FATES-SPITFIRE: Interaction of climate, fire, and vegetation state for coexistence of trees and grass

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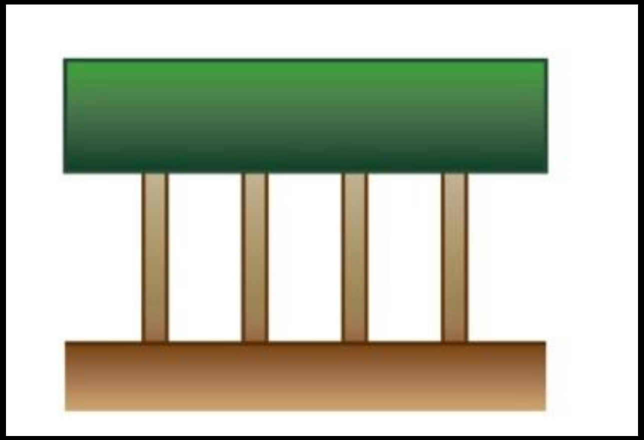
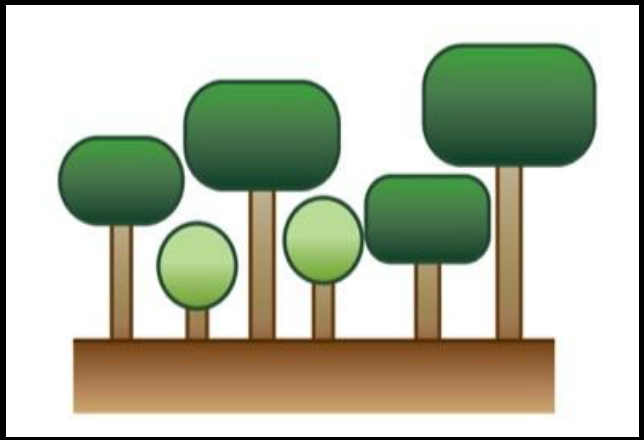
Image: http://www.scienceimage.csiro.au/tag/fire-management/i/393/fire-in-the-tropics/

What is FATES?

- Vegetation model, which replaces the unstructured bulk canopy representation in CLM with the size- and age-structured ED approximation of individual plant dynamics
- Modularized from CLM(ED) in order to: plug into multiple land models (CLM, E3SM/ALM)

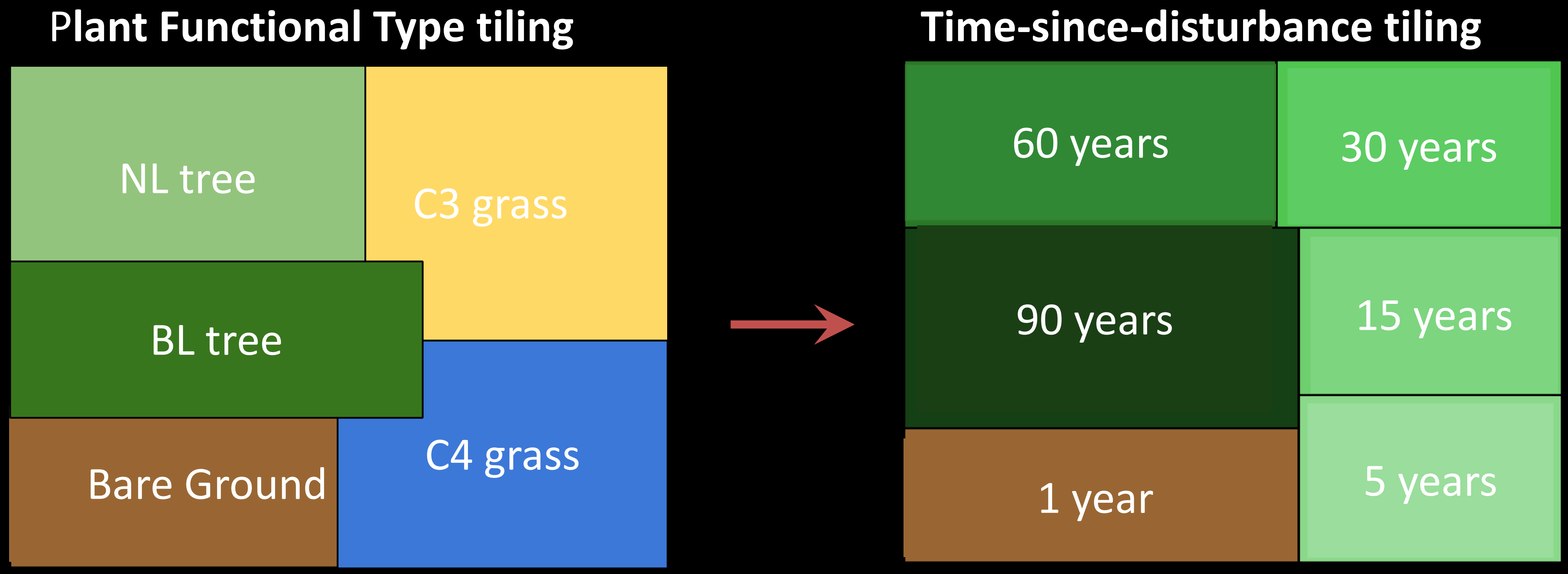


“Big-Leaf” vegetation



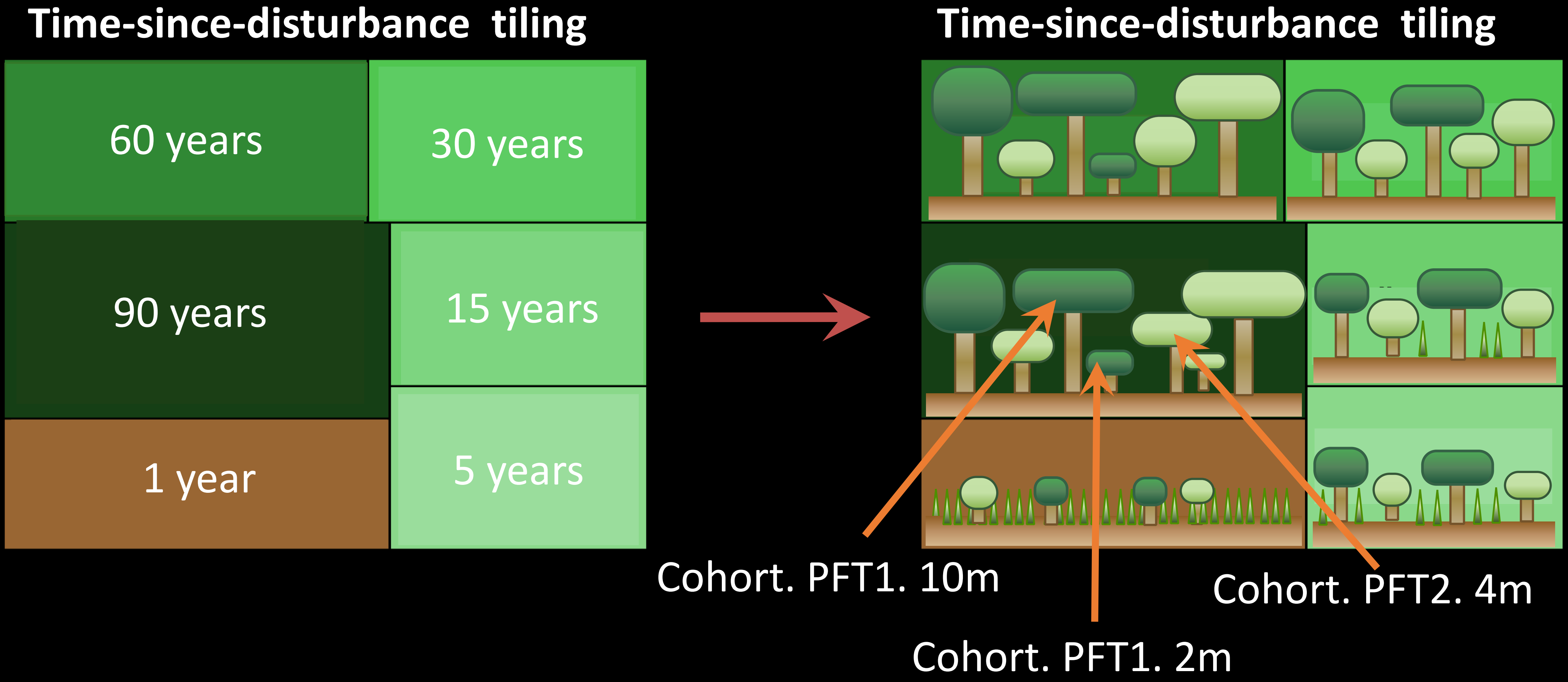
Demographic Vegetation

Vegetation structure in FATES



Vegetation structure in FATES

Each **time-since-disturbance** tile contains cohorts of plants, defined by **PFT** and **size**.



Importance of Fire

- Fire regimes determine species composition and biomass accumulation, and structure (Pellegrini et al. 2017, Rogers et al. 2015, Staver et al. 2011, Hoffman et al. 2012)

- Causes and consequences of fire require understanding of interaction of climate, vegetation (fuel) and fire: fuel load and rainfall in savanna; temperature and fire season length in boreal and temperate (Randerson et al. 2005, Schimel & Granstrom 1997, French et al. 2002, Sukhinin et al. 2004)

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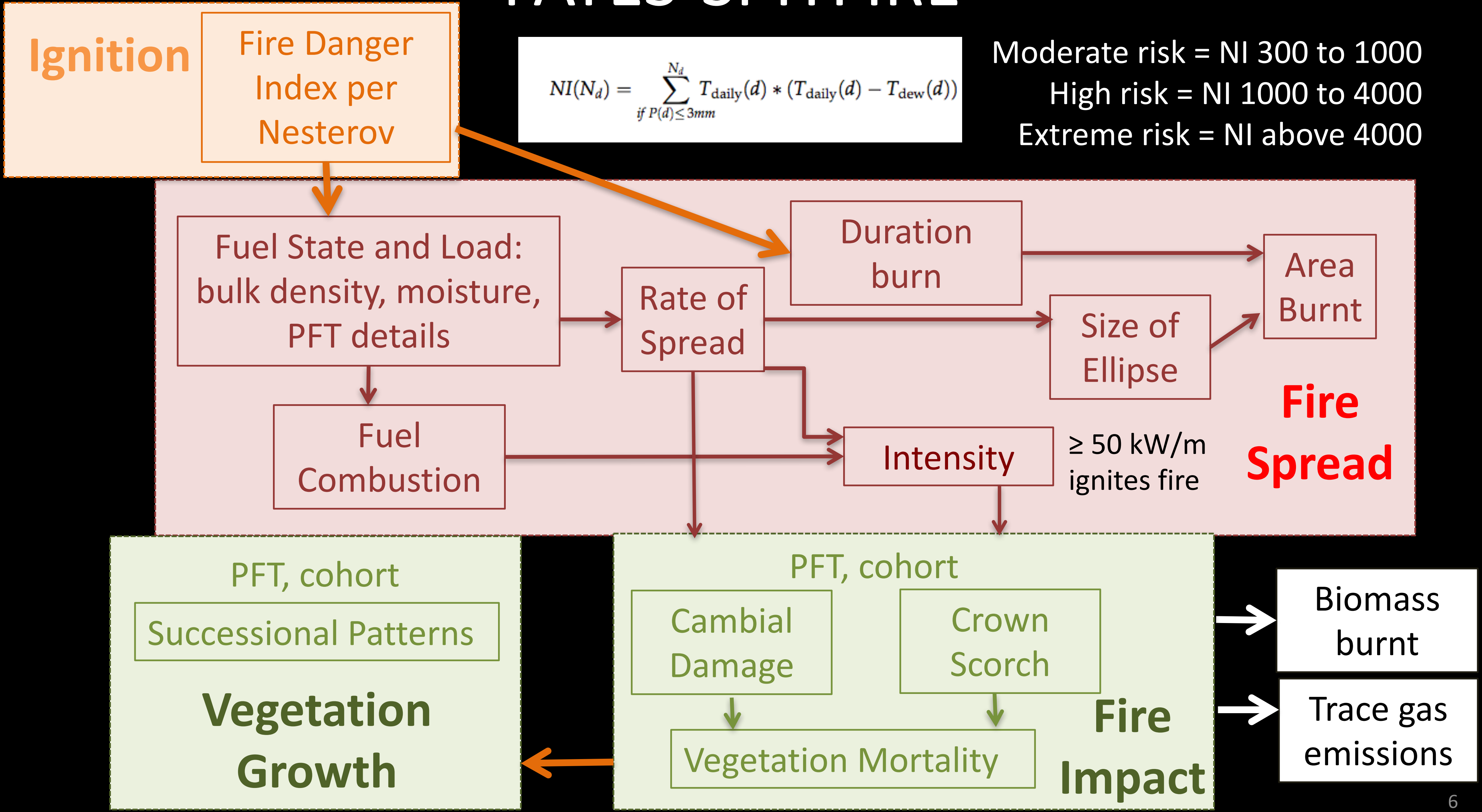
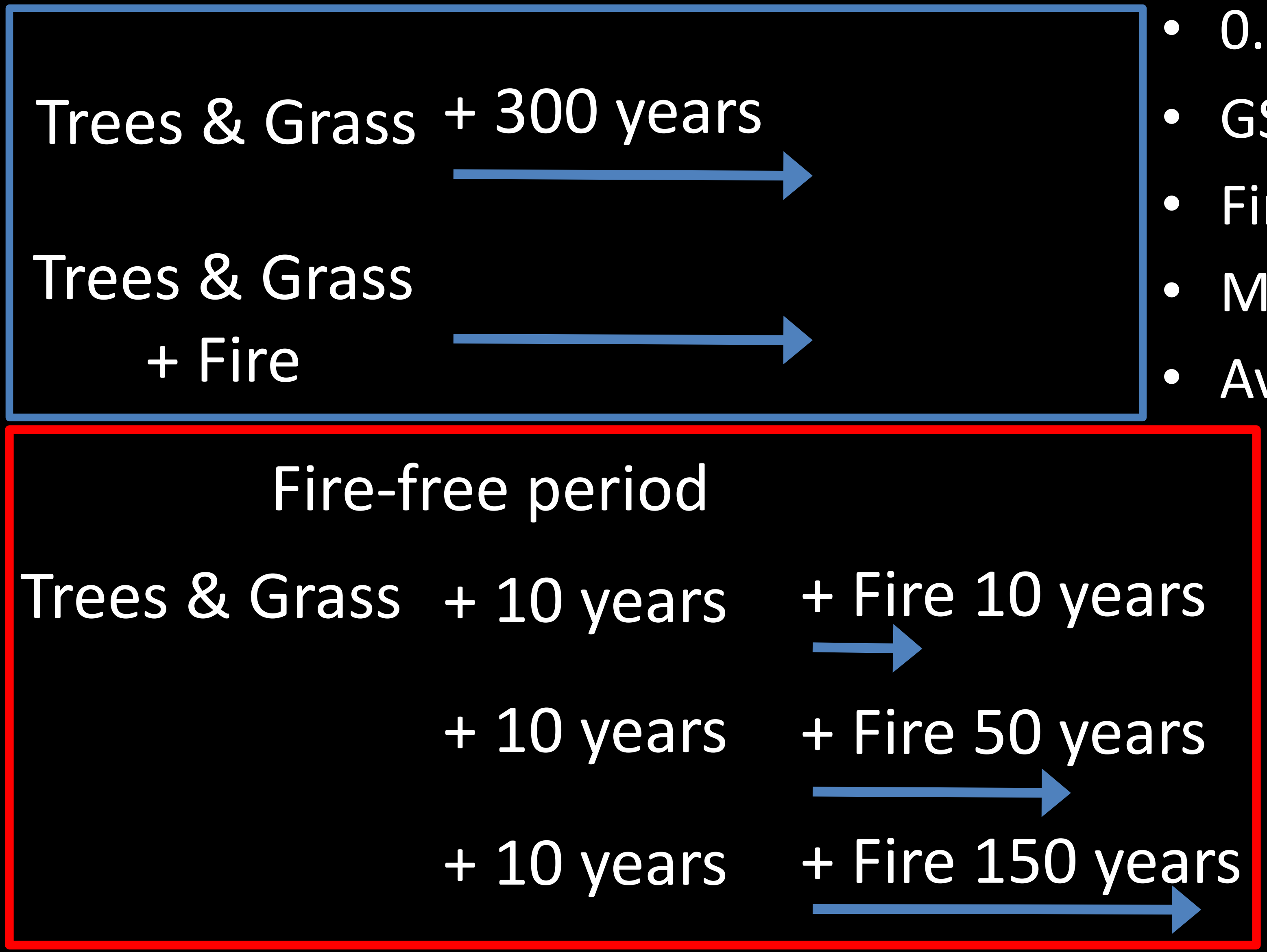
FATES-SPITFIRE



Adapted from Thonicke *et al.* 2010 *Biogeosciences*

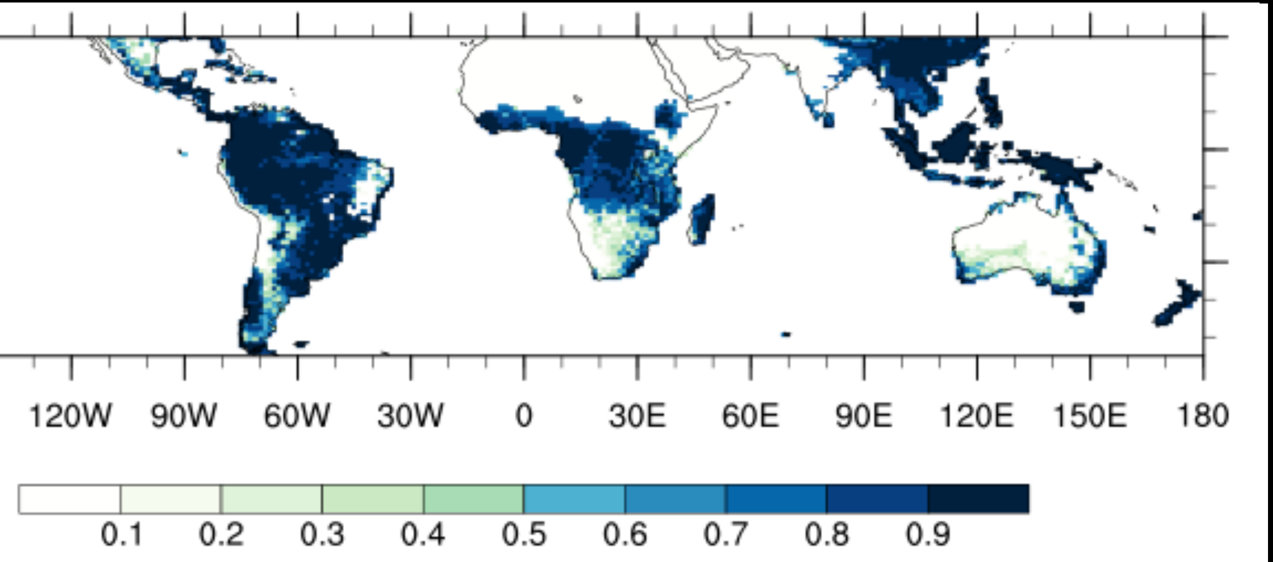
Preliminary Results



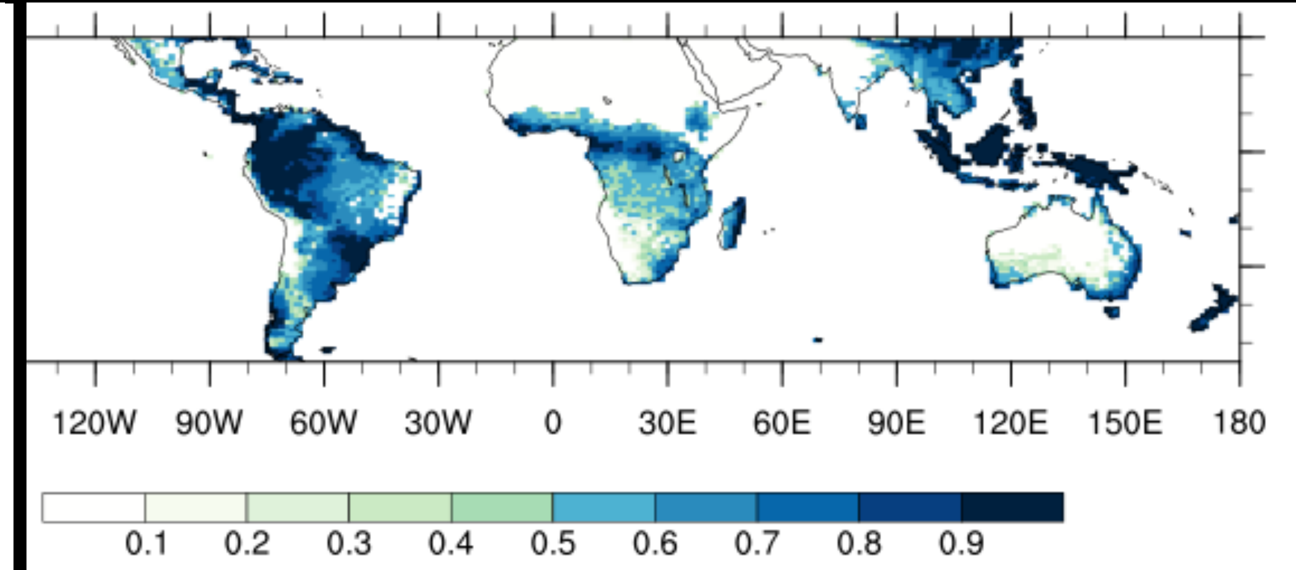
- 0.9 x 1.25 runs
- GSWP3 climate data (1991-2010)
- Fire ON and Fire OFF
- Multiple fire-free and fire periods
- Average across final 10 years

Fire acts to limit tree cover

Trees and Grass competing



Fraction of Tree Area, no fire

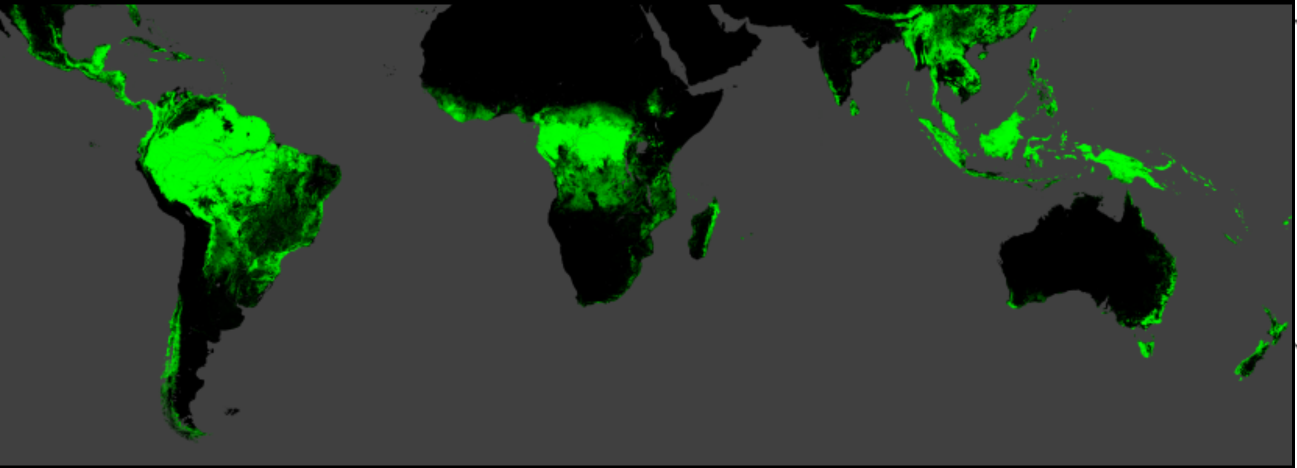


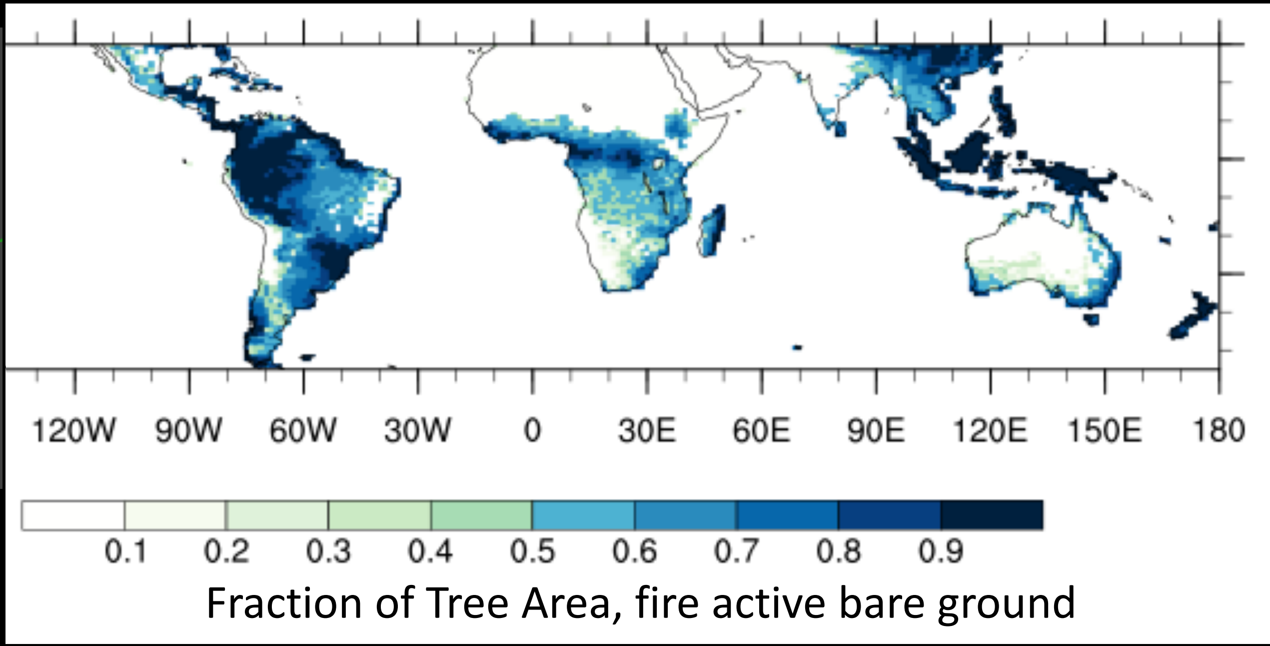
Fraction of Tree Area, fire active bare ground

- Fire reduces tree area across South America and Africa
- 150 years current climate GSWP3 (1991-2010) , Trees and Grass

Fire acts to limit tree cover

Trees and Grass competing



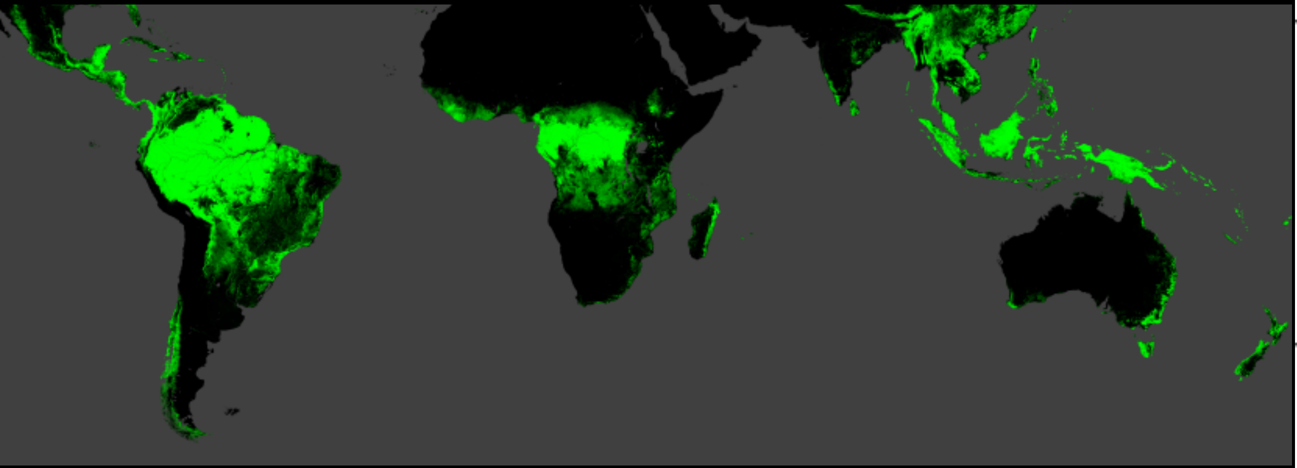


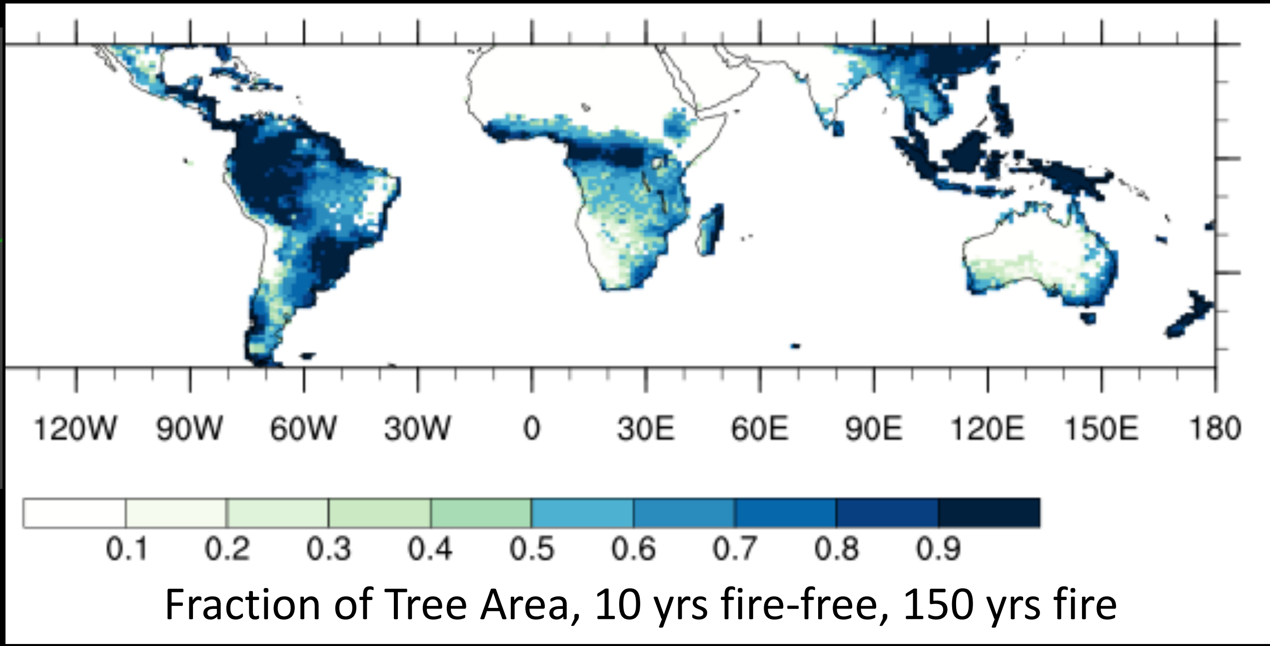
- Fire reduces tree area across South America and Africa
- 150 years current climate GSWP3 (1991-2010) , Trees and Grass

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, et. al. (2013) *Science*

Fire acts to limit tree cover

Trees and Grass competing

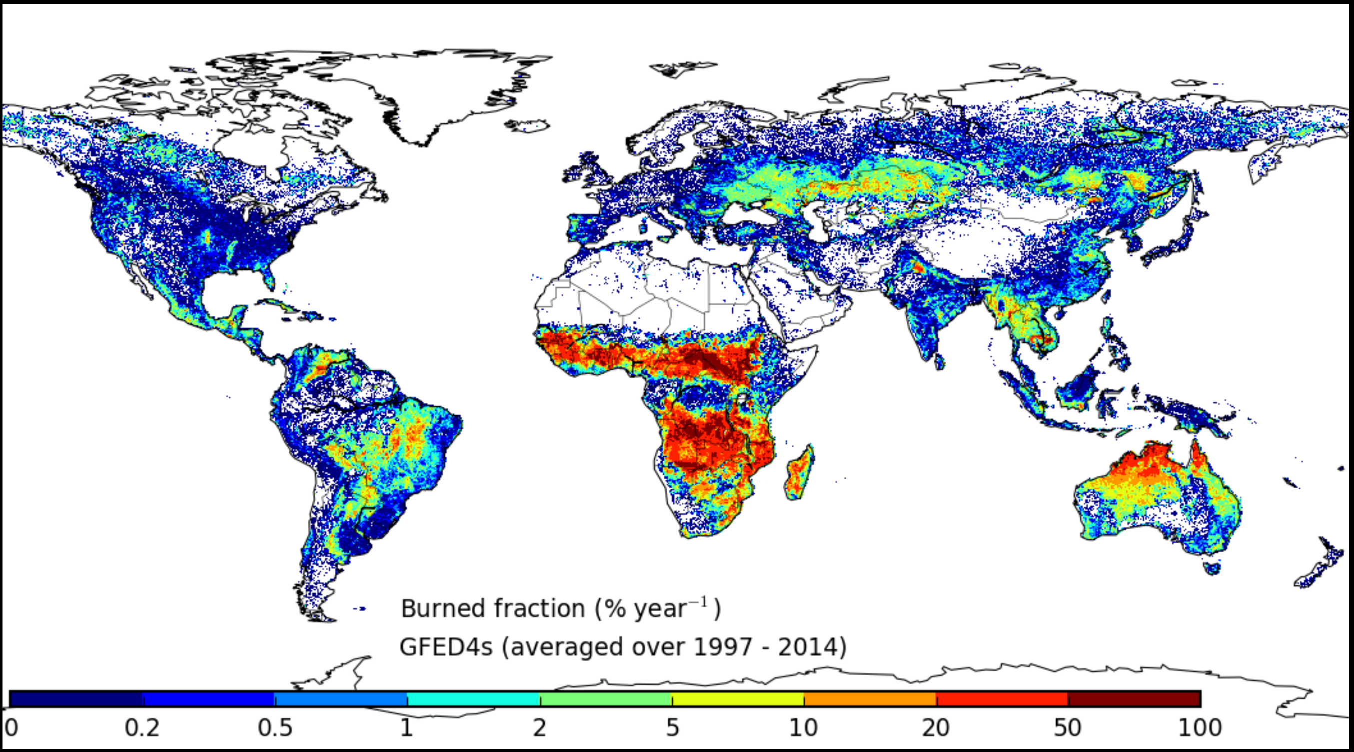




- Fire reduces tree area across South America and Africa
- Initial fire free period allows trees to escape “fire-trap”

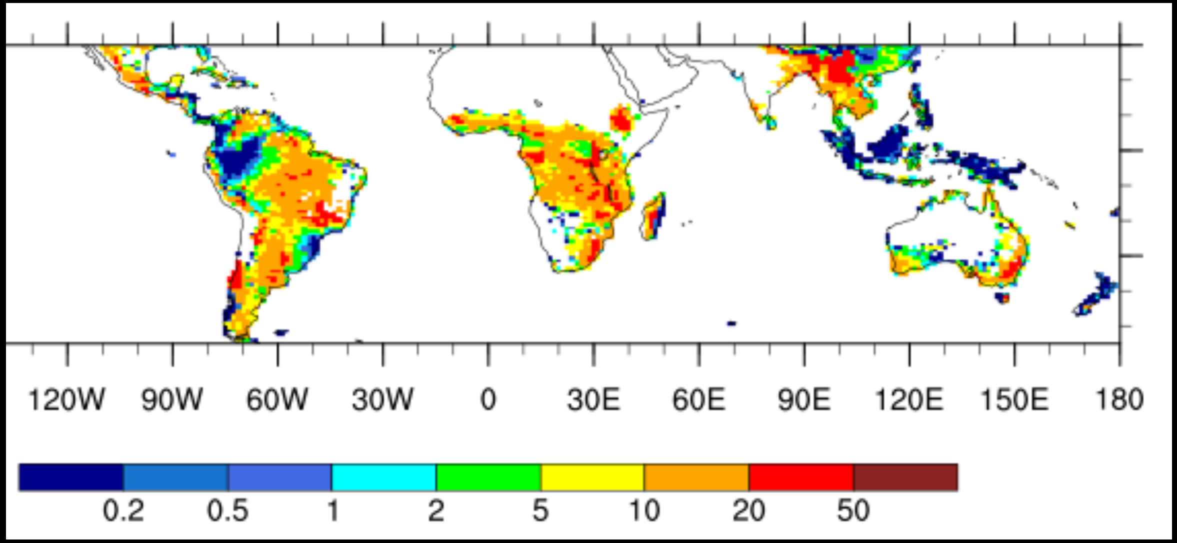
Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, et. al. (2013) *Science*

Burned fraction (% year^{-1})

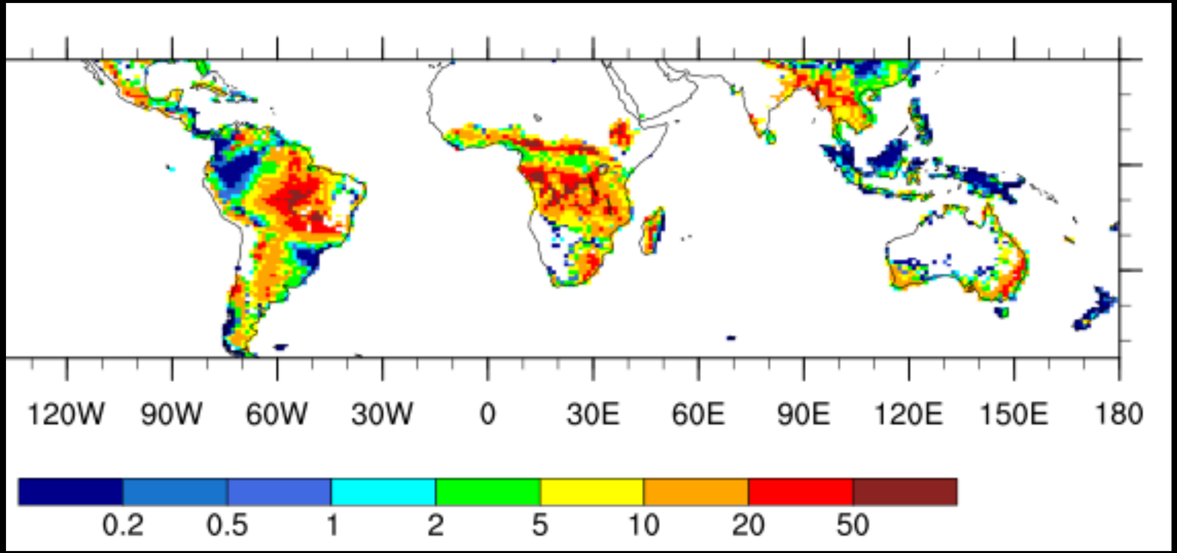


Van der Werf et al. 2017

10 yrs no Fire, 150 yrs Fire

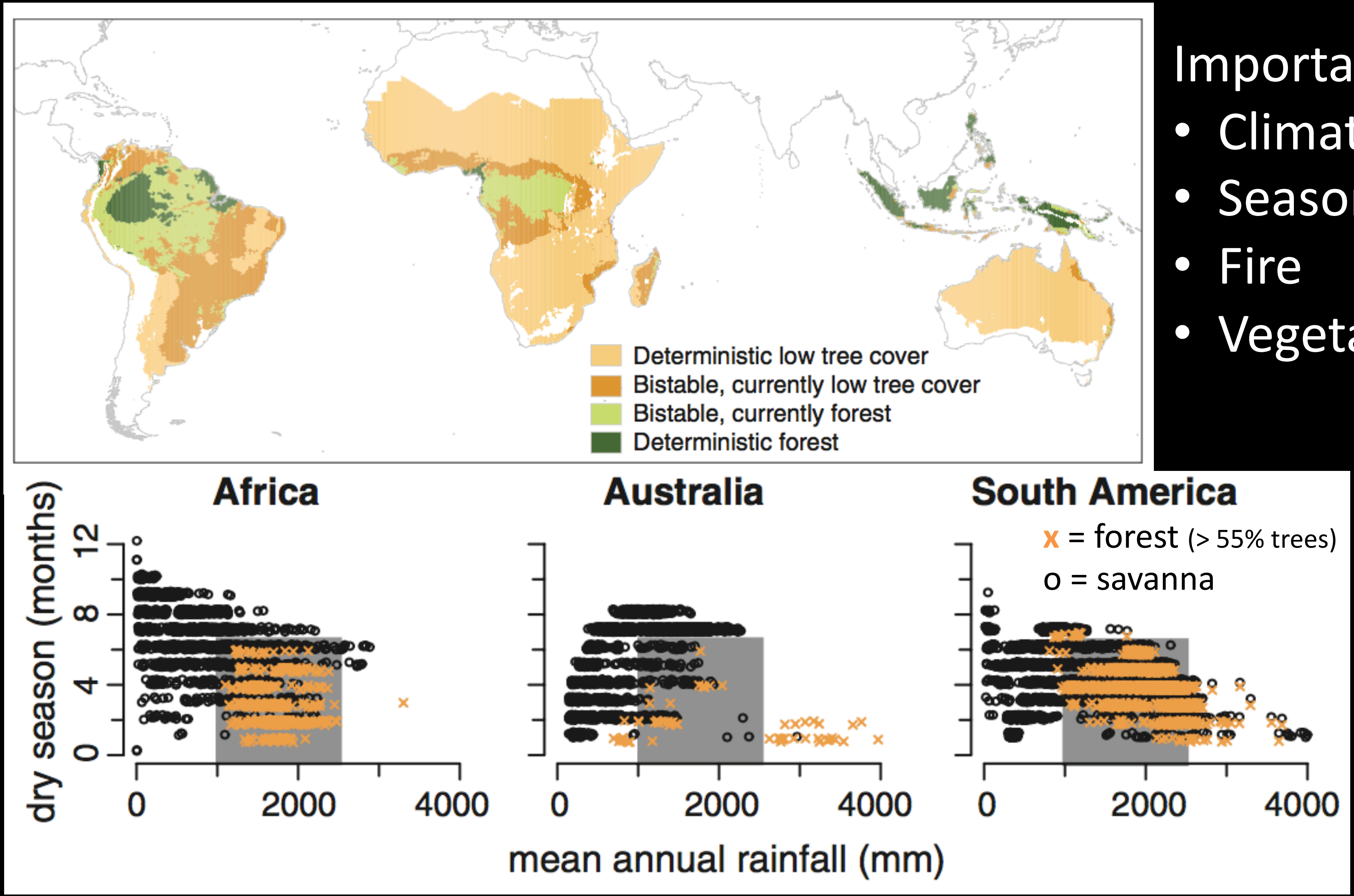


50 yrs no Fire, 150 yrs Fire



Captures low fire in forest
More fire in Forest/Savanna bi-stable areas
South America versus Africa

Forest/Savanna bi-stability



Important Factors:

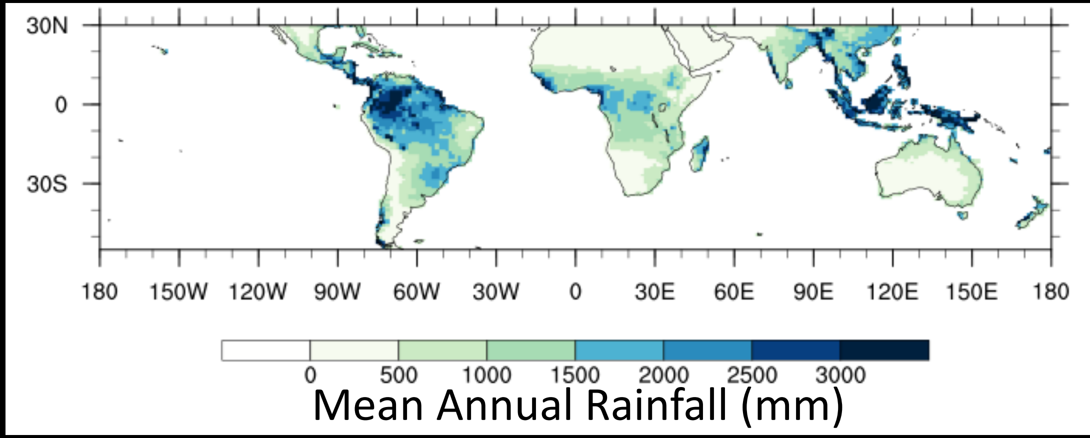
- Climate
- Seasonality (# dry months)
- Fire
- Vegetation Traits and state

Forest = +55% trees, minimal grass

Savanna = partial trees (20-80%), continuous grass

Staver *et al.* 2011 *Science*

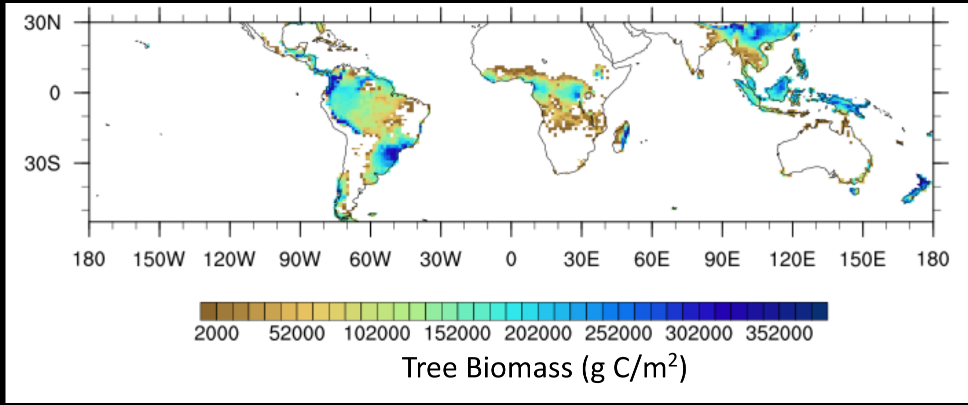
Tropical Coexistence of Trees and Grass biomass



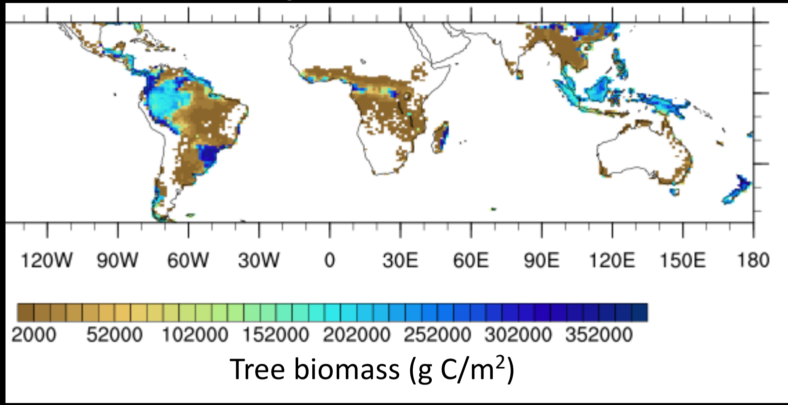
Tree biomass in areas of high MAR

Grass expands with fire

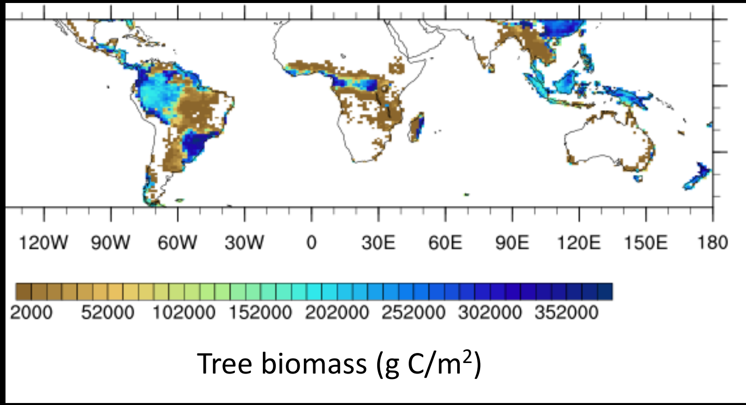
Tree biomass without Fire



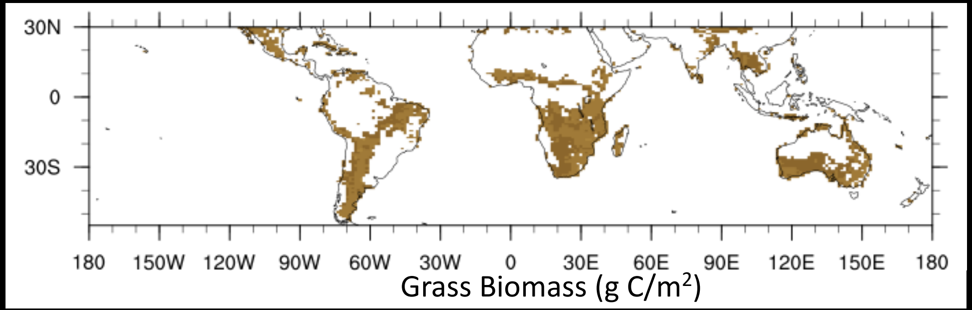
150 yrs with Fire



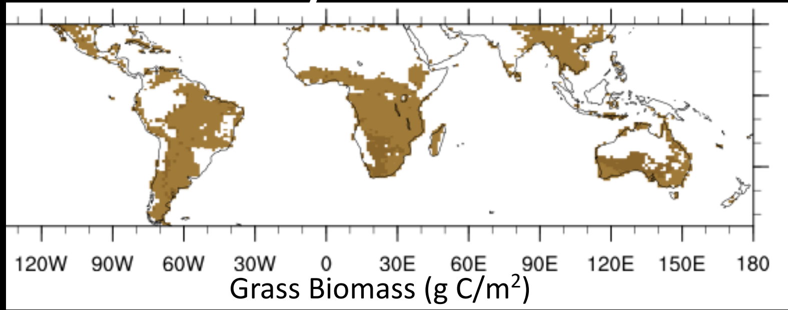
10 yrs no Fire, 150 yrs Fire



Grass biomass without Fire



150 yrs with Fire



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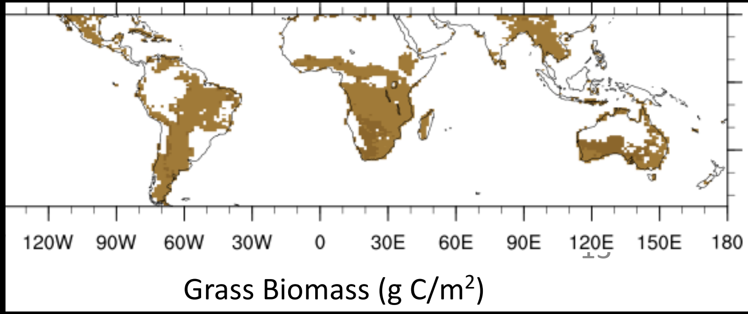
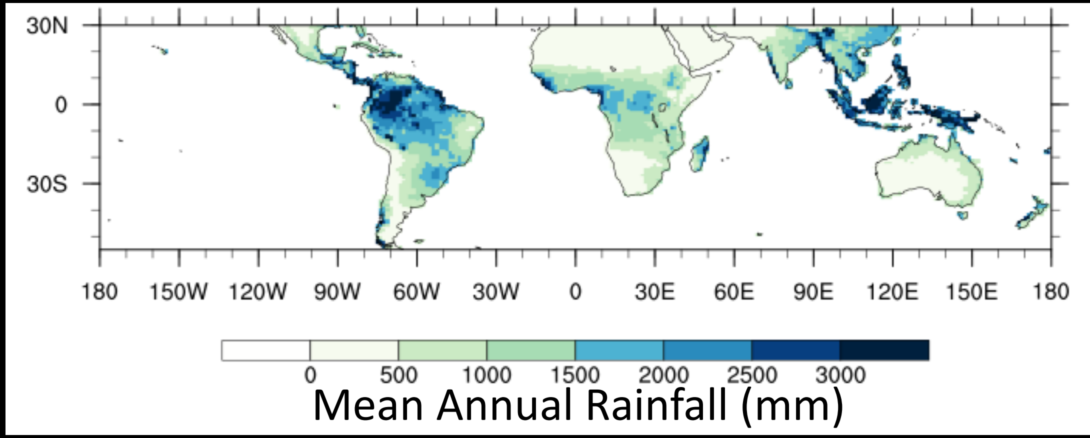


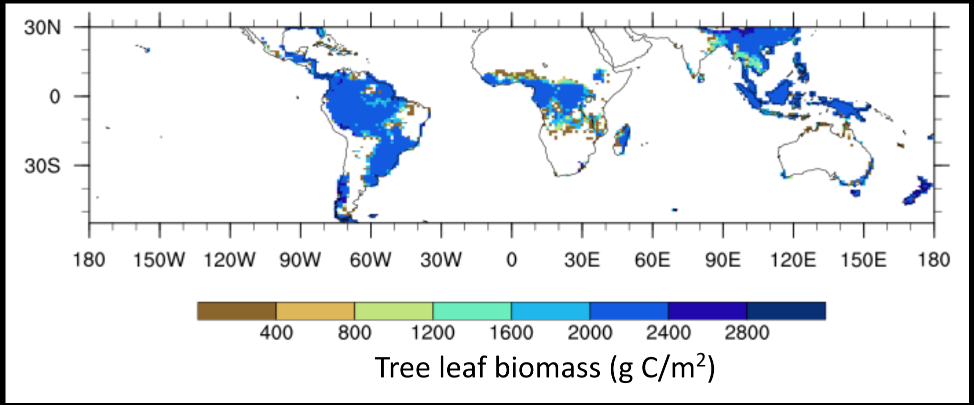
Tropical Coexistence of Trees and Grass leaf biomass



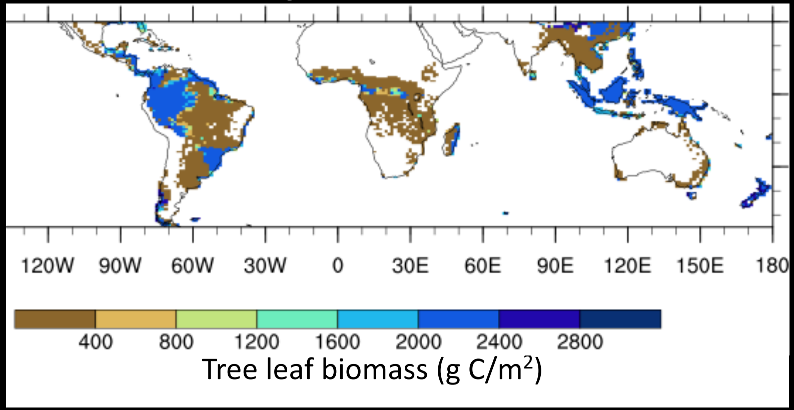
Tree leaf biomass higher than grass

High grass leaf biomass in high MAR

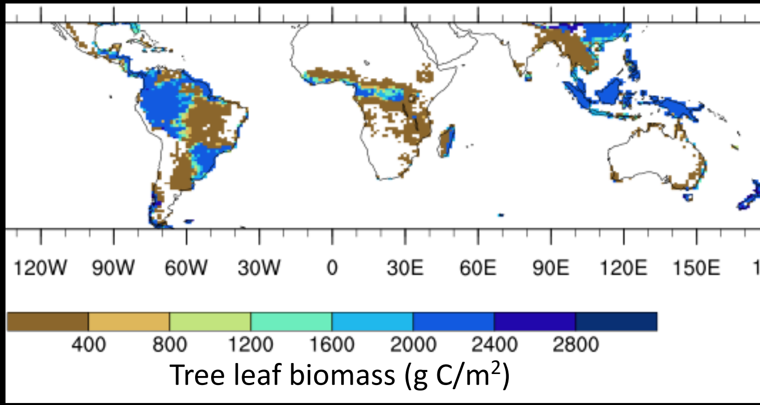
Tree leaf biomass without Fire



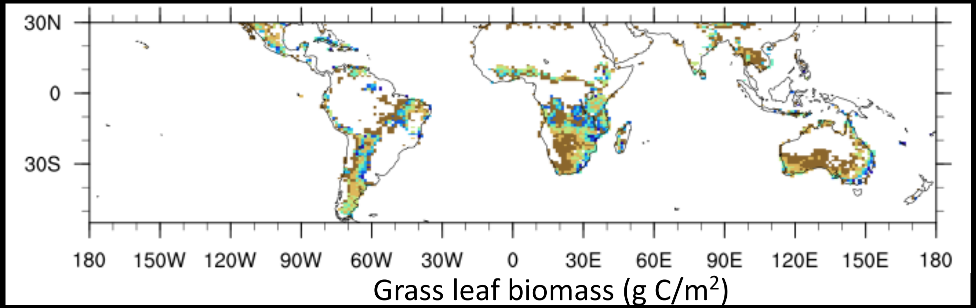
150 yrs with Fire



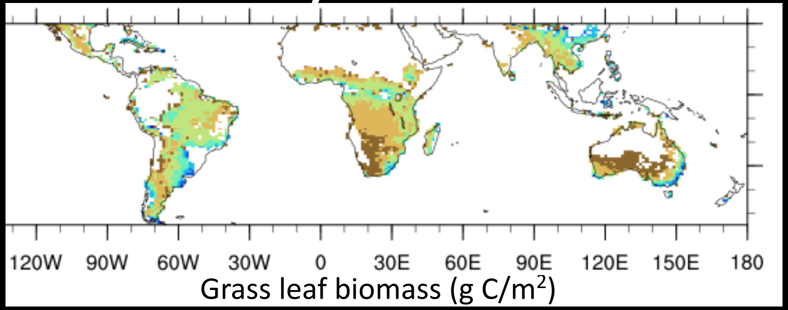
10 yrs no Fire, 150 yrs Fire



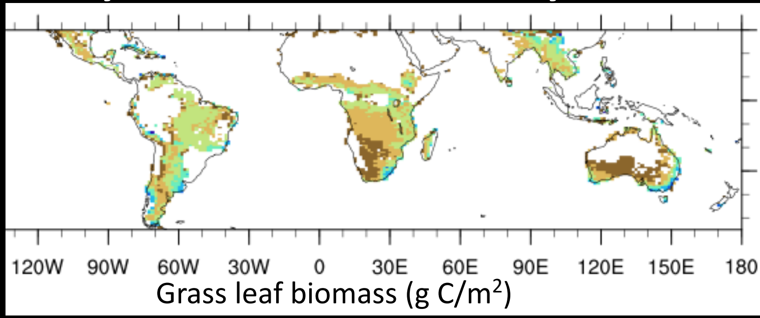
Grass leaf biomass without Fire



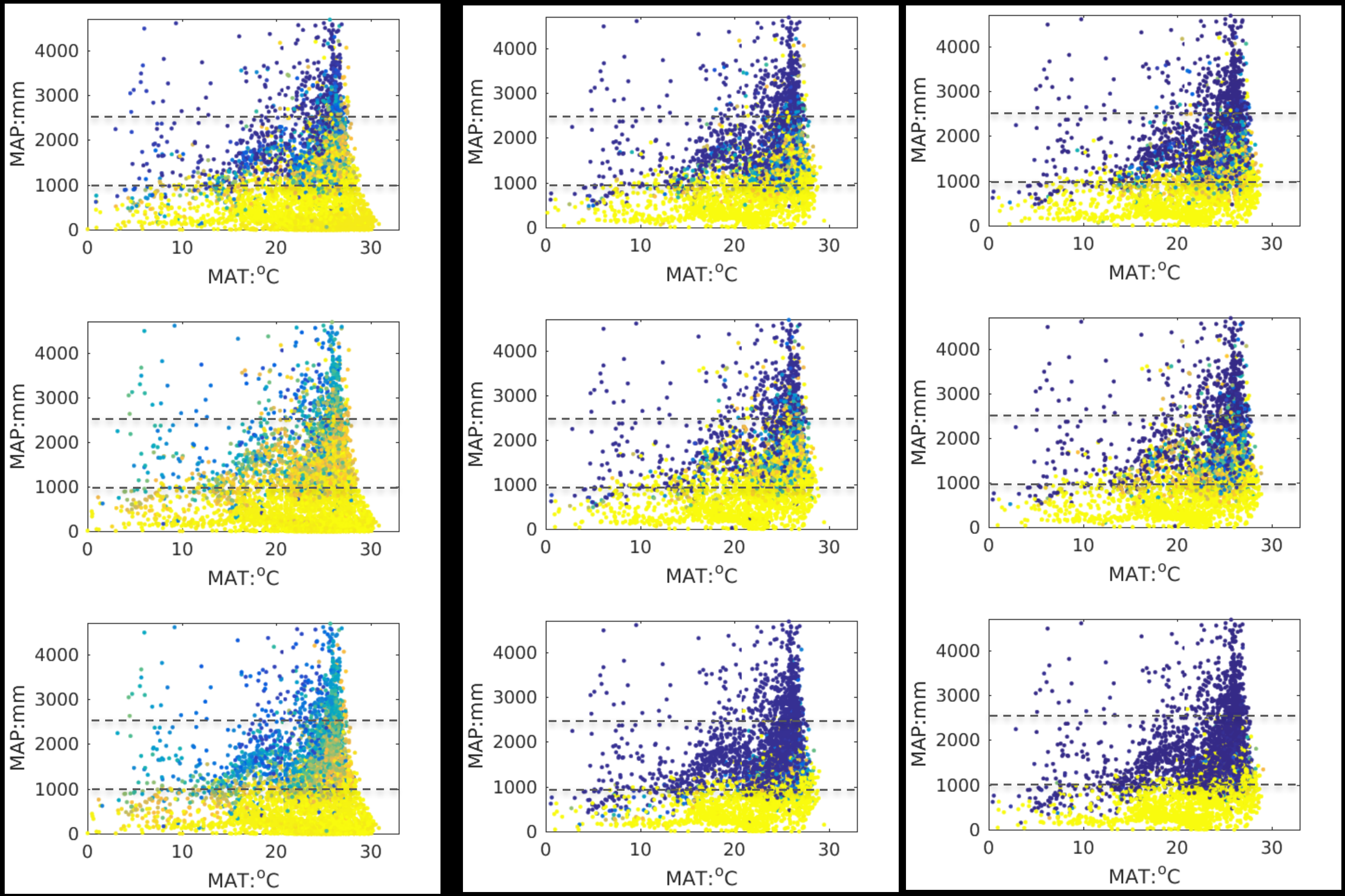
150 yrs with Fire



10 yrs no Fire, 150 yrs Fire



Tree-Grass coexistence (Total biomass)

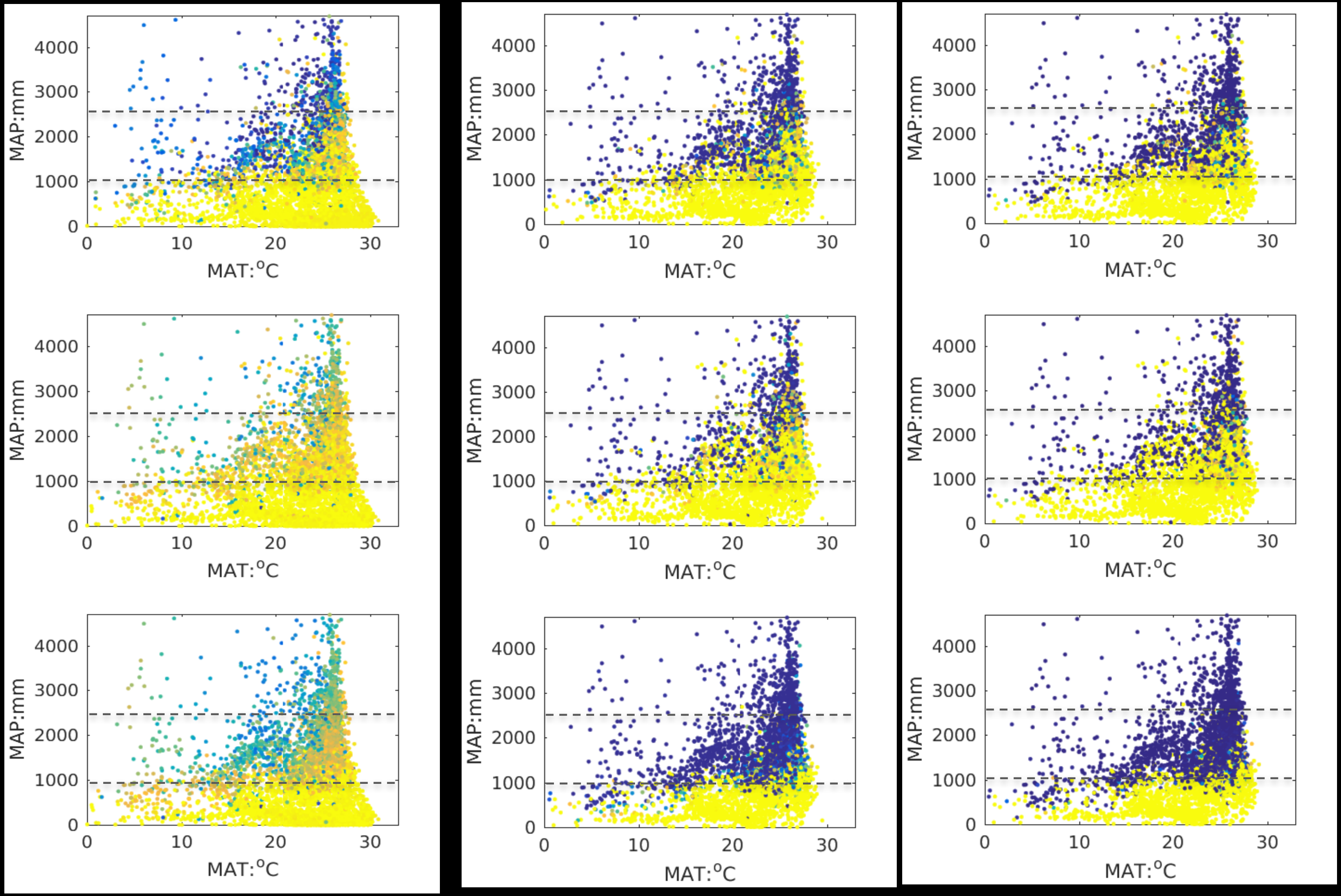


Fire after period without:
Disturbance important for coexistence

Fire from Bare Ground:
Co-existence within 1000 to 2500 mm MAP

No Fire:
Grass dominates below 1000 mm MAP

Tree-Grass coexistence (leaf biomass)

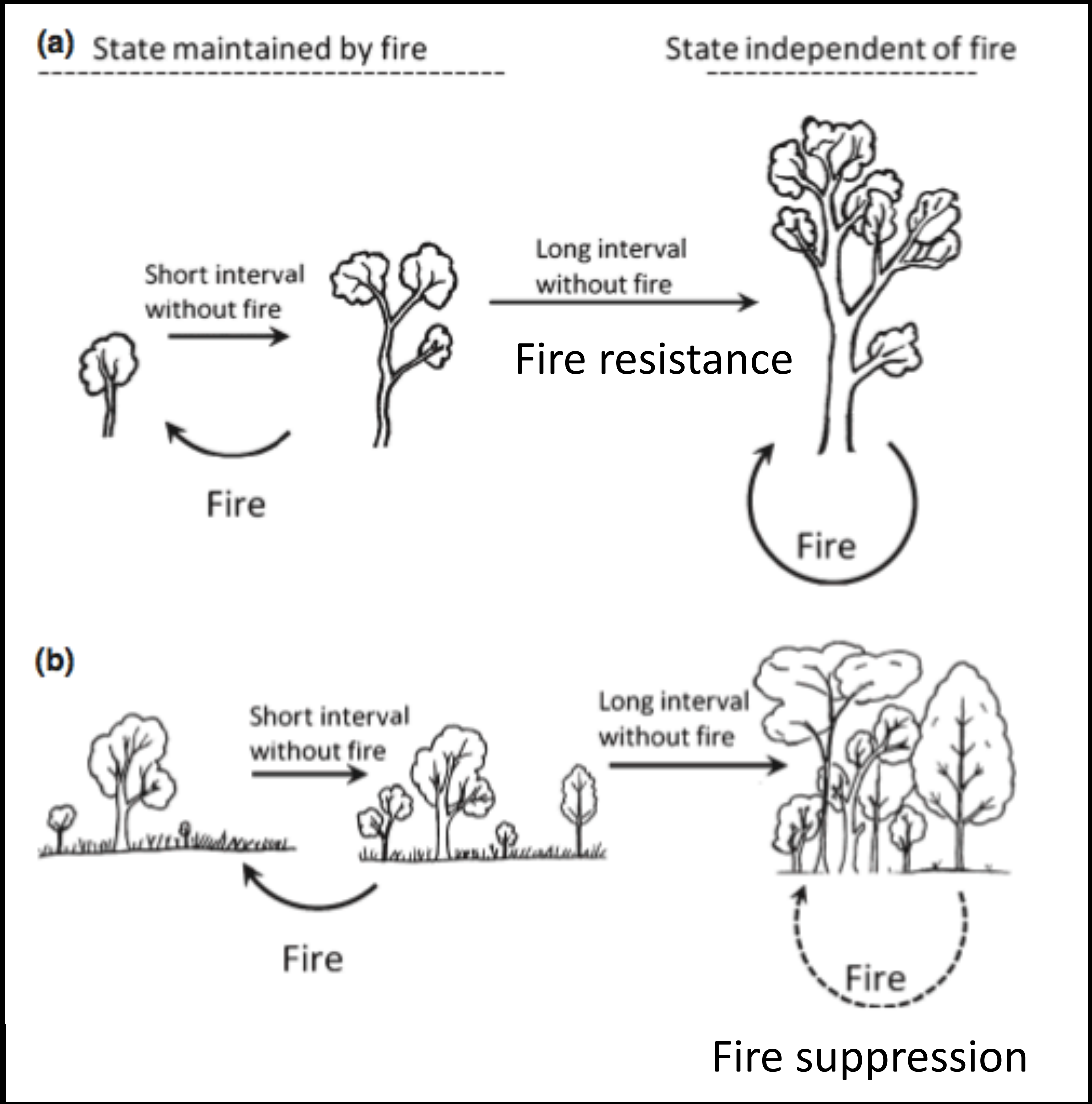


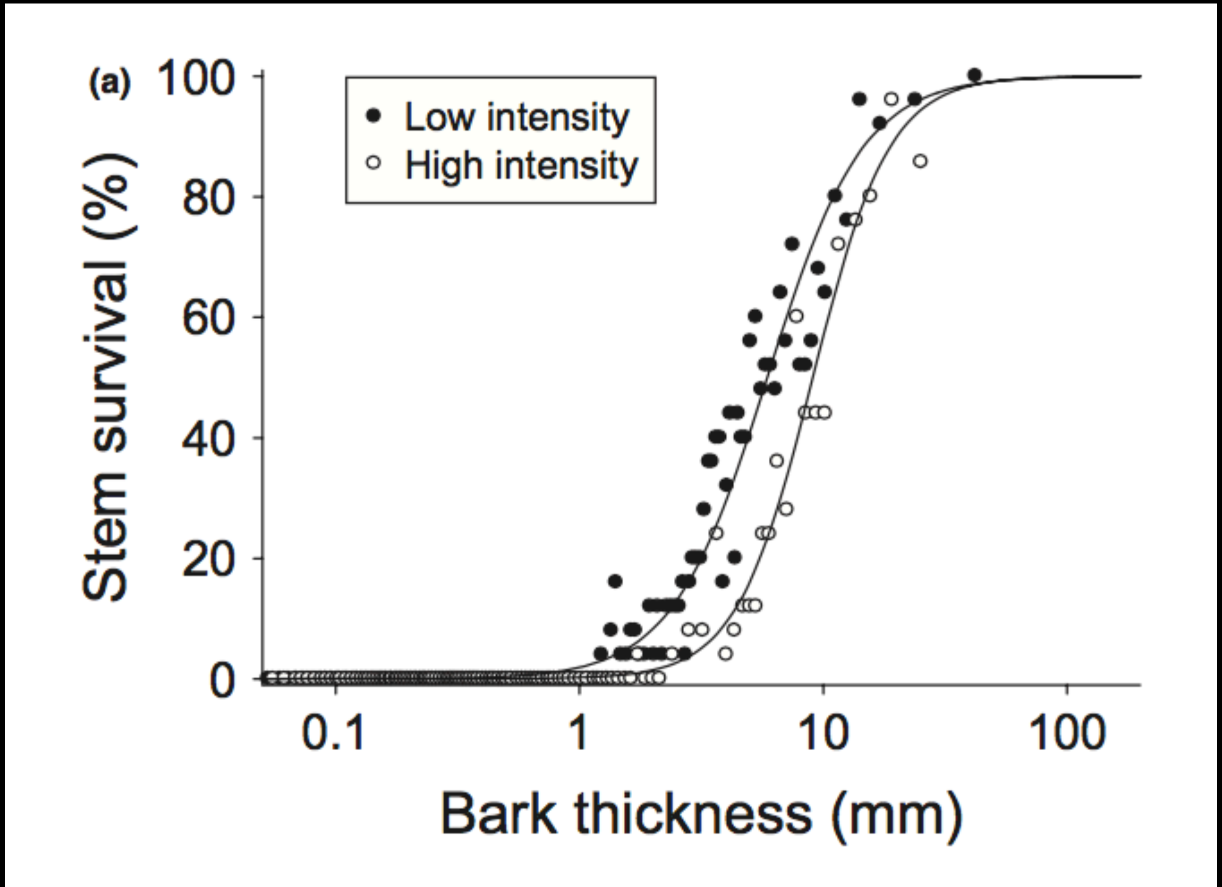
Fire after period without:
Initial veg state maintains tree leaf biomass

Fire from Bare Ground:
More grass leaf biomass 1000 to 2500 mm MAP

No Fire:
Grass dominates below 1000 mm MAP

Fire Trap and Bark Thickness



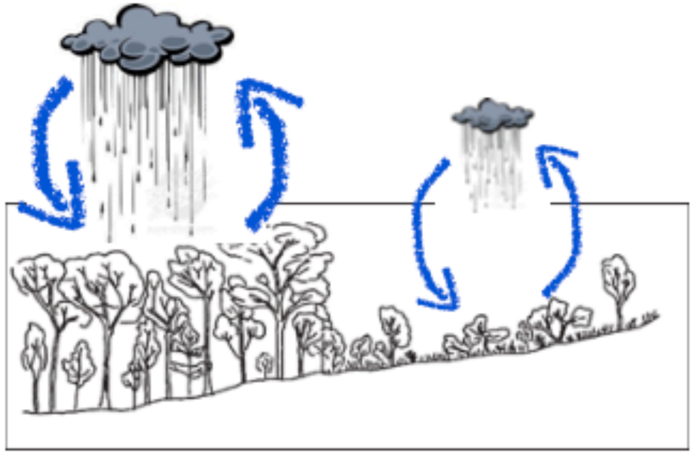


Multiple feedbacks due to vegetation structure

50% survival: Low-intensity fire 5.9 mm
High-intensity fire 9.1 mm
Low-intensity fire char height ≤ 2m

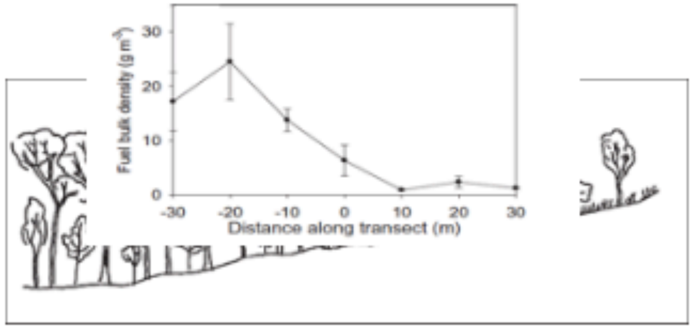
Hoffman *et al.* 2012 *Ecology Letters*

Multiple scales of feedback

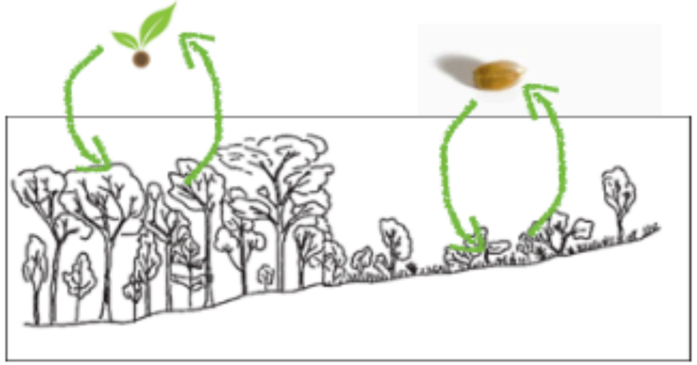


Land-atmosphere feedback

Wind speed feedback



Flammability feedback

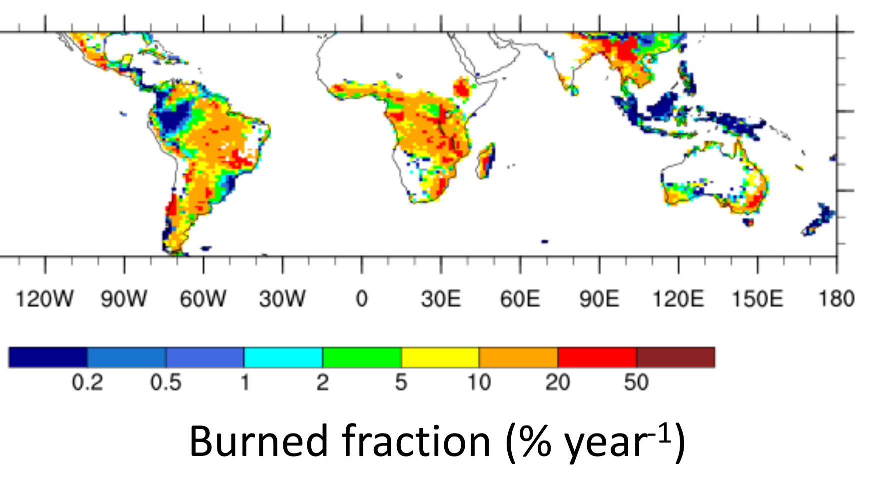


Demographic feedback

adapted from concepts in Hoffman et al., 2012, 2013

Fire in the Savanna

10 yrs no Fire, 150 yrs Fire



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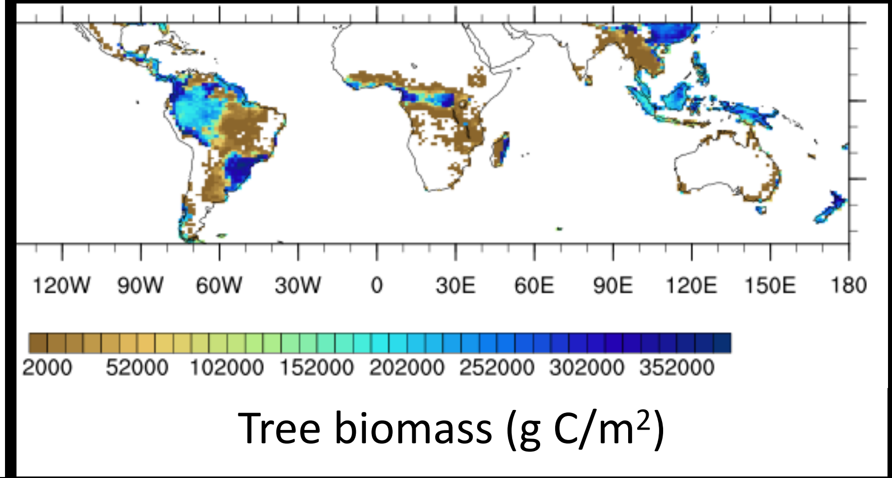

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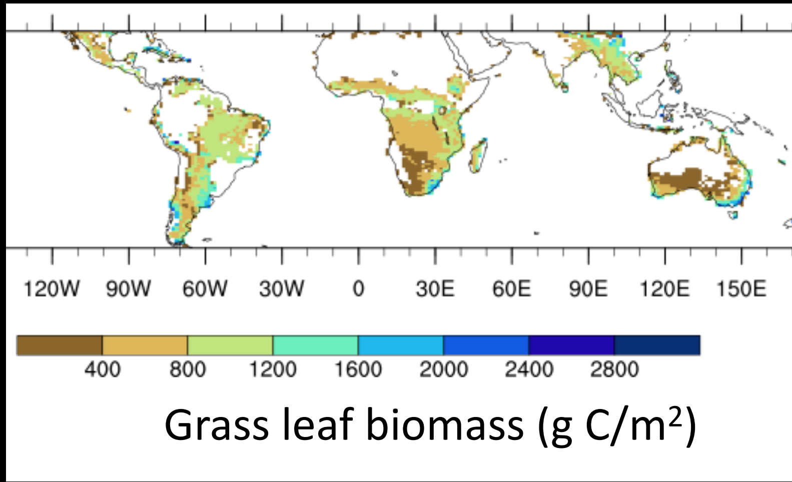
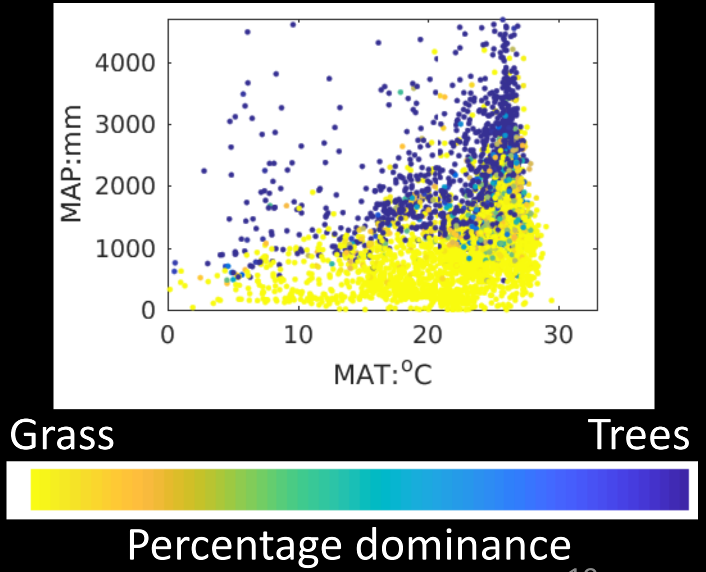


- Capture low burned fraction in stable forest areas
- Fire-Free period for Trees to escape fire-trap
- S.A. versus Africa:
  - separate forest and savanna trees (resprouting)
  - diversity of bark thickness (within and across PFTs)
  - update critical time of cambial heating
- Shift to drier conditions would favor grasses



Future Directions:

Application within temperate and boreal regions
Coupling with social (agent based) models
Paleo applications