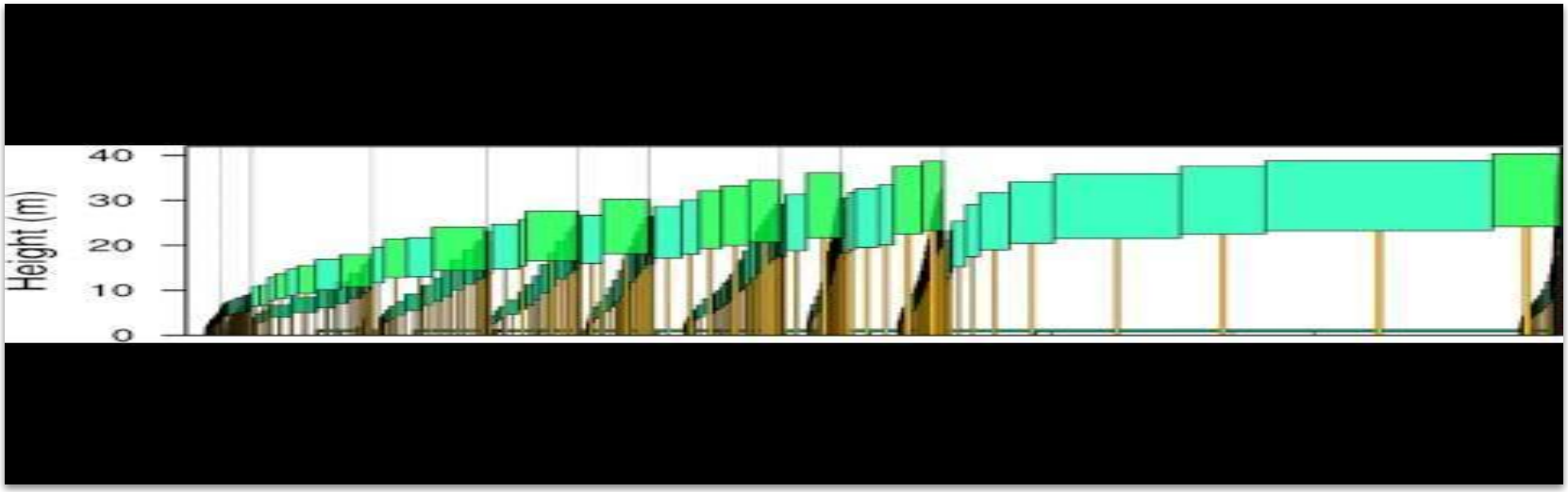
FATES Overview and Some Recent Developments (including land use)

Charlie Koven, Alan Di Vittorio, Maoyi Huang, Yi Xu, Rosie Fisher, Ryan Knox, Jackie Shuman, Lara Kueppers, Greg Lemieux, Chonggang Xu, Sam Levis, and many others

CESM LMWG Session
June 16, 2020

FATES resolves plant growth, competition, death, and disturbance dynamics

Structurally complex ecosystems emerge through interactions between plants, based on plant traits, climate and soil conditions. Example below is 600 years of forest dynamics from bare ground conditions at a tropical forest site under constant climate and CO_2.



Short Tree Cohorts
Young Patches

Early Successional PFT
Late Successional PFT

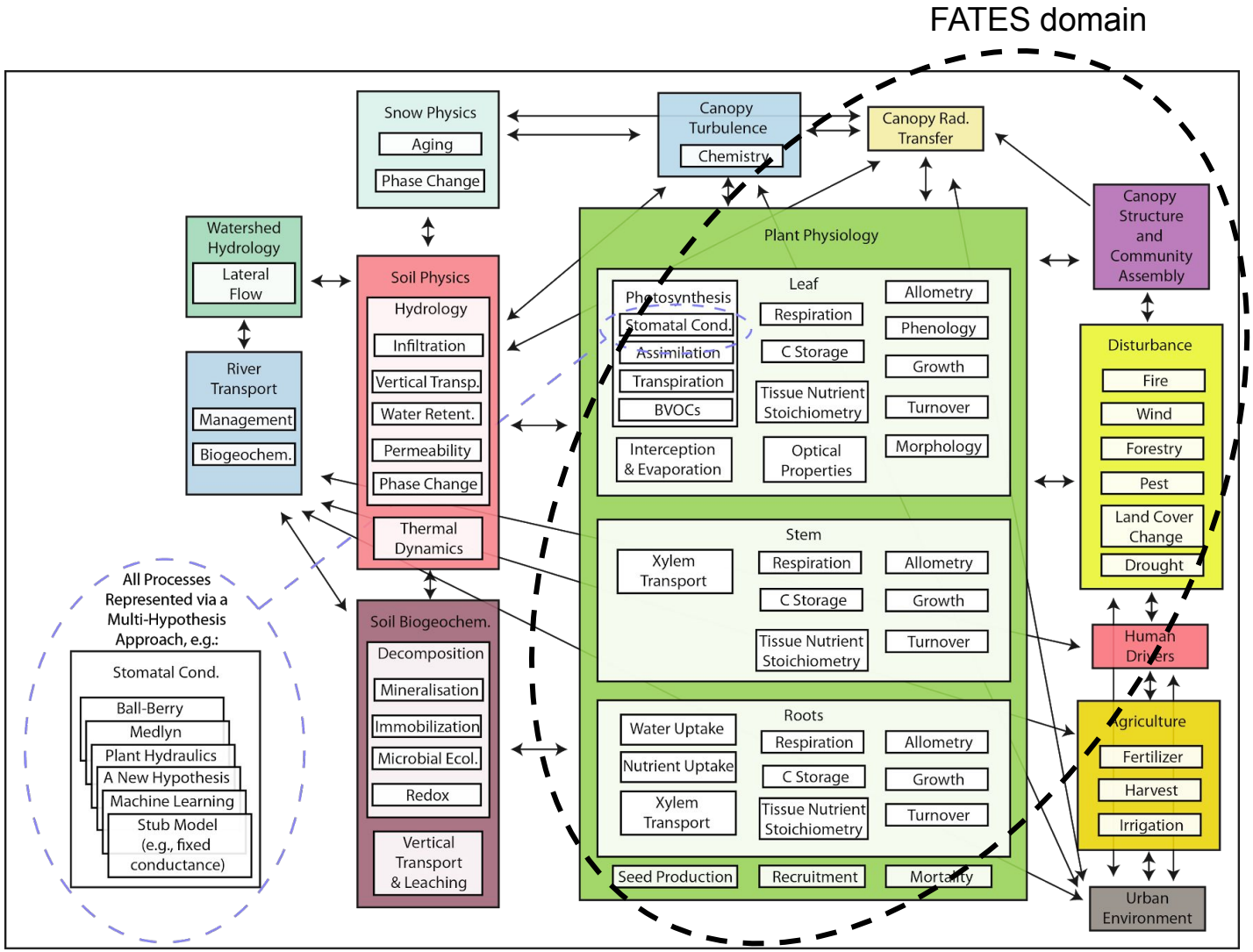
Tall Tree Cohorts
Old Patches

Koven et al., 2020

What are some new types of questions that CESM-FATES would allow one to ask?

- How do variations in plant traits within any biome, such as gradients in drought tolerance within tropical forests, affect land surface function?
- How do changing climate-driven disturbance agents such as fire, drought, and windstorms lead to changes in ecosystem structure and composition, and feed back to climate change?
- How do plant height dependent processes, such as fire, insects, drought, or surface roughness, evolve under global change?
- How do transient changes to forest-savanna, forest-grassland, or forest-tundra boundaries feed back to physical climate system?
- How do primary and secondary lands behave differently in physical and biogeochemical functioning of the Earth system?
- How do CO_2 fertilization or nutrient cycling changes induce changes to plant community composition, thereby affecting growth, turnover, and feedbacks to the carbon cycle?
- How does resolving any particular axis of plant functional diversity across the world affect the dynamics of the land surface,land-atmosphere coupling, and terrestrial feedbacks to climate change?

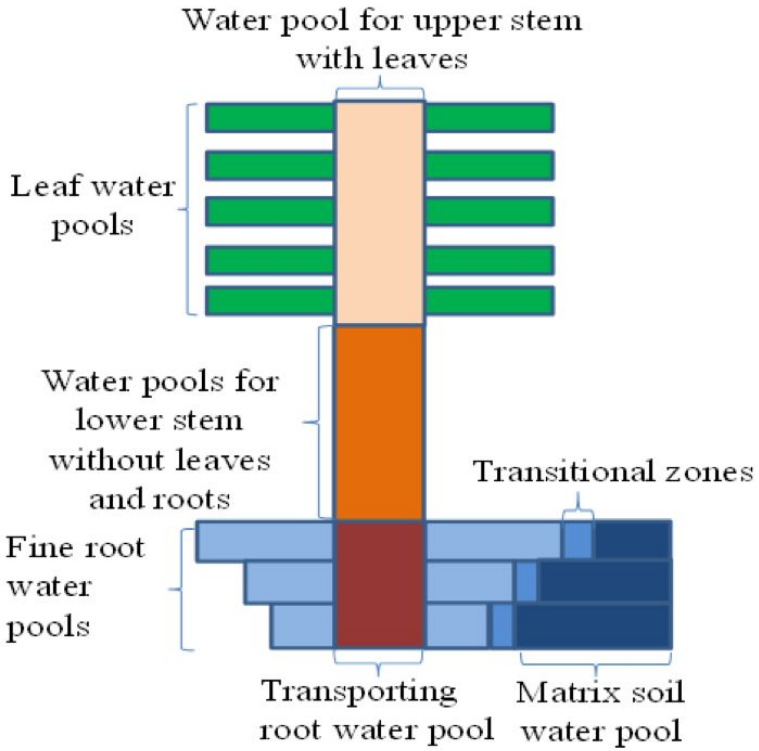
Where is FATES within a CLM process diagram?



Fisher and Koven, 2020

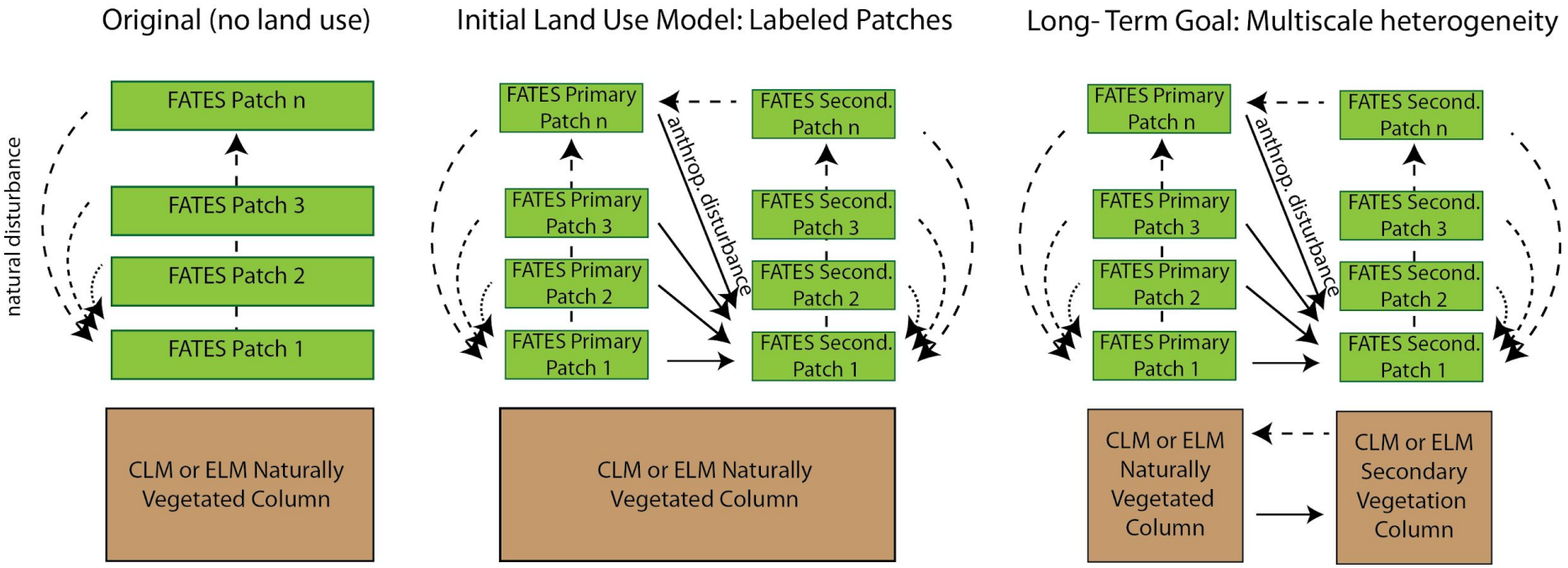
Some key recent process developments in FATES

- Plant hydraulics based on Sperry model (Christoffersen et al., *in prep;* Xu et al., *in prep*; Ding et al., *submitted*)
- Multi-nutrient and/or isotope mass budgeting logic throughout all plant organs, litterfall, & disturbance (Knox et al., *in prep*)
- Fire dynamics and fire-mediated plant competition (Shuman et al., *in prep,* Buotte et al.*, in prep*)
- Alternate stomatal conductance models (Li et al., *in prep*)
- Leaf age discretization
- Plant damage and recovery (Needham et al., *in prep*)



Simplified FATES hydraulics schematic, Xu et al. in prep.

Overall Schematic of FATES with Land-Use



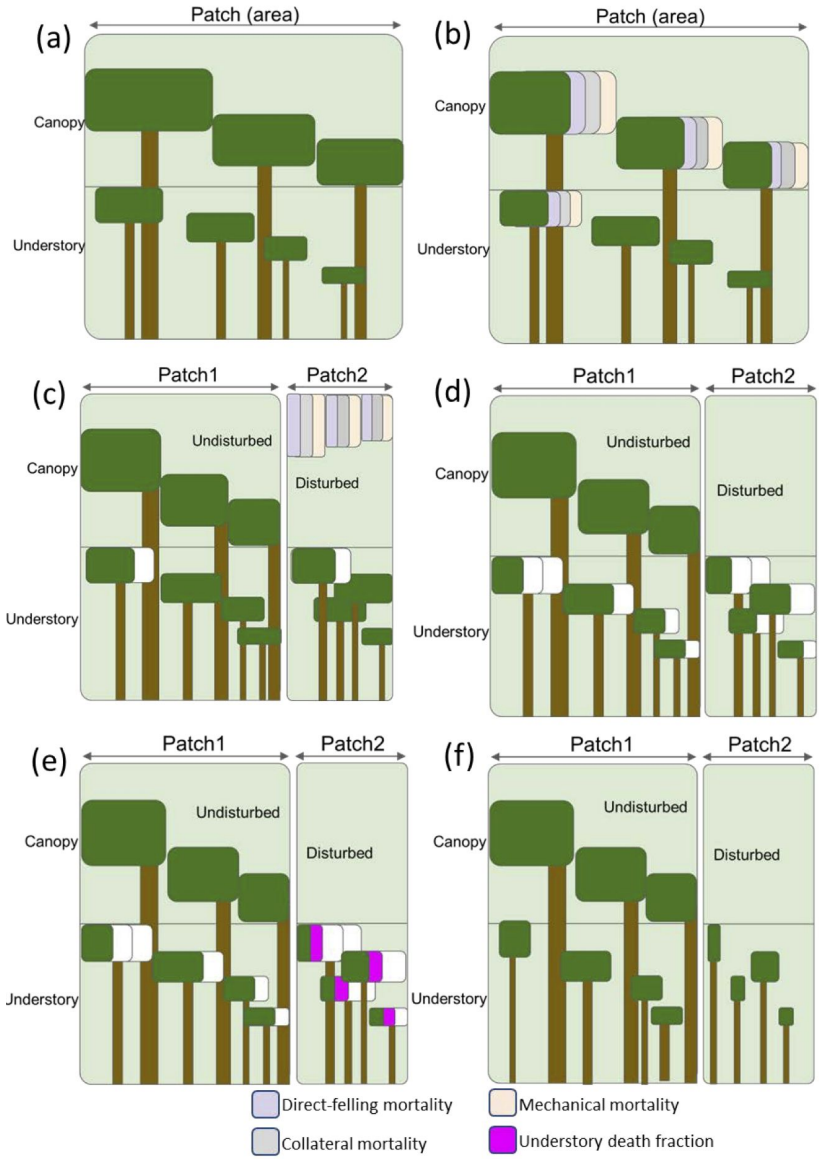
- New land-use code harvests separately from primary, young secondary, and old secondary patches, where young/old secondary is based on time since anthropogenic disturbance.
- V1 Land use code uses area-based harvest rates, next step is to diagnose the harvestable carbon and calculate area from mass-based drivers.

How logging is actually applied in FATES (1: closed-canopy forest case)

(a) Original patch structure

(c) Newly-disturbed patch area diagnosed as the area underneath the crowns of canopy trees that are dying.

(e) Some fraction of understory trees in newly-disturbed area are killed.



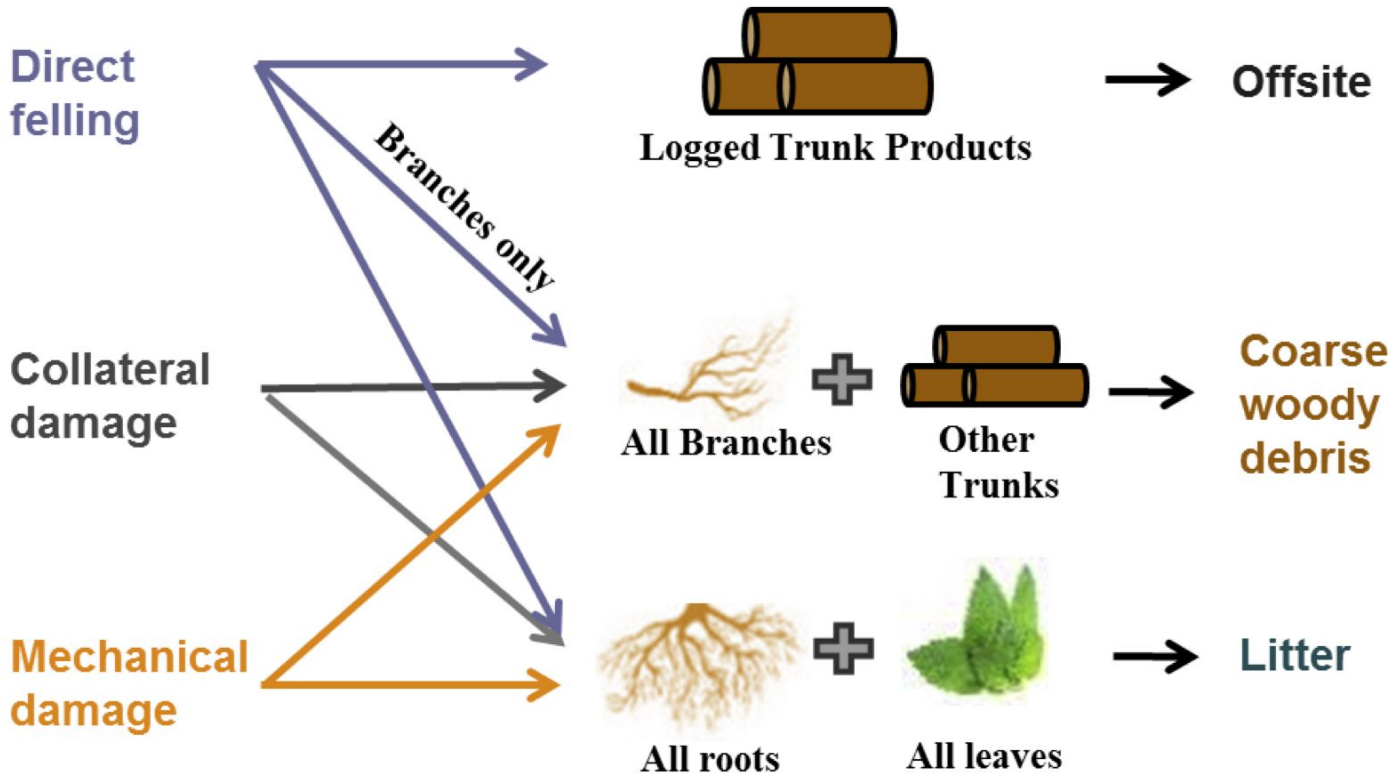
(b) Direct effects of logging, including collateral mortality and mechanical (roadbuilding) mortality

(d) Crown area of dying trees removed.

(e) Resulting structures of new and old patches.

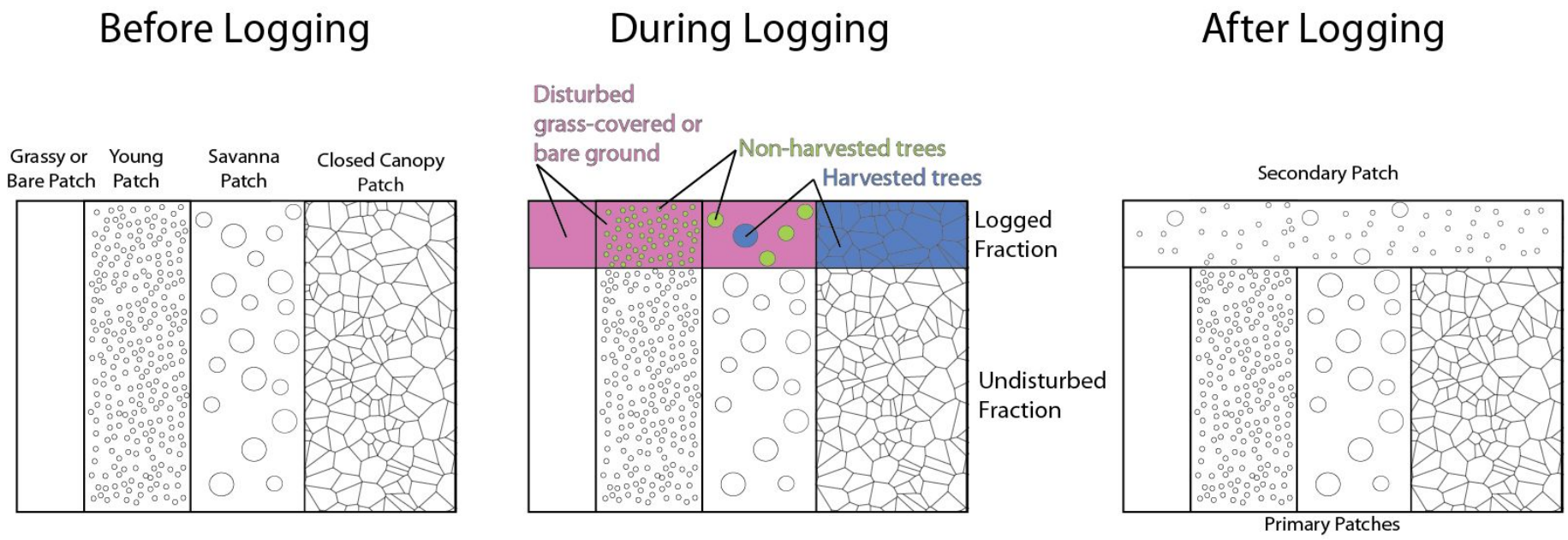
Huang et al., *Biogeosciences Discussions, in review*

Harvested trees split into wood products, litter, and coarse woody debris



Huang et al.,
Biogeosciences Discussions, in review

How logging is actually applied in FATES (2: possibly open-canopy ecosystem case, and switching to top-down view for schematic)



Some next and later steps with logging and land use

- Testing!
- Integration with prescribed biogeography mode (Rosie describing in a bit)
- Add mass-based specification of logging rates
- Thinking more about how to specify parameters. Right now they are applied to all logging types on all gridcells at all times.
- Sensitivity to existing and to-be-added logging parameters: fraction of trees killed during logging, min/max stem diameters, preferential logging of different PFTs, etc.
- How to handle lack of agreement between harvestable biomass estimate from logging driver datasets and FATES simulations? Already a problem in big-leaf model, will existing strategies work in FATES?
- Moving to multiple FATES sites / CTSM columns, along with ability to pass patch structures from one column to another during land cover transitions, both FATES -> crop and crop -> FATES.
- Addition of managed land types: e.g., pastures (some overlap with prescribed biogeography)

Bonus Slide: FATES containerization effort

- General goals
  - Improve portability, particularly for new users running locally
  - Improve repeatability and reproducibility of tests
- Hosted on NGEE-Tropics Docker Hub Organization: https://hub.docker.com/u/ngeetropics
  - CTSM-FATES and ELM-FATES images available
  - General orientation and overview: https://github.com/NGEET/docker-fates-tutorial
- Next steps
  - Generate new images of more recent stable versions of FATES
  - Input data handling: how to handle and possibly reduce download of large input data sets
  - Jupyter and Globus docker image integration to improve user experience