Incorporation of Global Land Use Change in ELM-FATES (with a focus on a prescribed land cover configuration)

Charlie Koven

With input and help from many others: Greg Lemieux, Rosie Fisher, Ryan Knox, Shijie Shu, Jackie Shuman, Peter Lawrence, Jennifer Holm, Adrianna Foster, Alan Di Vittorio, Jessie Needham, Marcos Longo, David Lawrence, Bill Sacks, Erik Kluzek

CESM LMWG meeting. Feb. 2024

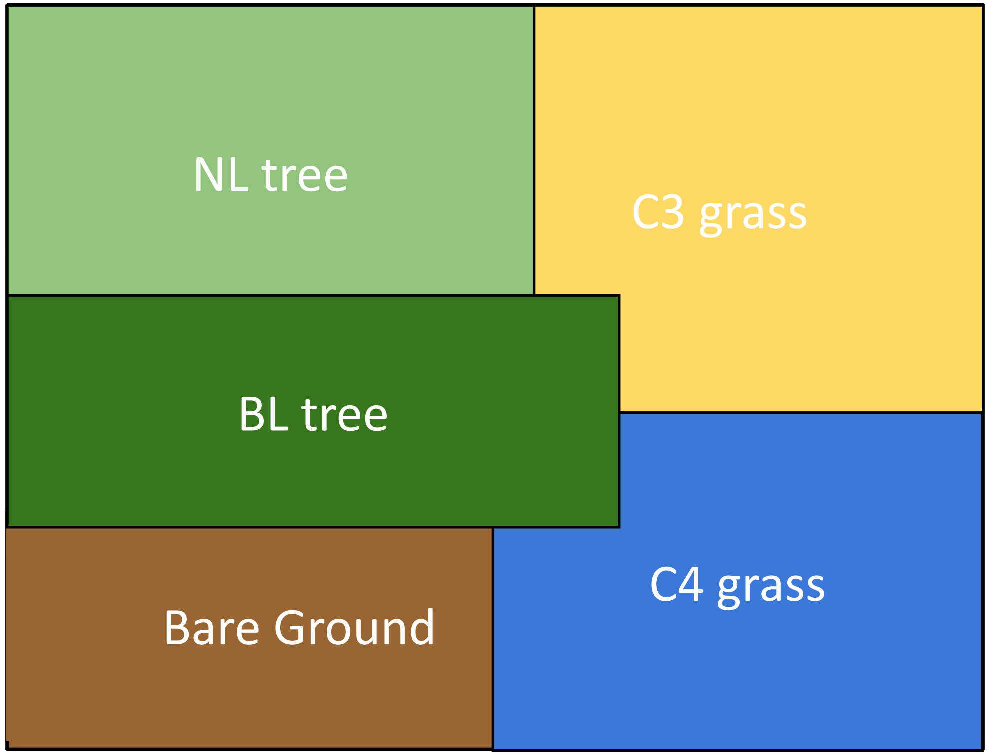
NGEE–TROPICS
NEXT-GENERATION ECOSYSTEM EXPERIMENTS–TROPICS

Motivation

- So far, FATES has had elements of land use, but not a full CMIP- or TRENDY-class representation of land use, land use and land cover change, and forestry
- At the same time, FATES has much greater potential than the legacy CLM and ELM vegetation models to represent land use:
  - Disturbance history is resolved and dynamic
  - Possibility to represent ecosystem succession
  - Plant-centered rather than ecosystem-centered view of allows better representing land use effects
- Want to start off by doing looking at transient global dynamics with the training wheels reattached (but removable!), so prescribing land cover rather than prognosing it.

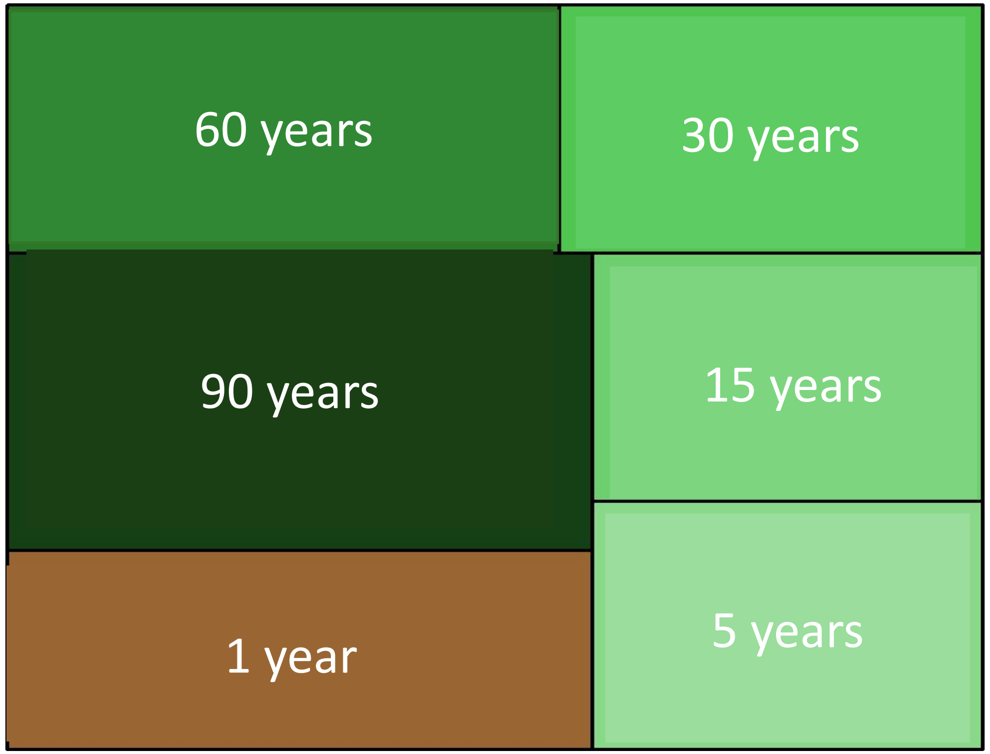
“Nocomp” configuration synthesizes aspects of both PFT-based and disturbance-based tiling

Plant Functional Type tiling



+

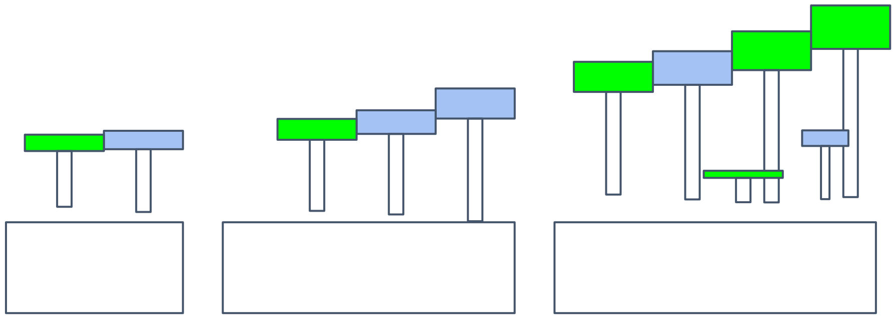
Time-Since-Disturbance tiling



Adapted from one of Rosie’s FATES tutorial slides

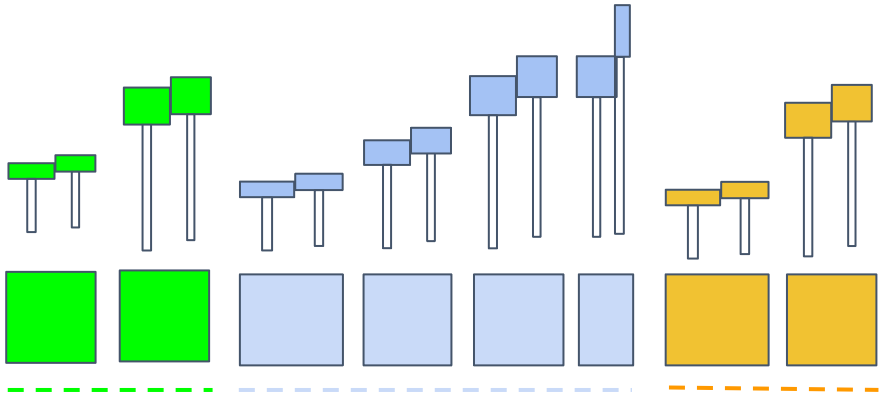
Nocomp configuration vs Full-FATES configuration

Full FATES
Growth, disturbance, and competition everywhere.



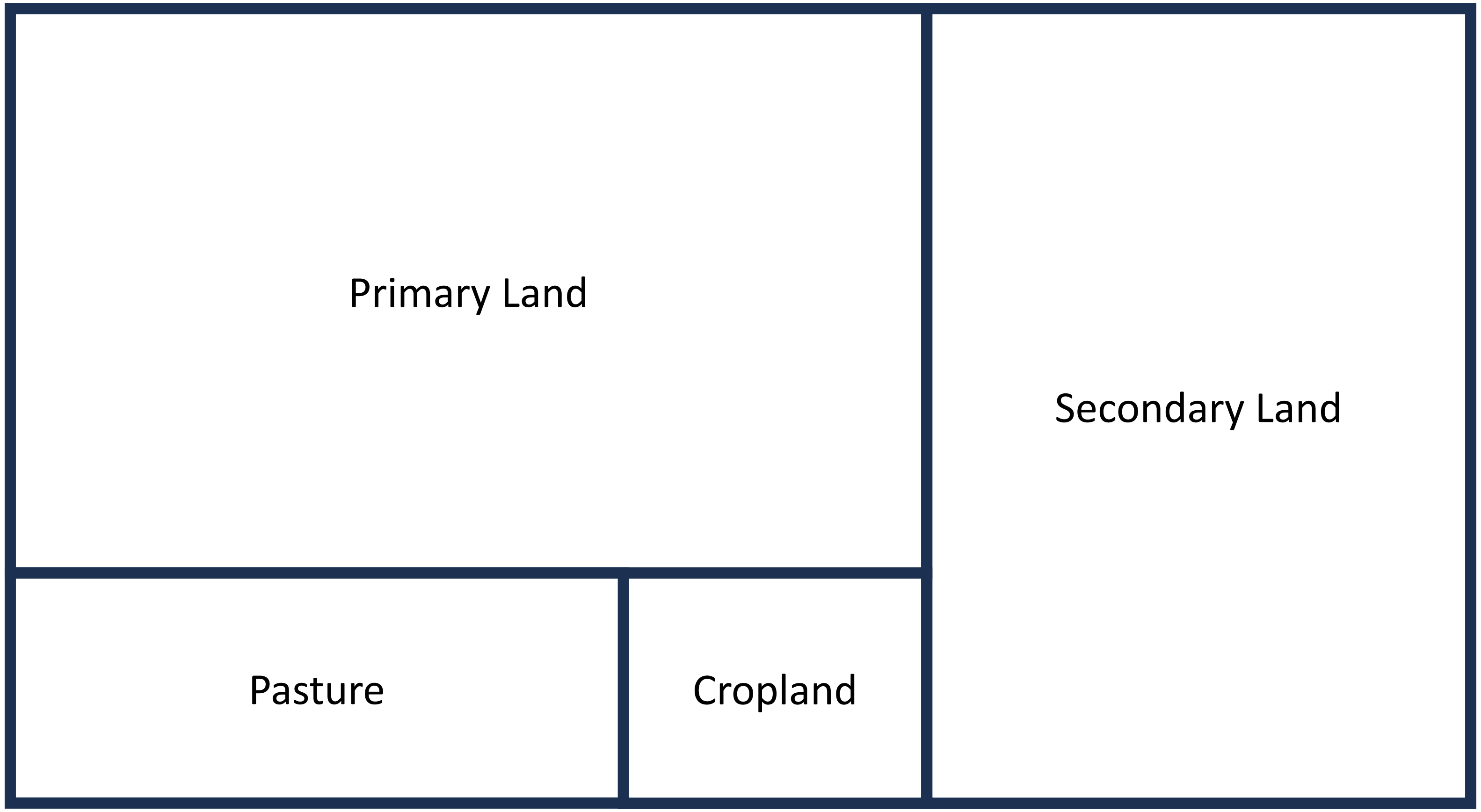
- Patches resolved only by a single continuous variable: age
- PFT composition on any patch is emergent

nocomp = True
Prescribed Biogeography = True
All PFTs given a fixed area to grow.
Growth and disturbance but no competition for light.

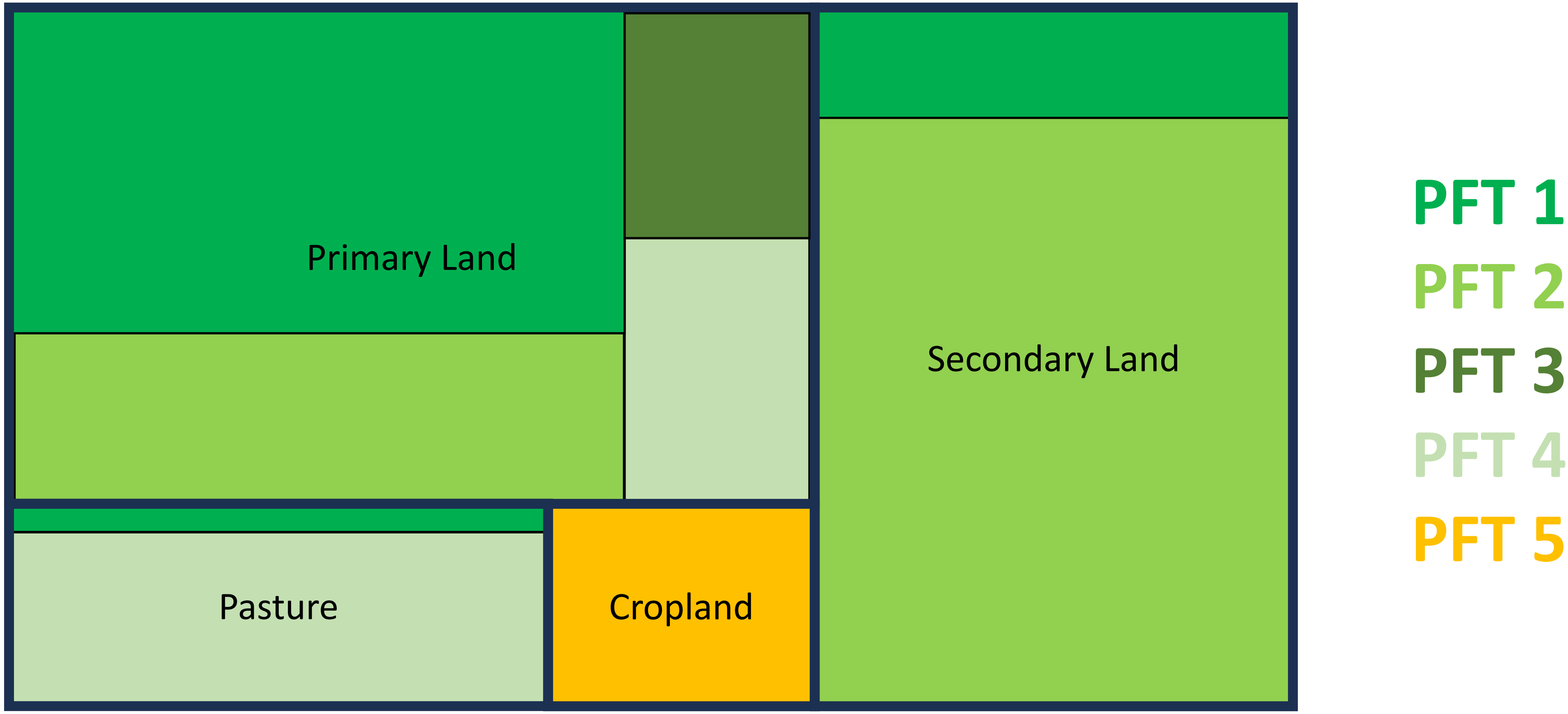


- Patches resolved by both a continuous variable (age) and a categorical variable (PFT)
- PFT composition on any patch is prescribed by the patch identity

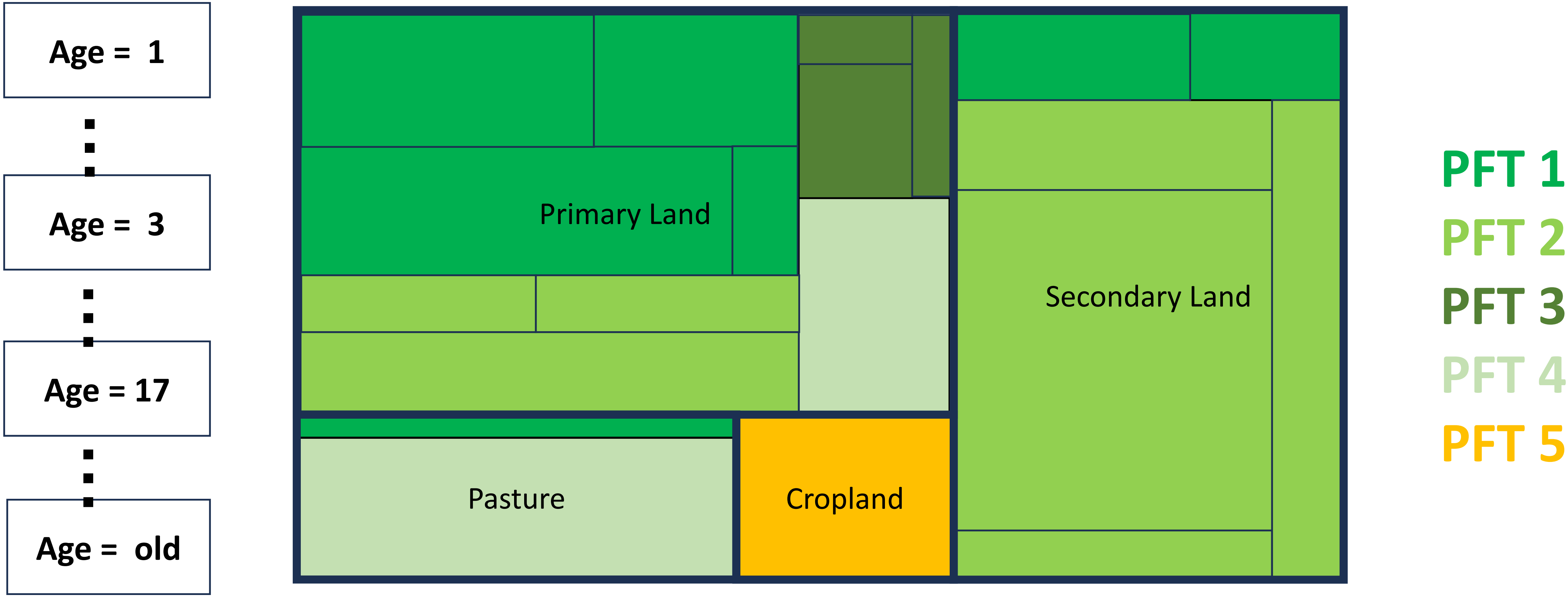
What we want is to layer land-use type as a high-level categorical variable for patches…



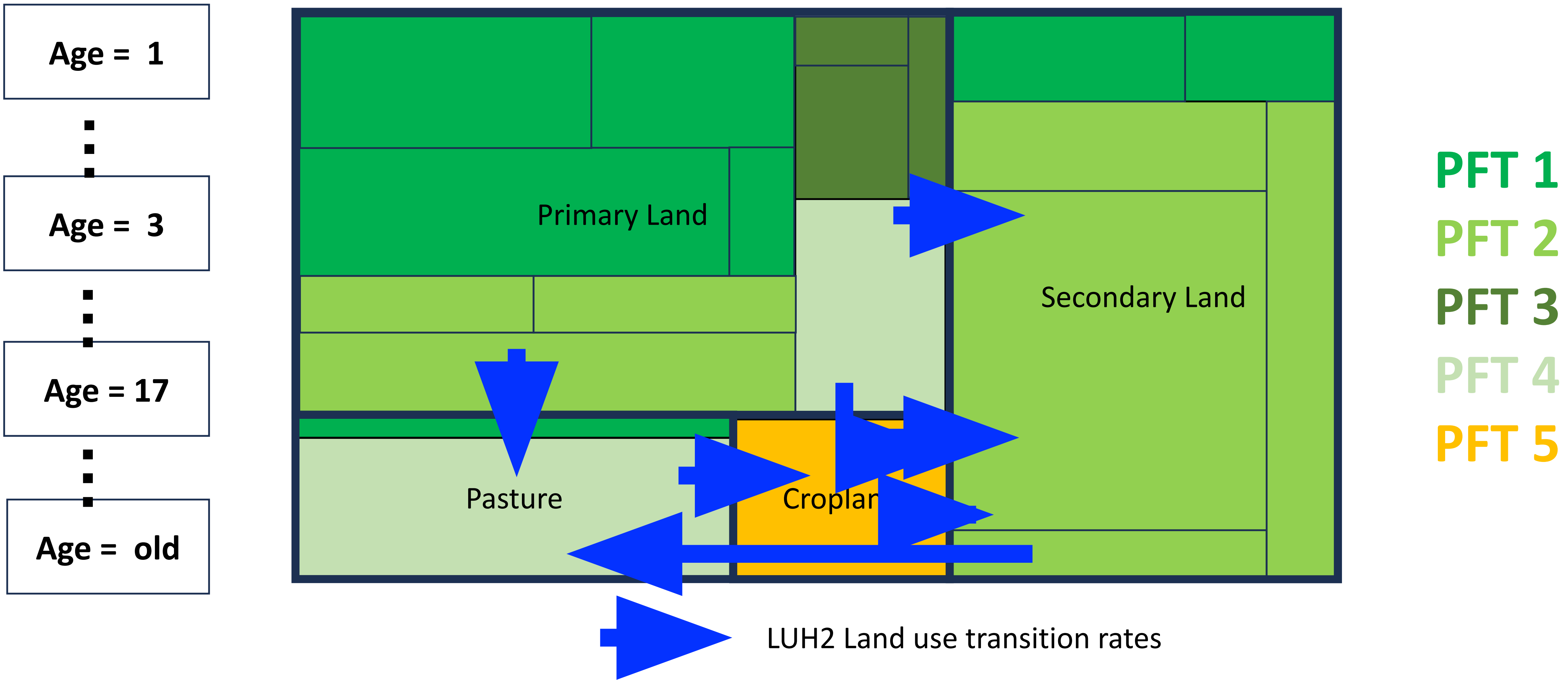
…with prescribed landcover (aka nocomp PFT) as another categorical patch variable layered within that…



…and then age-since-disturbance as a continuous patch variable within both of those…



…all in a dynamic way, where gross land-use transition rates drive updates to the patch PFT- and age-mosaics in a way that makes sense.



OK, so how do we do that?

- We need 2 pieces of information:

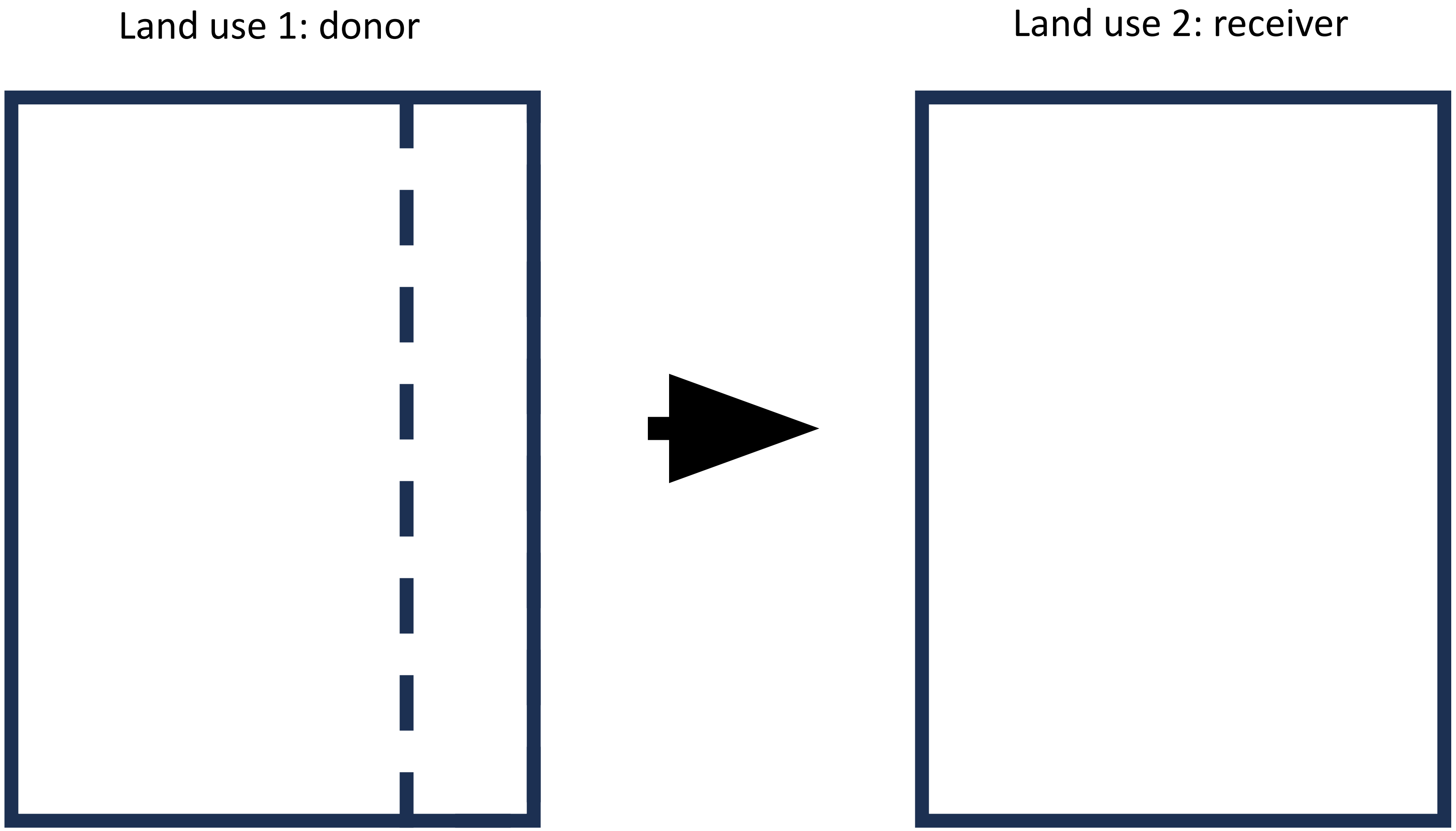
(1) Land use transition rates. This is a five-dimensional dataset:

   (1) Land-use donor type
   (2) Land-use receiver type
   (3) Latitude
   (4) Longitude
   (5) Time (and scenario)

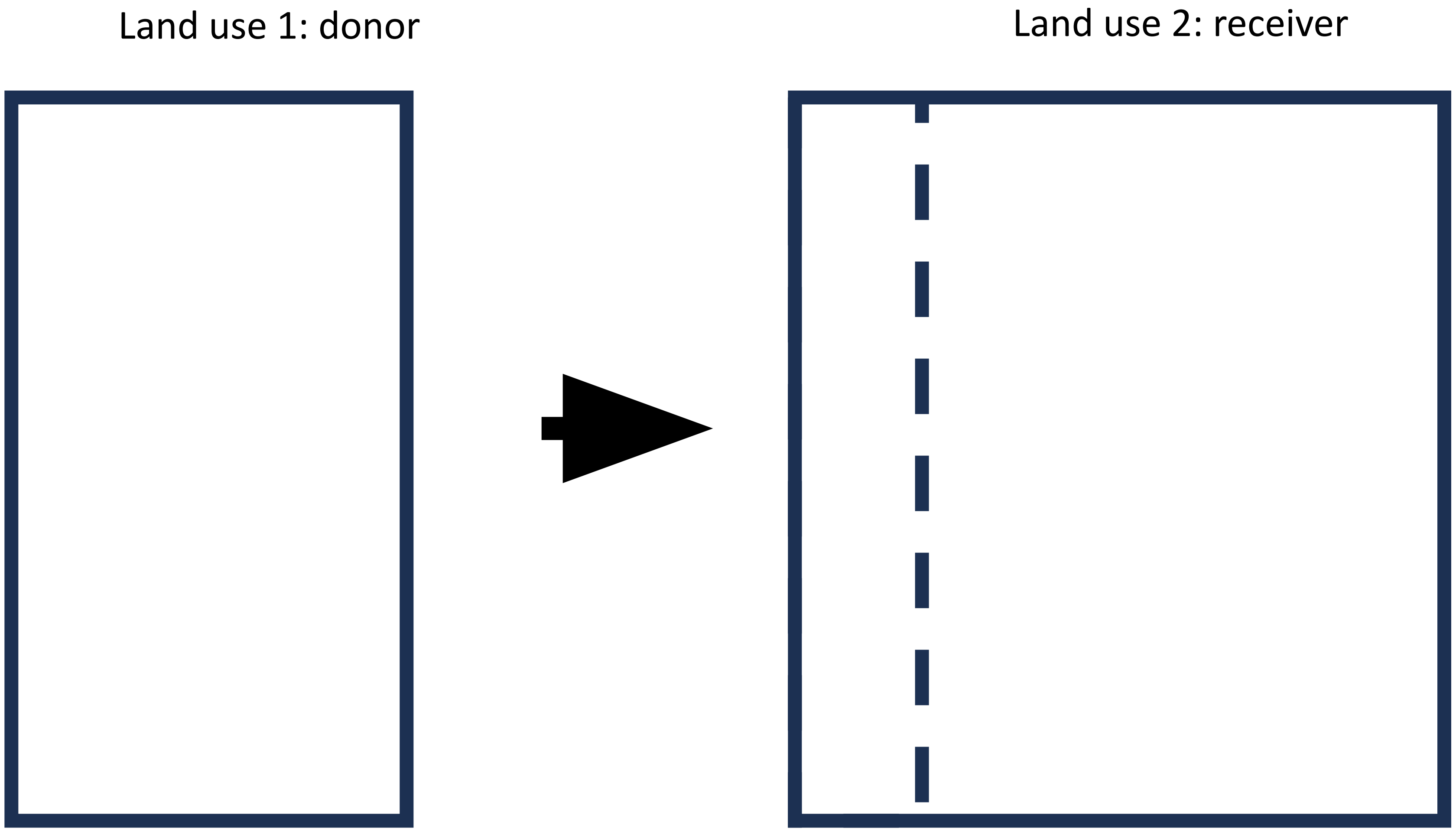
(2) PFT composition, conditional on land use type. This is a four-dimensional dataset (note that it is time- and scenario-independent, at least for now!):

   (1) Land-use type
   (2) PFT
   (3) Latitude
   (4) Longitude

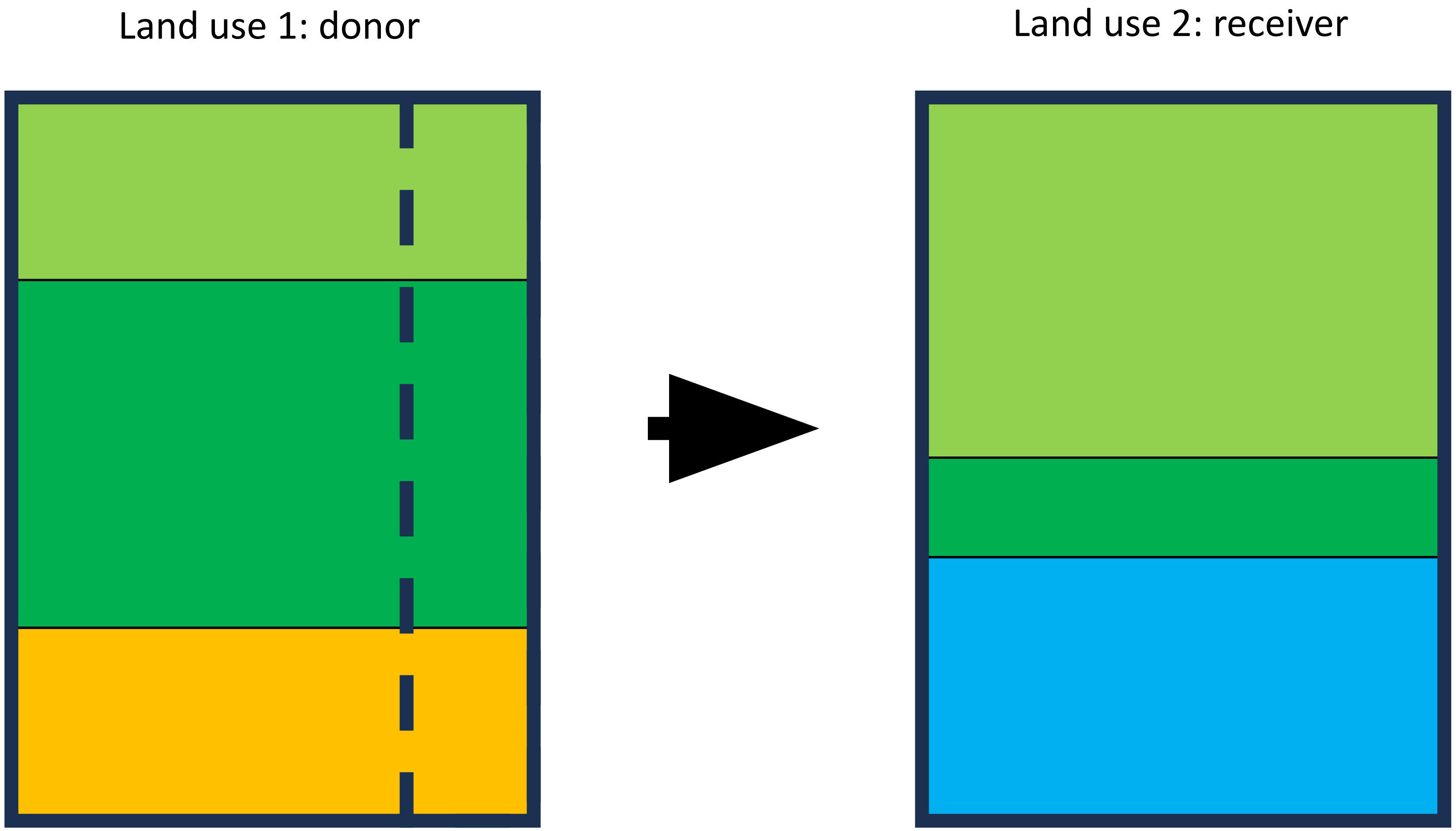
How does the code actually work?
Point 1: land-use change is disturbance, so fundamentally just patch splitting and relabeling



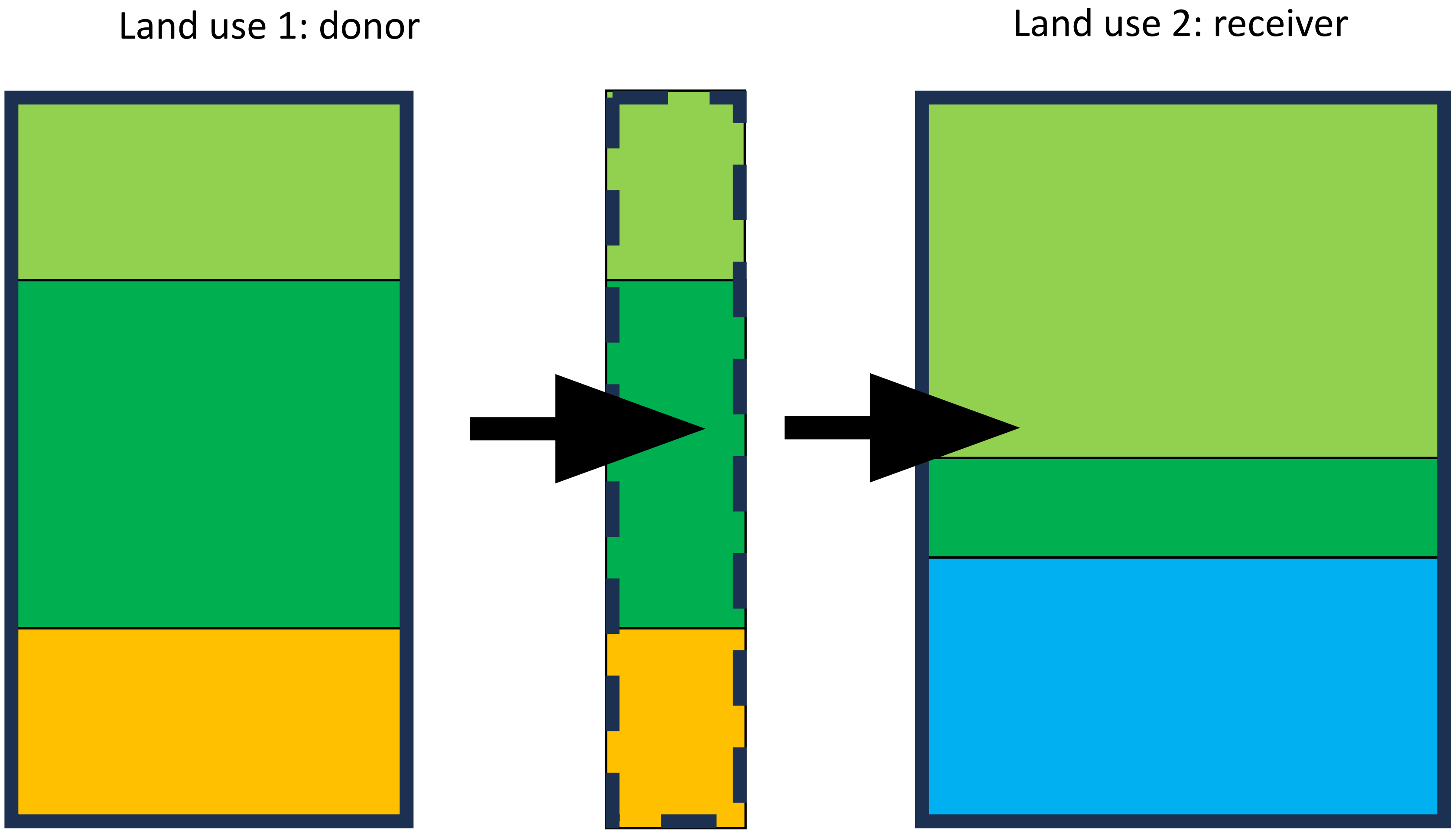
How does the code actually work?
Point 1: land-use change is disturbance, so fundamentally just patch splitting and relabeling



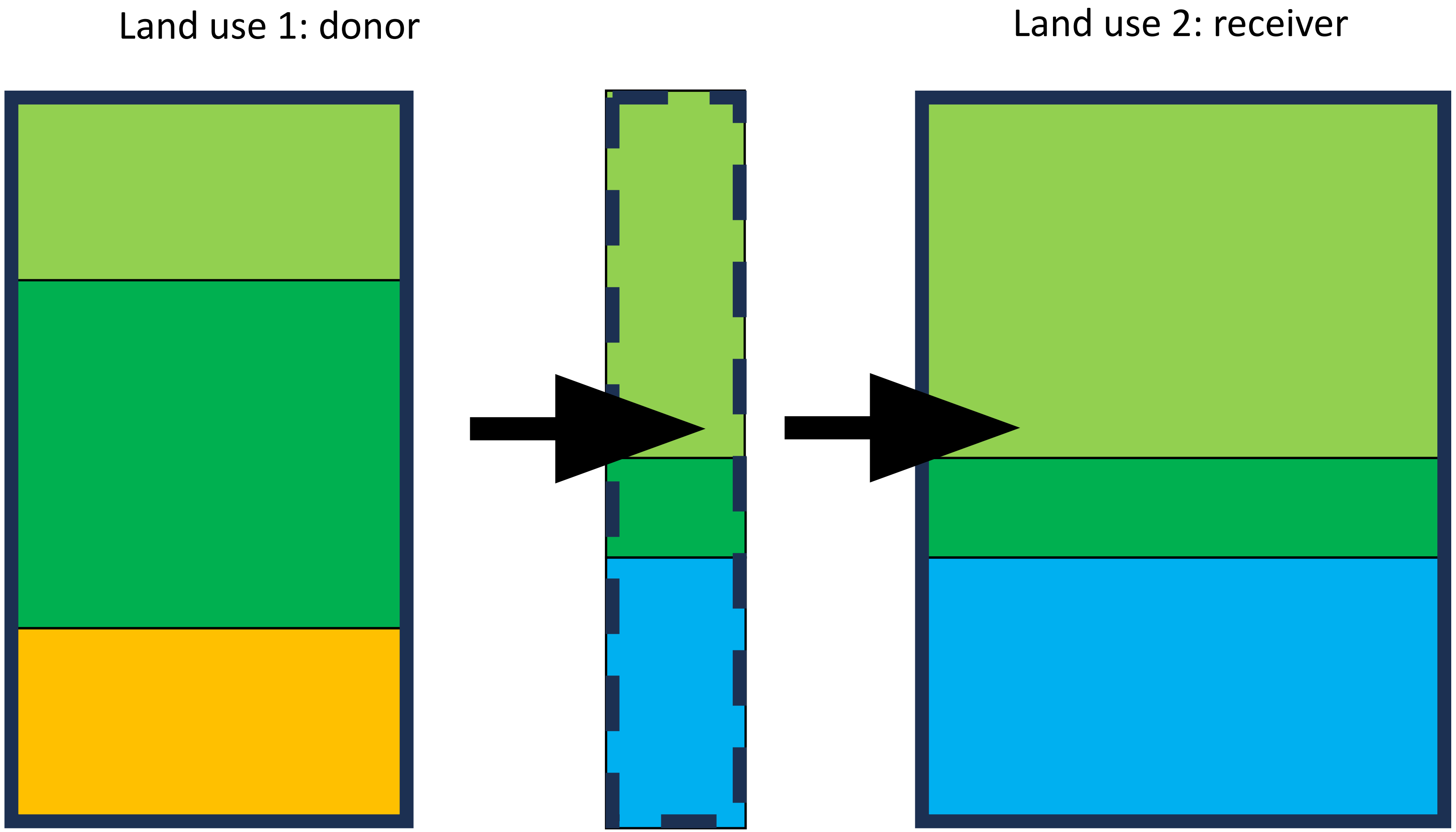
How does land cover change logic work?
1: disturb all patches from donor type



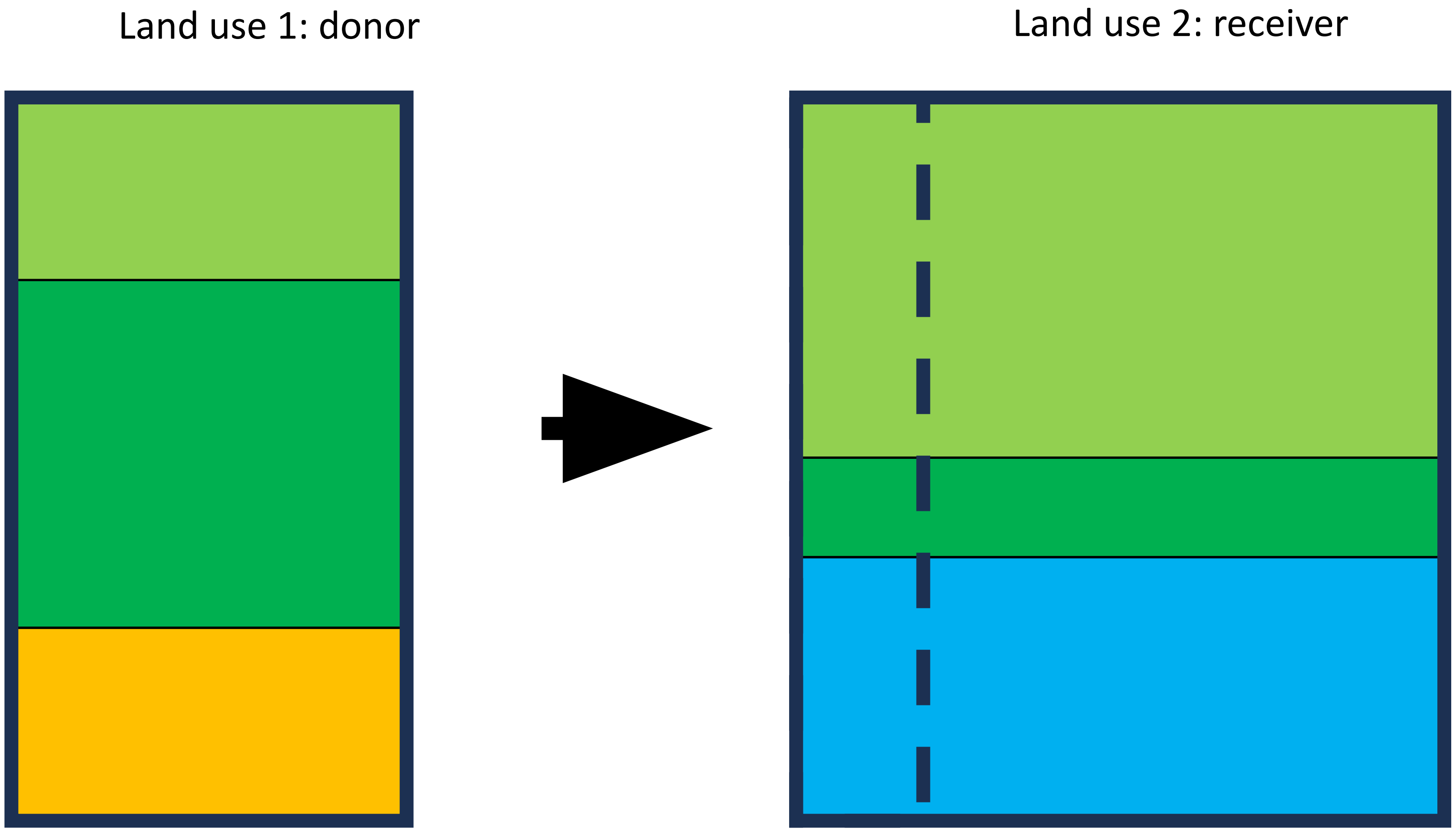
How does land cover change logic work? 2: compare composition of transitioning patches to composition of receiver land use type



How does land cover change logic work?
3: adjust sizes and PFT labels of transitioning patches accordingly



How does land cover change logic work? 3: adjust sizes and PFT labels of transitioning patches accordingly



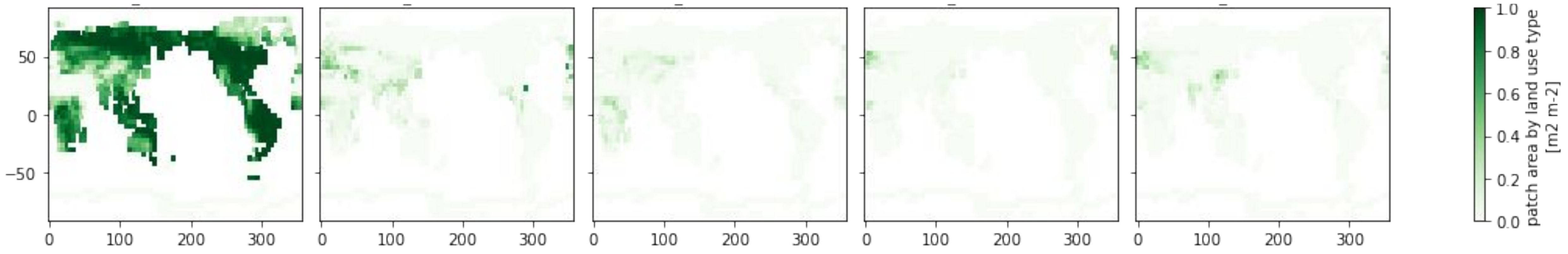
Simple! So, does it work?

- Results from a proof-of-concept transient historical run
  - Completely uncalibrated, will redo once we have an initial nocomp calibration
  - Climate and CO2 held constant, so dynamics are entirely due to either initial drift or forced transient land use.
- Testing a new spinup procedure:
  1. AD-spinup and then post-AD spinup, all in "potential vegetation mode" (i.e. all primary lands, so no human land use at all)
  2. Transient land-use, starting well before the period of interest.
     - On first timestep after exiting potential vegetation mode, all land-use change required to get the land-use state at the start of the transient simulation is applied on the first day.
       - This all happens automagically, based on restart flags, just like the AD-mode exit procedure
     - This creates a transient pulse, which is why we need to start before the period of interest
     - Here, starting in 1750 for a run whose period of interest is 1850-2015

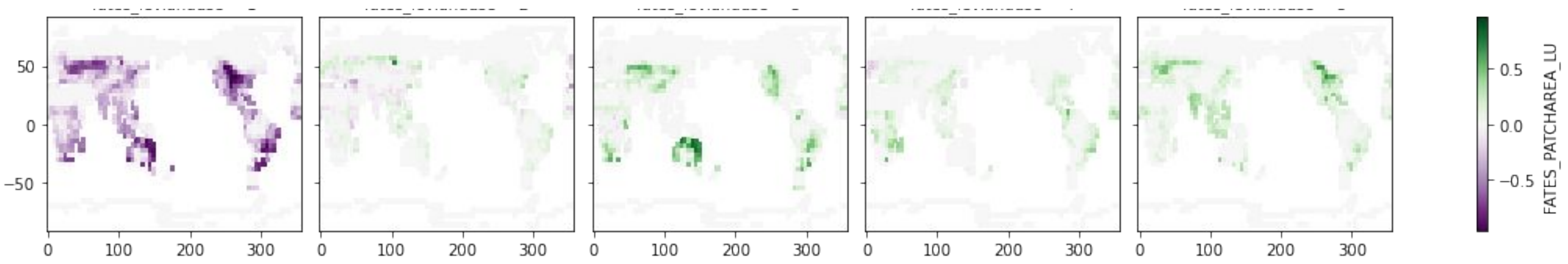
Results!

Land use type fraction at year 1750

Primary Lands | Secondary Lands | Rangelands | Pasture | Croplands



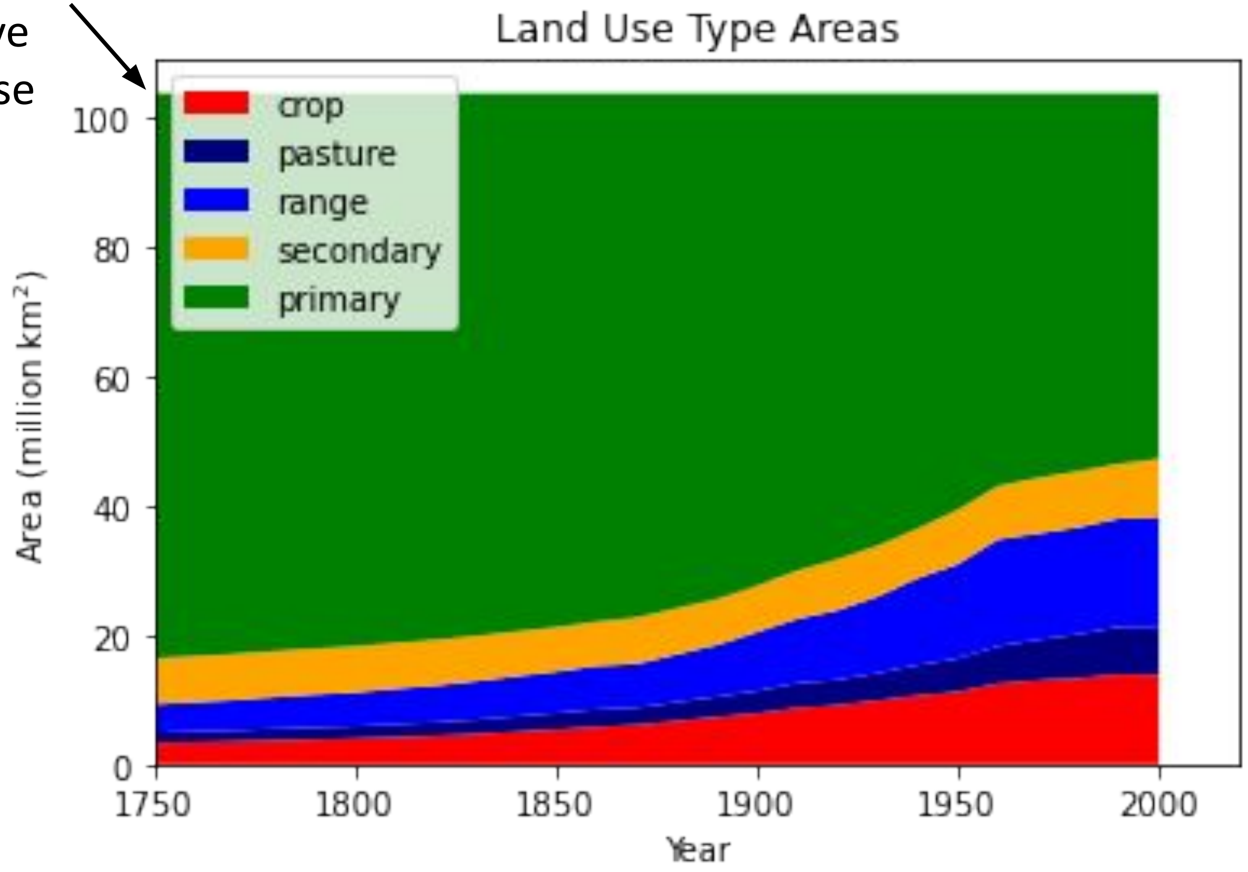
Change in land use fraction: 2000 - 1750

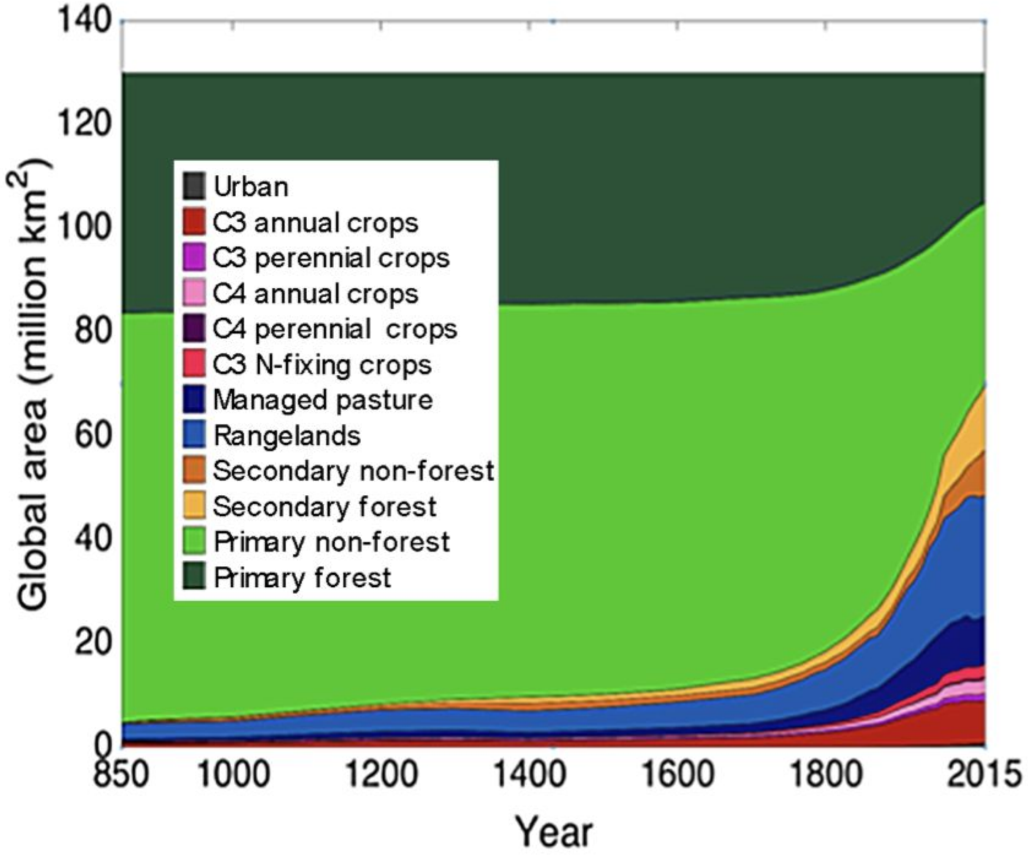


Some globally-integrated areal changes

Note: excluding all "bare-ground" areas, which do not have any land use identity

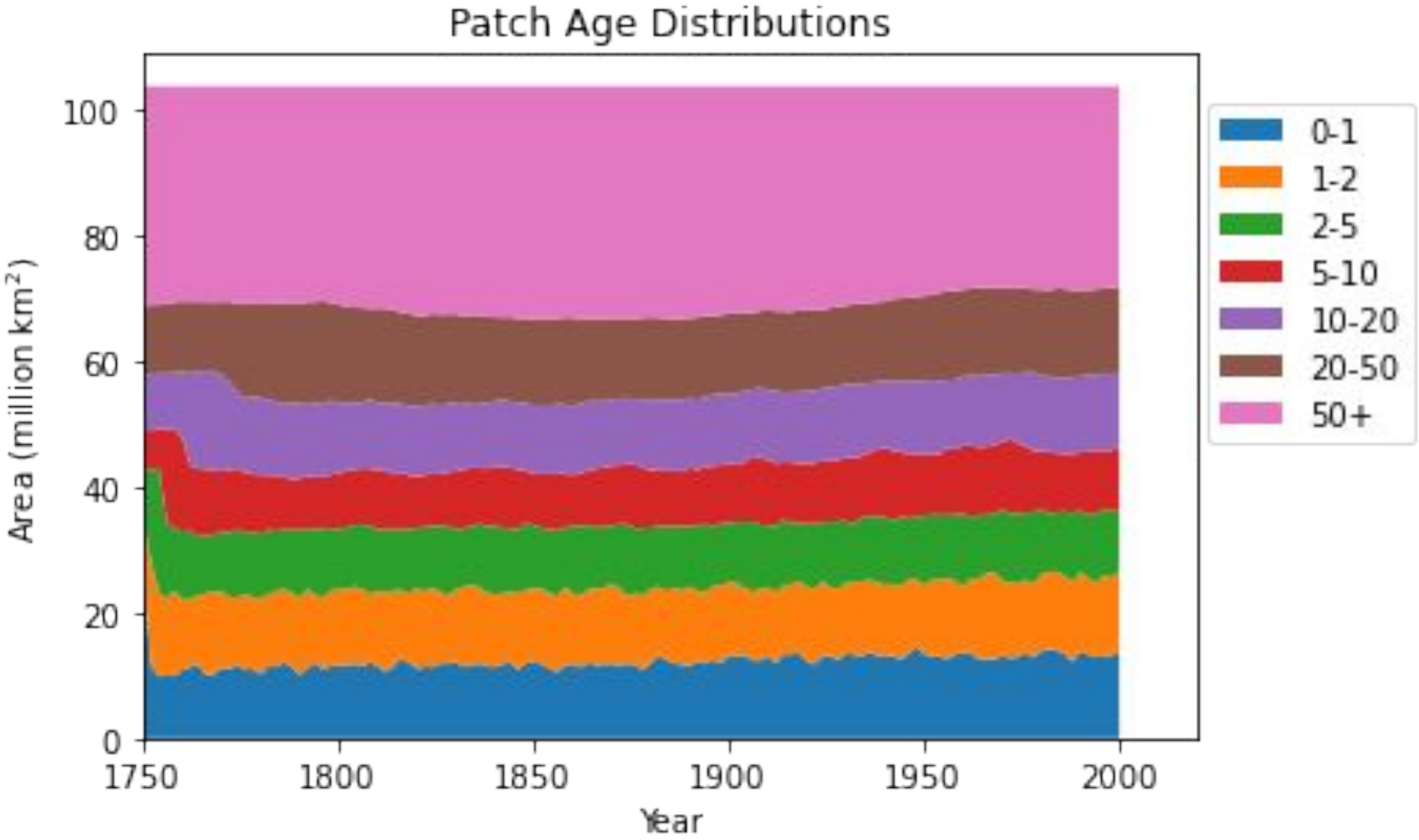
Comparison of land use areas against driving data



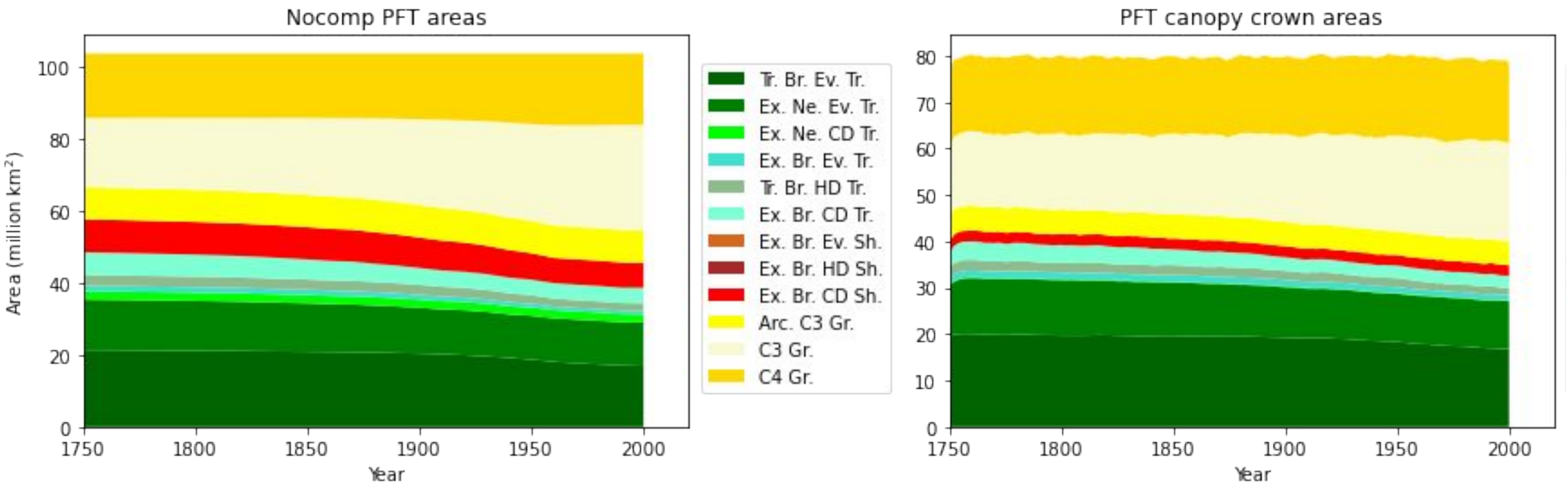


LUMIP: Lawrence et al., 2016

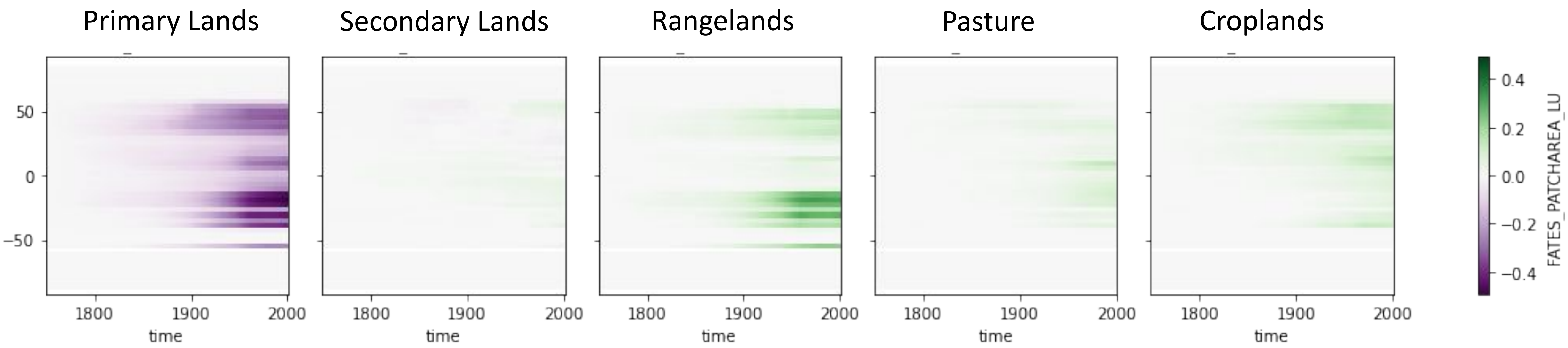
Some globally-integrated areal changes



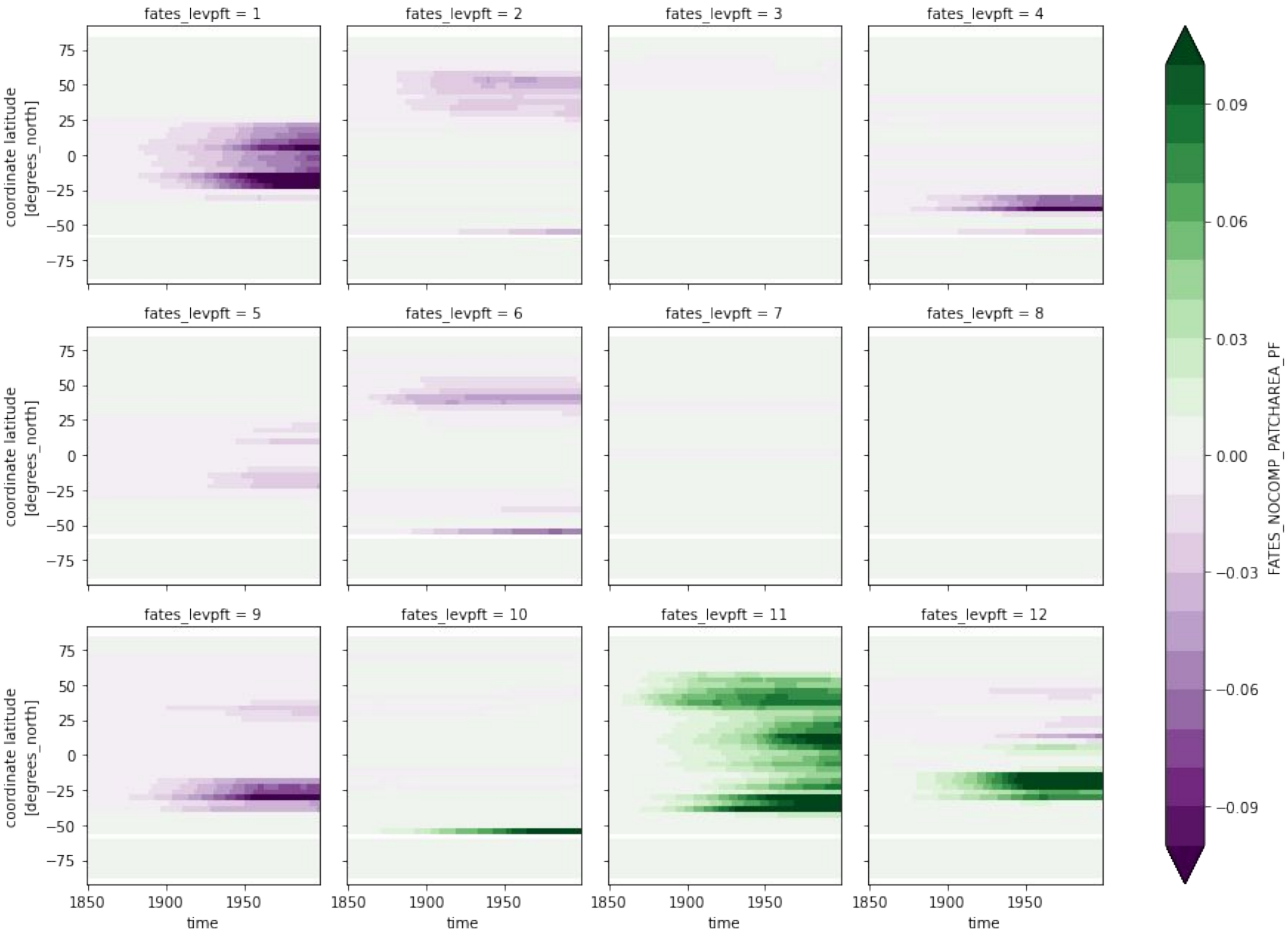
Some globally-integrated areal changes



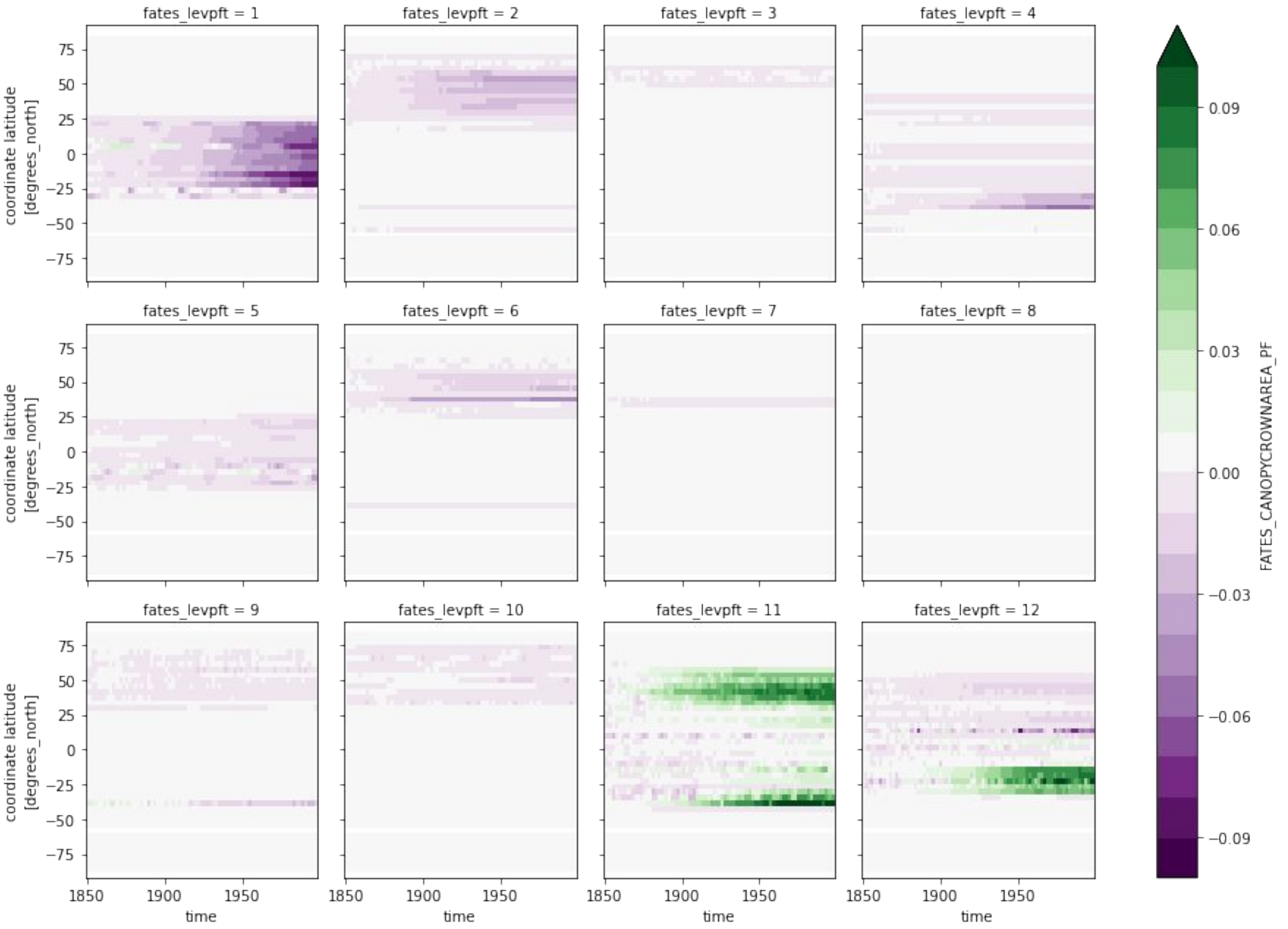
Zonal-mean transient dynamics of integrated land use change



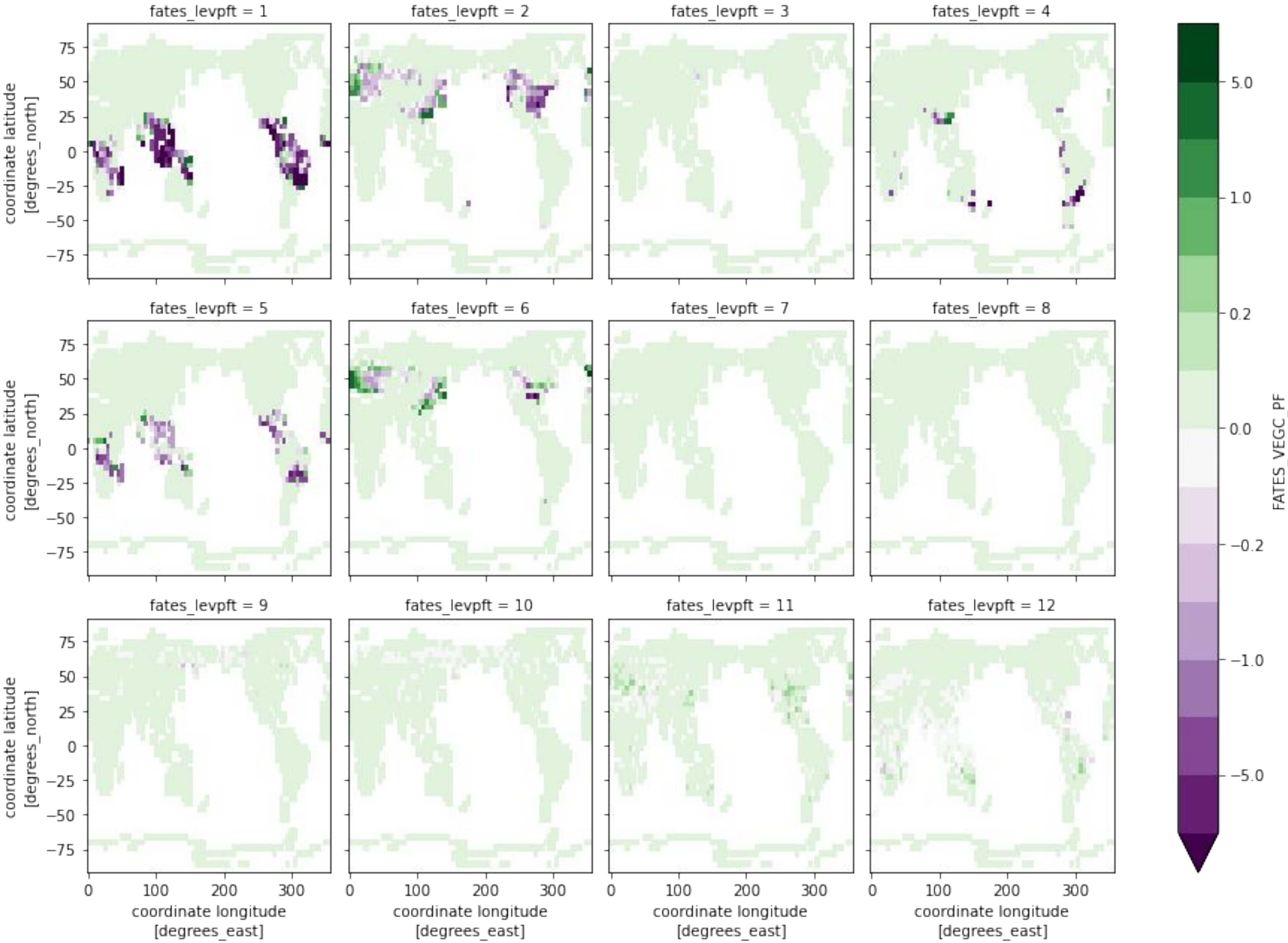
Resulting prescribed land cover change (i.e. change in nocomp PFT areas)



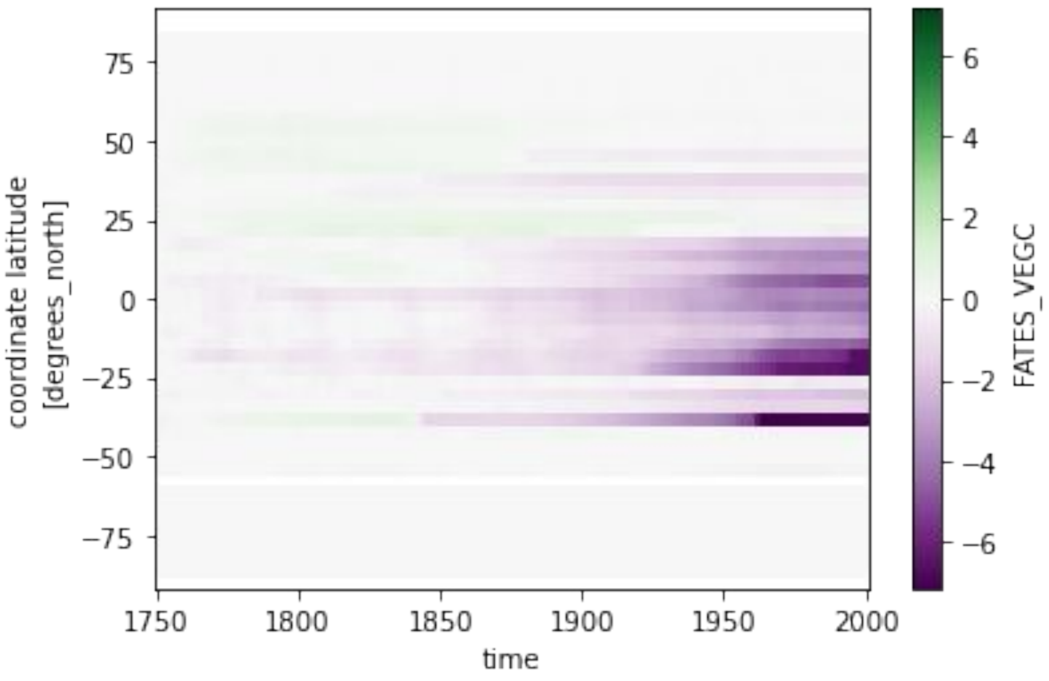
And the resulting PFT-resolved plant canopy area changes

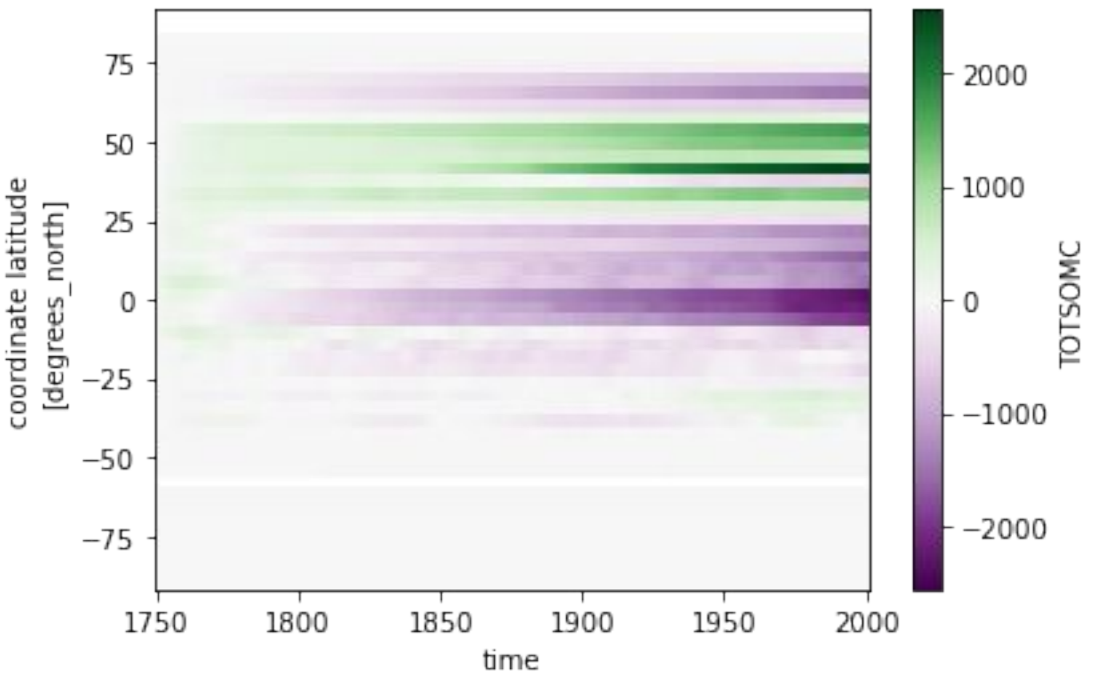


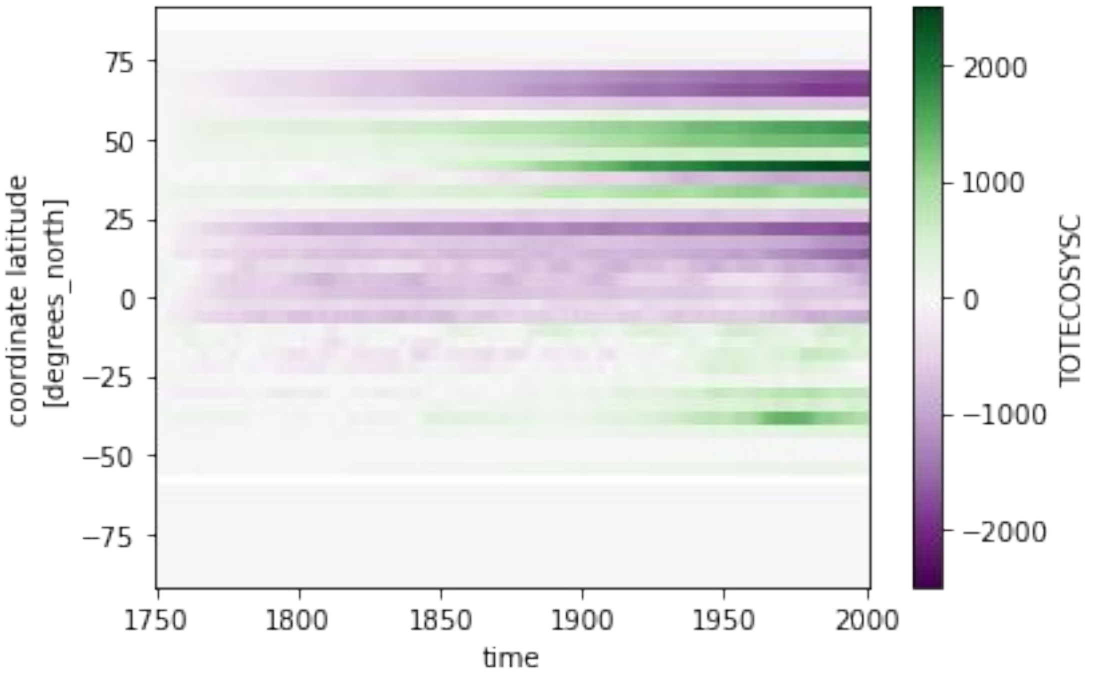
Maps of resulting vegetation carbon change: 2000-1750



Zonal-mean carbon cycle dynamics







Conclusions

- Basic framework to include direct land use-driven transient land cover dynamics now possible in FATES
- Still in basic sanity-checking phase
- So far the results appear to basically make sense
- Now that this is possible, the real work to apply the model and understand how demography changes our understanding of the global carbon cycle begins!