FATES Land use initialization and dynamics

Charlie Koven

Lawrence Berkeley Lab

CESM LMWG Meeting

Feb. 25 2025

NGEE–TROPICS

NEXT-GENERATION ECOSYSTEM EXPERIMENTS

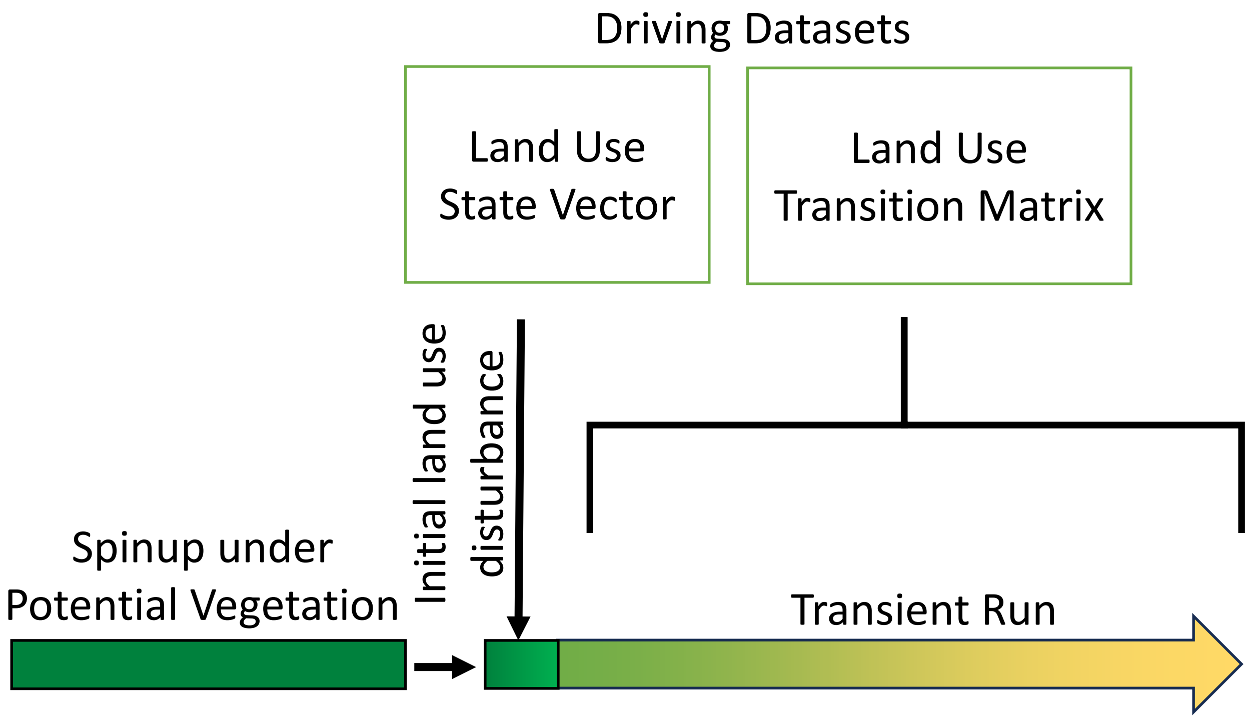
Background: FATES and Land Use

- Implementing dynamic global land use change has been one of the remaining barriers to using FATES in historical and future scenarios
- At the same time, FATES offers new opportunities for land use beyond what is in CLM5/6, because it is oriented around disturbance, and much of land use is disturbance.
- In particular, FATES allows a wider diversity of land use types, including distinguishing primary from secondary lands, and directly representing pasture and rangelands.
- Here I want to focus on the problem of model initialization.

Problem: FATES is structured around tracking disturbance history. How do we capture the disturbance history that had occurred before the start of a simulation?

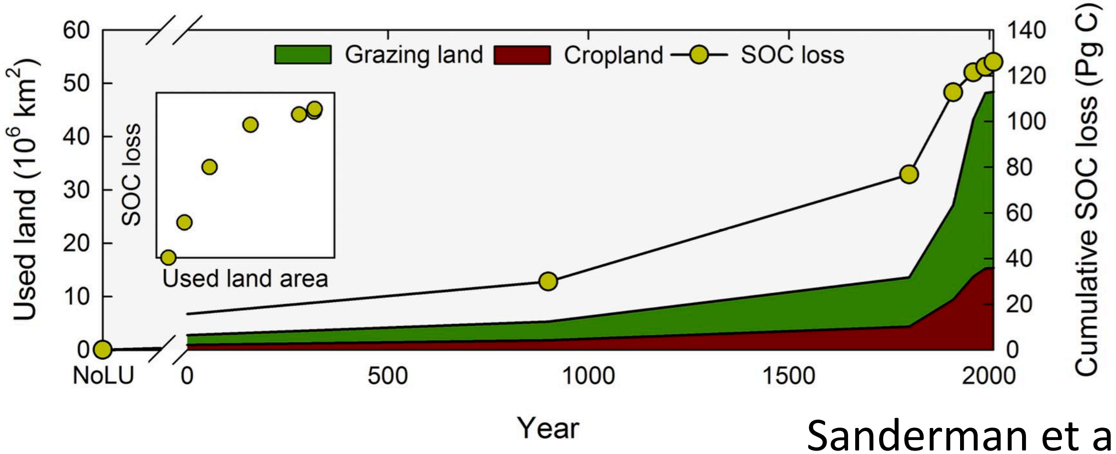
Breugel, 1565

Solution 1: Spin up under no land use ("potential vegetation"), then start the run before the time period of interest, representing all prior historical land use on first timestep, to let the transient dynamics stabilize by start of run.



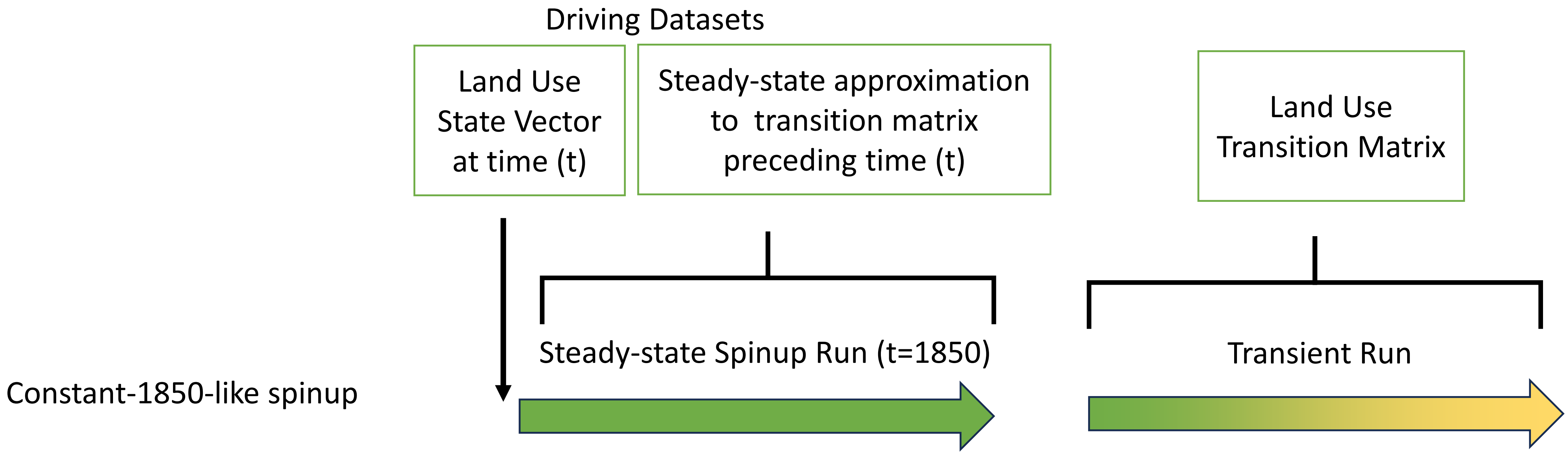
Problems with solution 1

- Spinup conditions are fundamentally different from any point in transient run. May lead to long-term disequilibria.
- Need to make a decision about how small the pulse from initial disturbance should be by the start of the period of interest.
- Expensive, as it requires extra period of time before period of interest
- Very unclear how any of this works under emissions-driven simulation
- Long-term legacies of land use should really be present in early land state

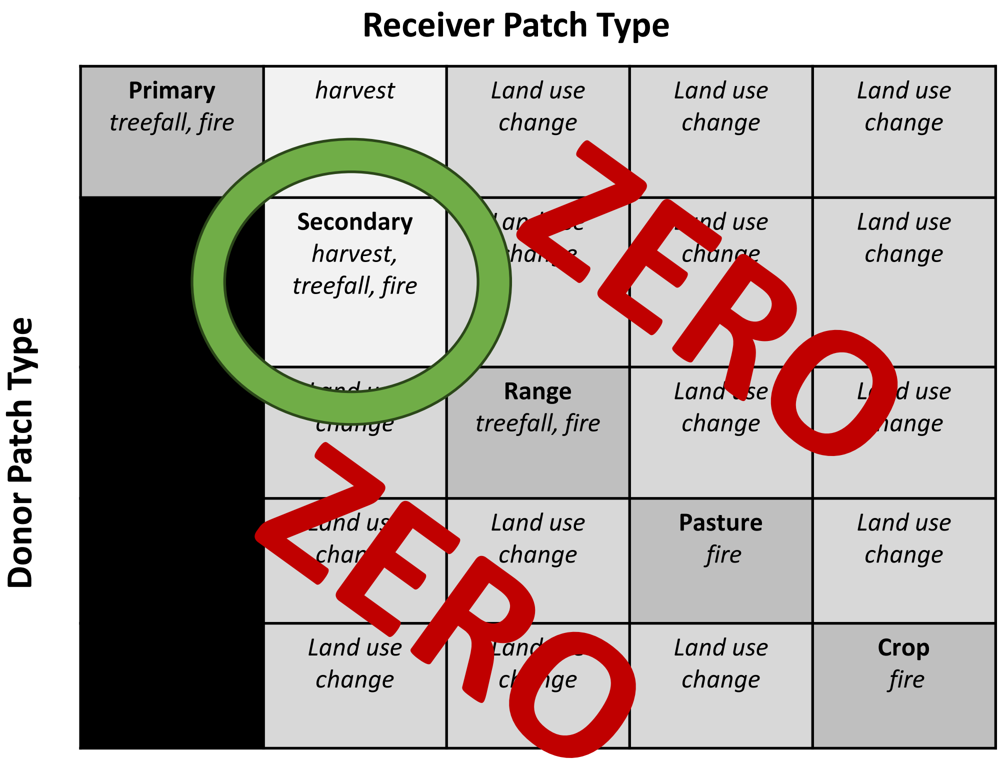


Sanderman et al., 2017

Solution 2: find a steady state transition matrix that leads to approximate 1850 conditions and spin up using that. (analogous to classic ELM/CLM I1850 compsets)



How to construct approximate transition matrix for steady-state cases?



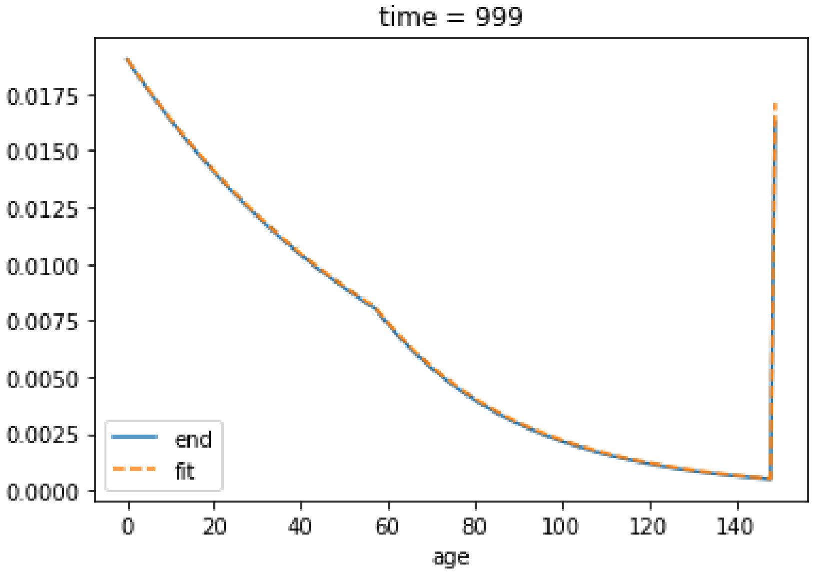
1. Zero all off-diagonal elements to transition matrix
2. Find a set of secondary young and secondary mature harvest rates whose resulting steady-state age distribution best approximates the transient secondary age distribution at time (t)

   Note: this is the simplest solution. Other steady-state transition matrices with nonzero off-diagonals are also possible, so long as the sum of gross fluxes to and from all land use types are equal.

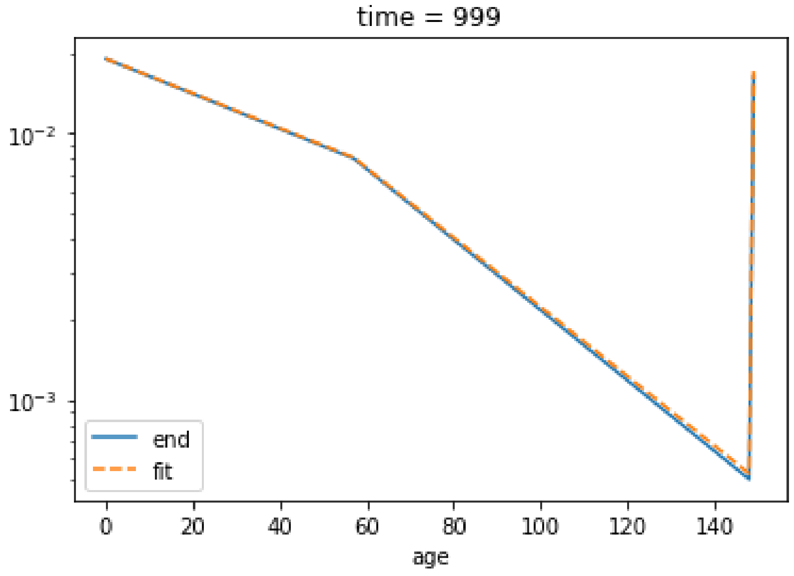
There is an analytic solution (piecewise exponential) for constant harvest rates given a fixed young/mature forest age distinction

E.g., for some arbitrary set of young harvest rates, mature harvest rates, and young/mature forest age distinction

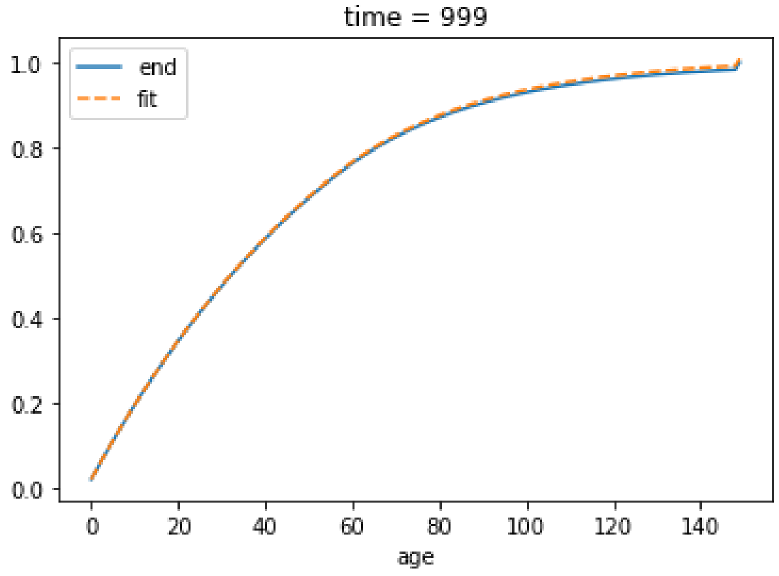
Age distribution



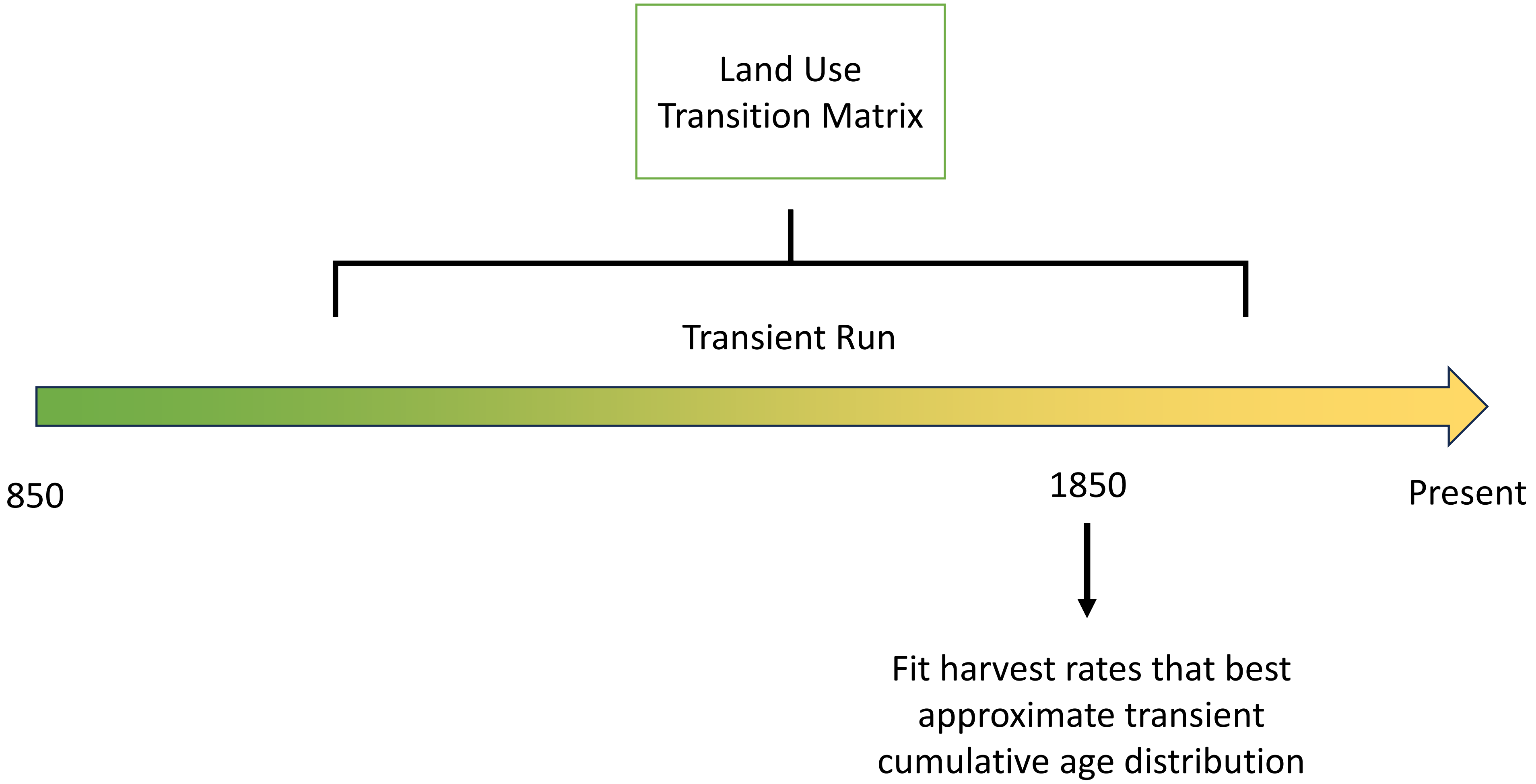
Log(Age distribution)



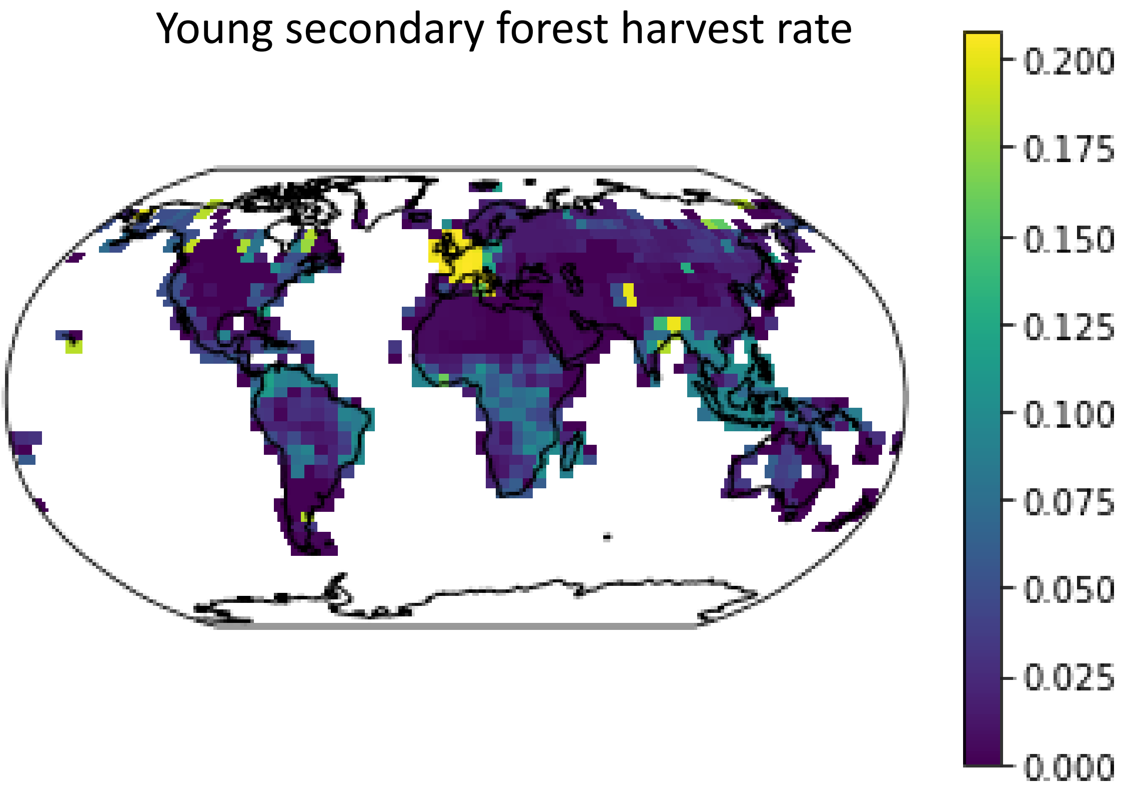
Cumulative Age distribution

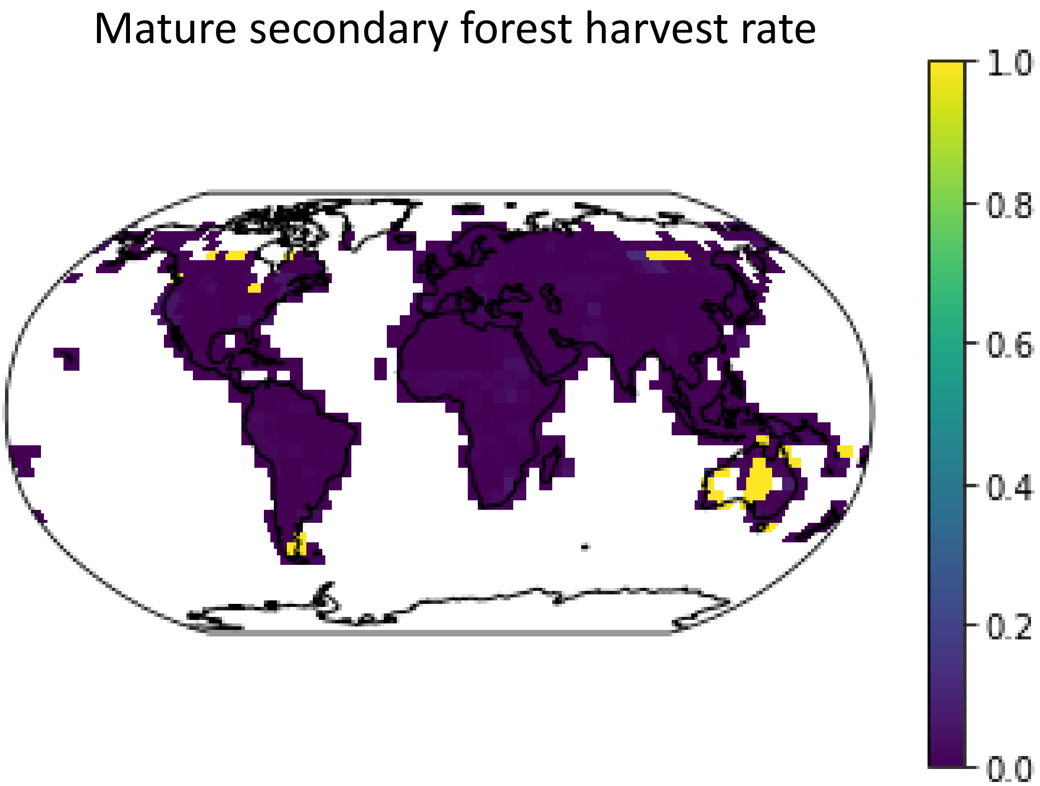


Using this relationship, we can (1) construct a toy model of secondary land age distribution, (2) run it through the full historical period, and then (3) try to find a set of steady-state harvest rates that approximate the cumulative age distribution at some time.



Resulting secondary young and mature harvest rates: constant year 1850-like case, for 4x5 degree simulation





OK, but does it work?

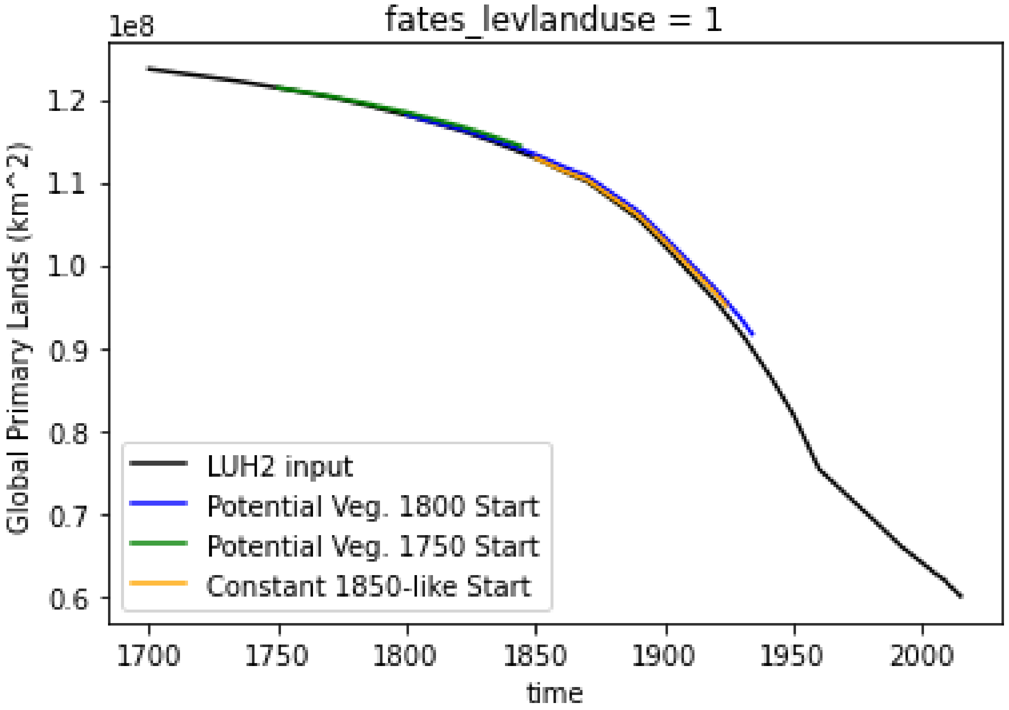
Experiment: compare three ELM-FATES cases:

- Potential veg spinup, 1800 transient start
- Potential veg spinup, 1750 transient start
- Steady-state 1850-like spinup, 1850 transient start

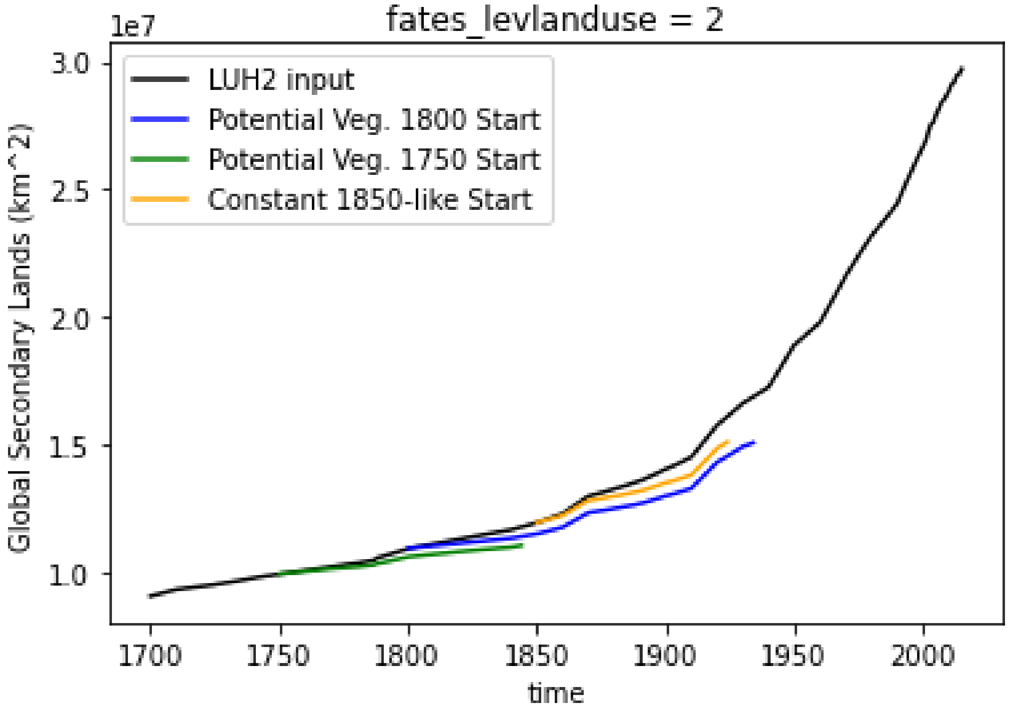
Climate, CO_2 all held constant for all runs, so only driver of change is land use

...but, this still being in-development code, ran into a problem. There was a bug that was leading to too-small transient harvest rates and thus too-little secondary land.

Primary Lands



Secondary Lands

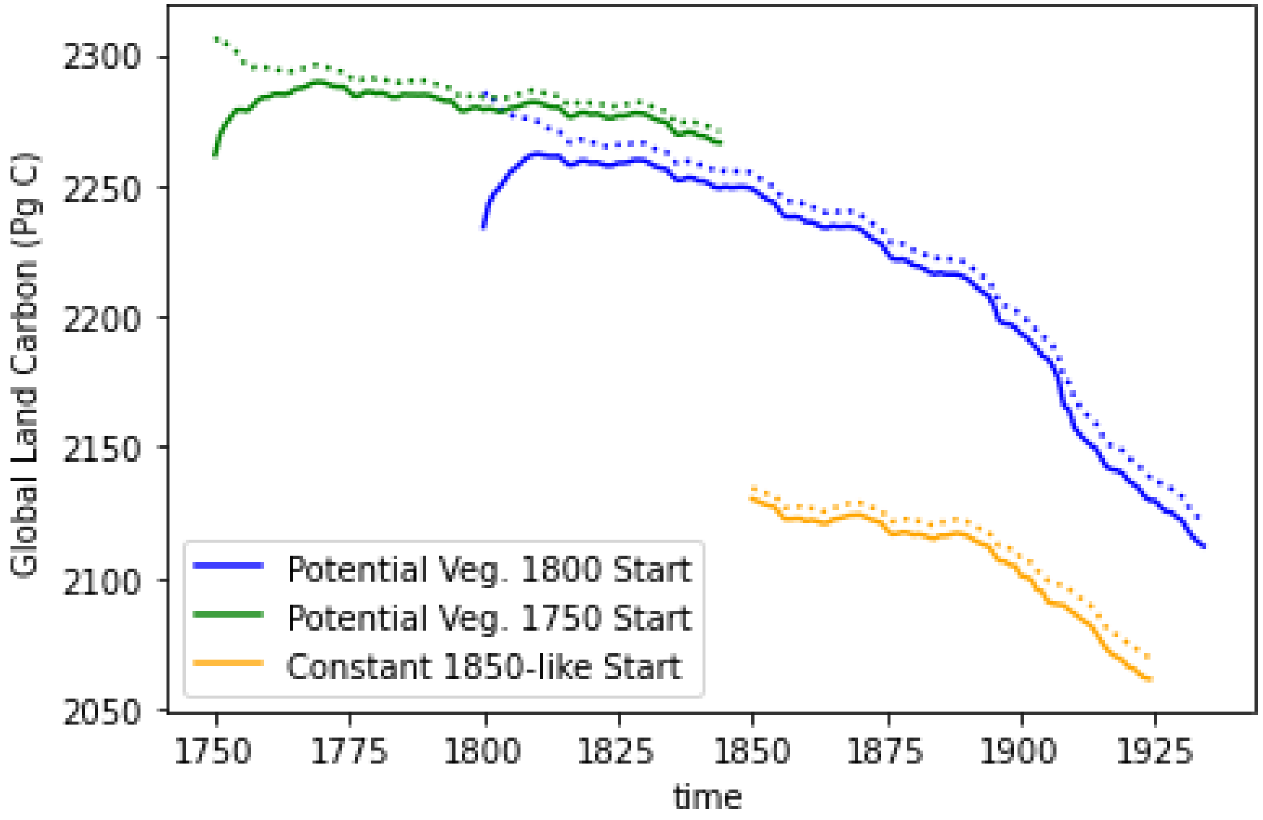


bugfix on harvesting of unoccupied canopy area

#1339 opened 13 hours ago by ckoven • Review required 4 tasks

(Nonetheless, and despite unfinished experiment, perhaps useful to analyze the dynamics)

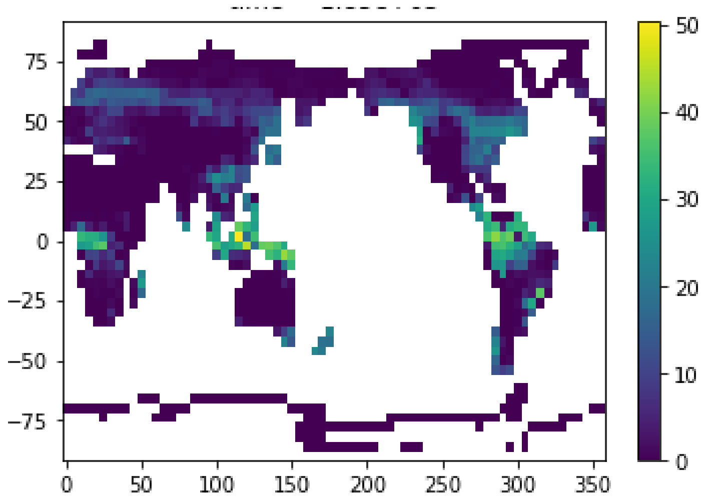
Total global carbon stocks



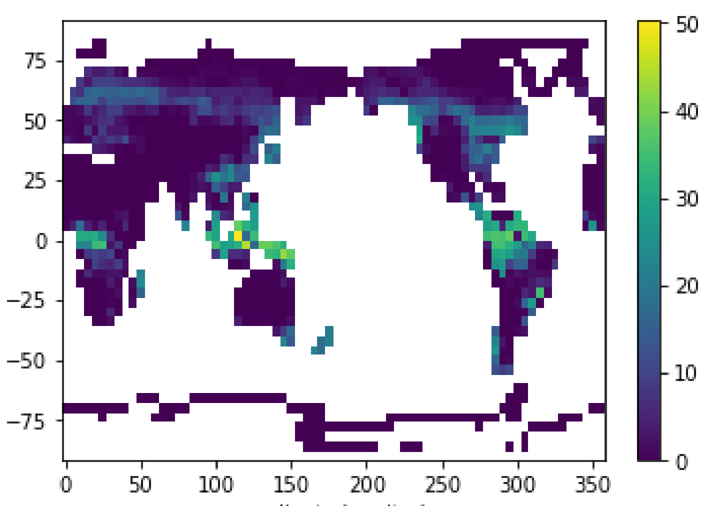
Dashed line includes product pools

Difference in Vegetation Carbon at 1850

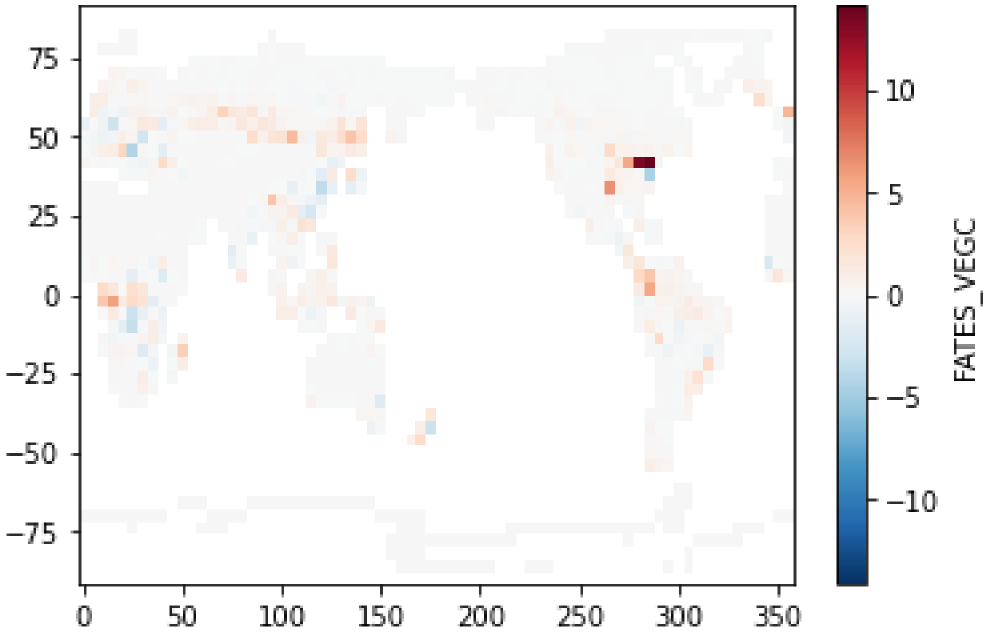
Potential Veg with 1800 start



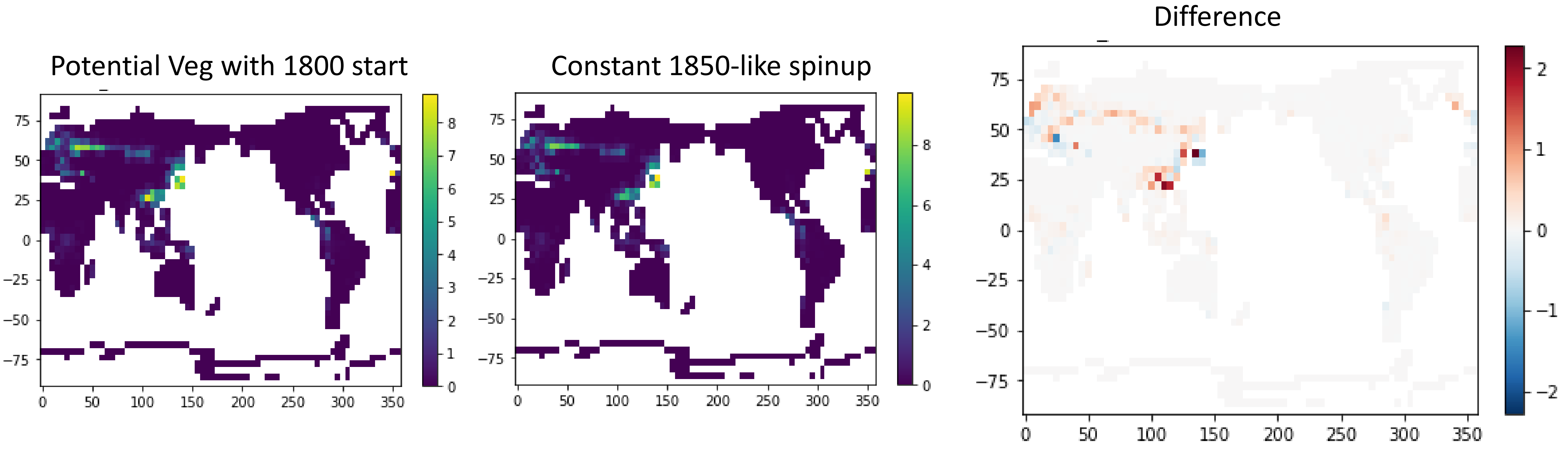
Constant 1850-like spinup



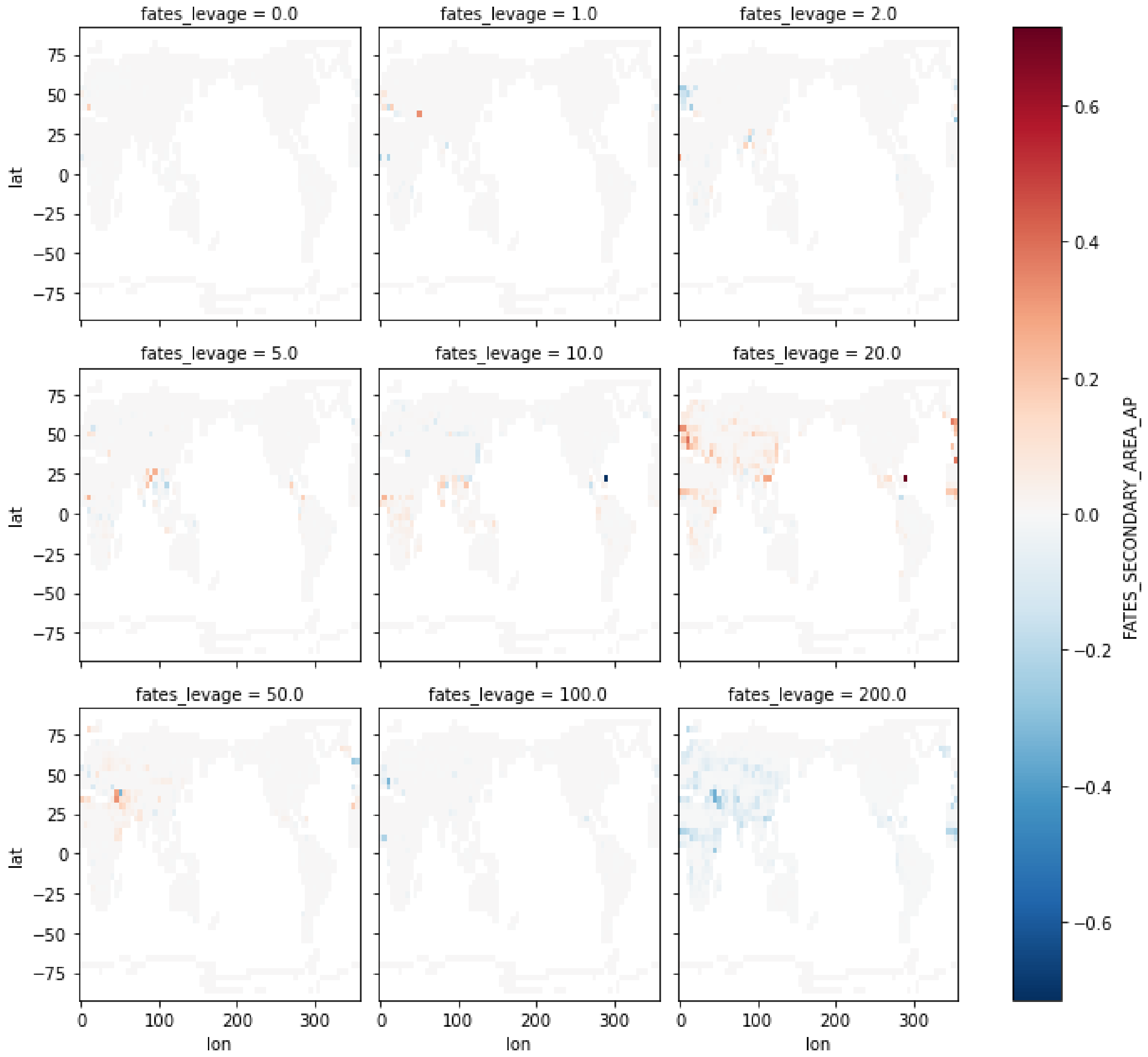
Difference



Difference in Vegetation Carbon of secondary lands only at 1850



Difference in secondary land age distributions at year 1850: (1800 start from potential veg minus constant-1850-like start)



Conclusions

- There appears to be a way to do an I1850-like spinup procedure in FATES, by finding secondary harvest rates that approximate the transient secondary forest age distribution for a given year. This would be good because it would be simpler than the alternative.
- Still working on assessing the differences between different spinup methods.
- Ran into a bug in transient runs, so re-running full experiment.

Pasture, range, and cropland areas doing what they should