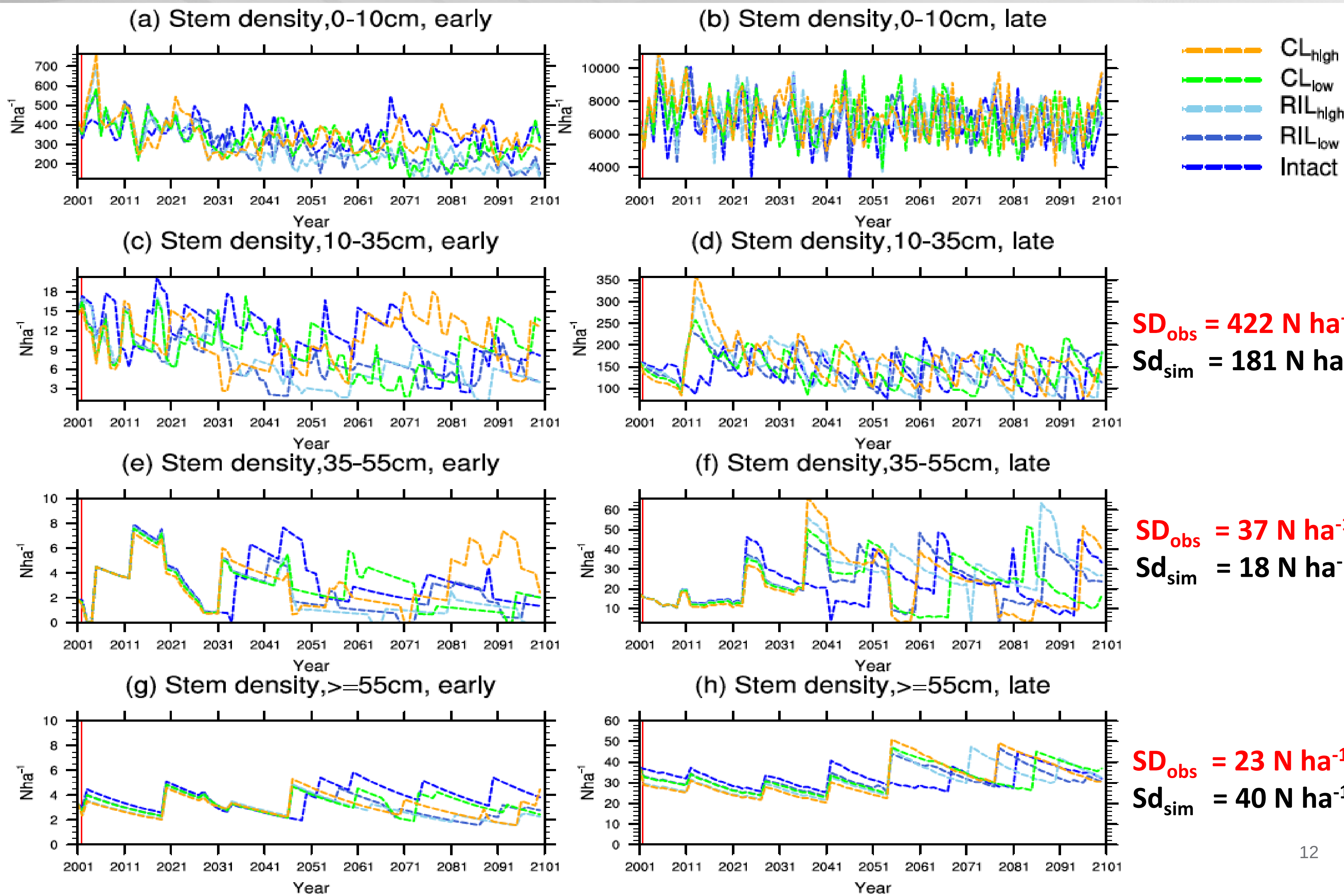


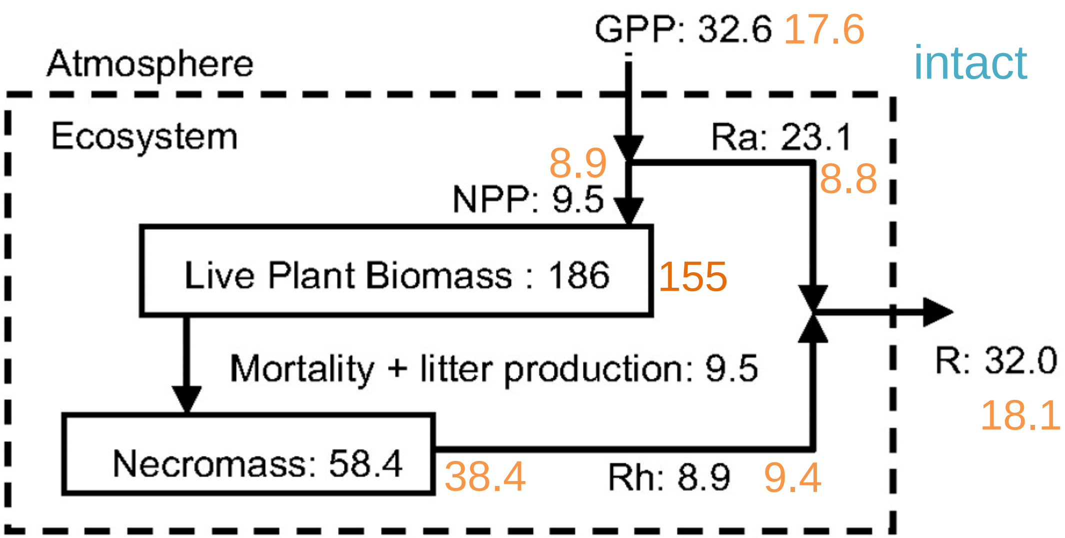
SD_{obs} = 422 N ha^{-1}
Sd_{sim} = 181 N ha^{-1}

SD_{obs} = 37 N ha^{-1}
Sd_{sim} = 18 N ha^{-1}

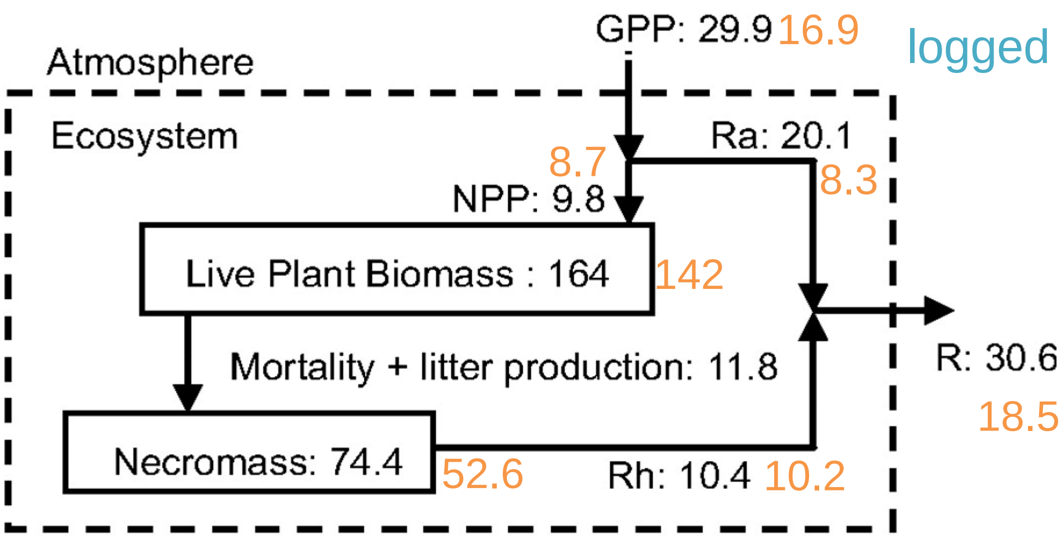
SD_{obs} = 23 N ha^{-1}
Sd_{sim} = 40 N ha^{-1}

Carbon Pools and fluxes before and following logging at km83

intact



logged



Observations

Simulated

Carbon pools (boxes, MgC ha^{-1})

Carbon fluxes (arrows, MgC·ha^{-1} y^{-1})

Miller et al., 2011

Keller et al., 2004

Summary and Future Work

- FATES was able to capture water and carbon fluxes/pools and their responses to disturbance in intact and logged forests reasonable well, although SH was overestimated by ~100%, especially in dry seasons;
- The model projections suggest that even though most degraded forests rapidly recover water and energy fluxes, the recovery times for carbon stocks, forest structure and composition are much longer. The recovery trajectories are highly dependent logging intensity and practice;
- Our numerical experiments suggest that there is a need to improve FATES structure and parameters for applications in the tropics.
  - The radiative scheme needs to be improved to allow more leaf area, which will help improve energy fluxes as well as autotrophic respiration simulations.
  - The model also suffers from significant water stresses in the dry season, indicating the need to improve plant hydraulics.
- Future development will be implementing land use capabilities to enable regional-scale applications, including tracking disturbance history associated with fire, logging, and transition between land use types.

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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)

Thank you!