A stand-alone tree demography and landscape structure module for Earth system models

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MOTIVATION

Motivation

- Changes in biomass storage of forest and savanna ecosystems are a major explanation for the global terrestrial C sink which offsets ~25% anthropogenic C emissions.
- ESMs show divergent responses of biomass turnover to changing climate, translating to divergence in simulated climate
  - ➢ Lack of representation of forest dynamics one of the greatest uncertainties in future climate prediction?
- DVMs in ESMs have no explicit treatment of demographic processes (recruitment, mortality, competition for resources)
  - ➢ Neglect information which informs stand-scale individual-based forest dynamics models
- The Impact of fire on the global Carbon budget
- Readily usable with other DVMs and/or ESMs

POP
POPULATION-ORDER-PHYSIOLOGY

Introducing demographics and landscape heterogeneity to CABLE — the POP model

Key features - demographics

•Forcing by whole-ecosystem stem biomass increment from CABLE

•Simulate recruitment, allometric growth and mortality of age-size cohorts of trees in stands

•Partition total stem biomass increment among stands and cohorts as a proportion of current size

•Stress mortality influenced by declining growth efficiency under crowding and with increased size

•Upscaling to landscape by interpolation among stands of different age-since-disturbance

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Key features - disturbances

•Account for age-size-density development of stands after (fire) disturbance

•Account for size-dependent mortality during (fire) disturbance

•Account for distribution of stand ages (after last disturbance) across landscape

•Allow for standard and catastrophic disturbances

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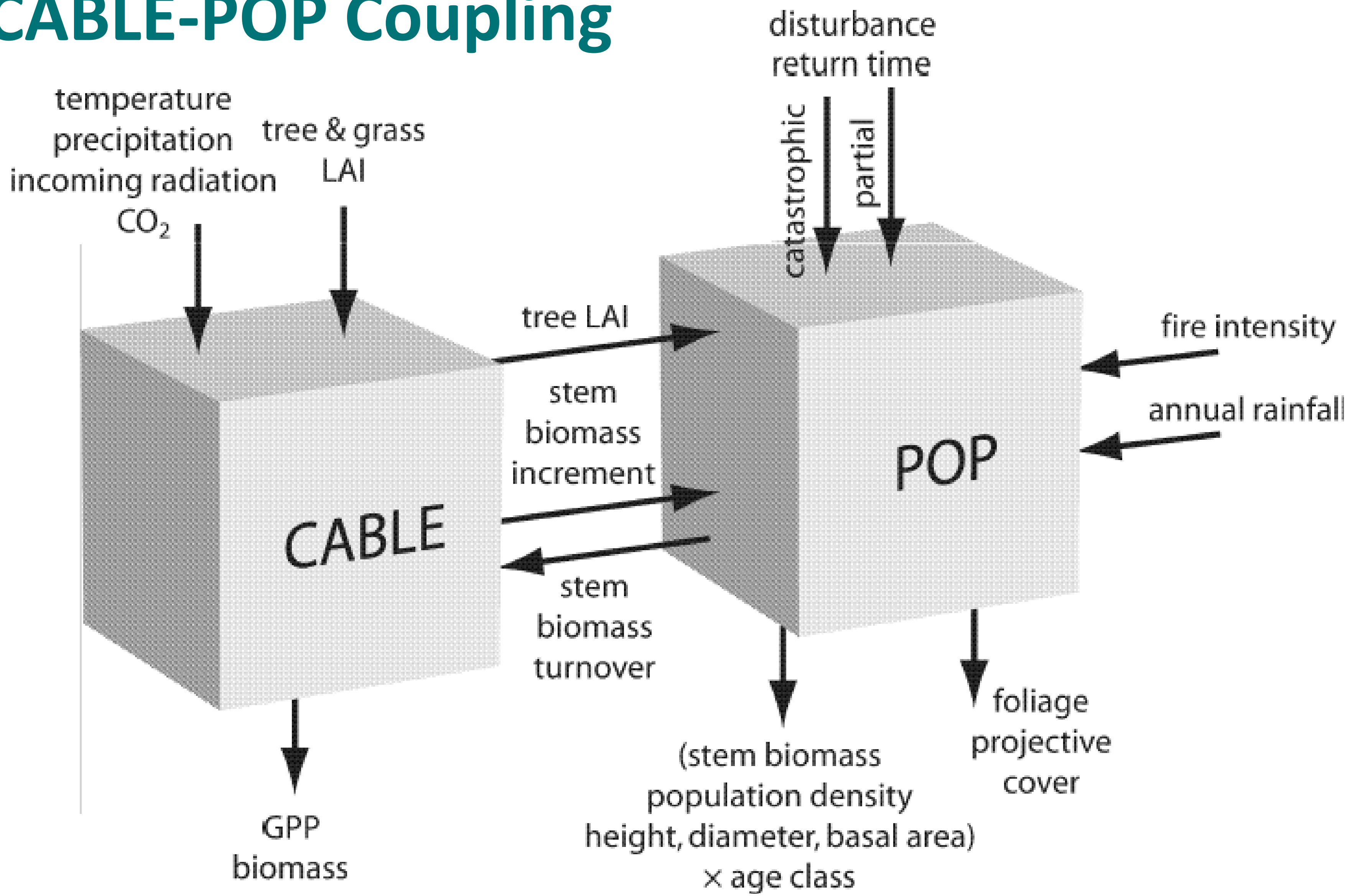
Key features – technical aspects

- Minimise increase in CPU and memory use

- Stand alone model that can be coupled to not integrated within CABLE or the terrestrial ecosystem component of any ESM

CABLE-POP Coupling



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POP outline

1 pixel ≈ 24 patches (patch representing a stand)

→1 patch = up to 20 kohorts

Each patch:

- Attempt of recruiting for 1 new cohort/year (if sufficient GPP)
- Cohorts with low growth efficiency die
- Has own disturbance history and frequency
- Disturbance Frequencies are randomly generated with an exponential distribution $E(\delta) = f_{dist}$

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Fire – Disturbance

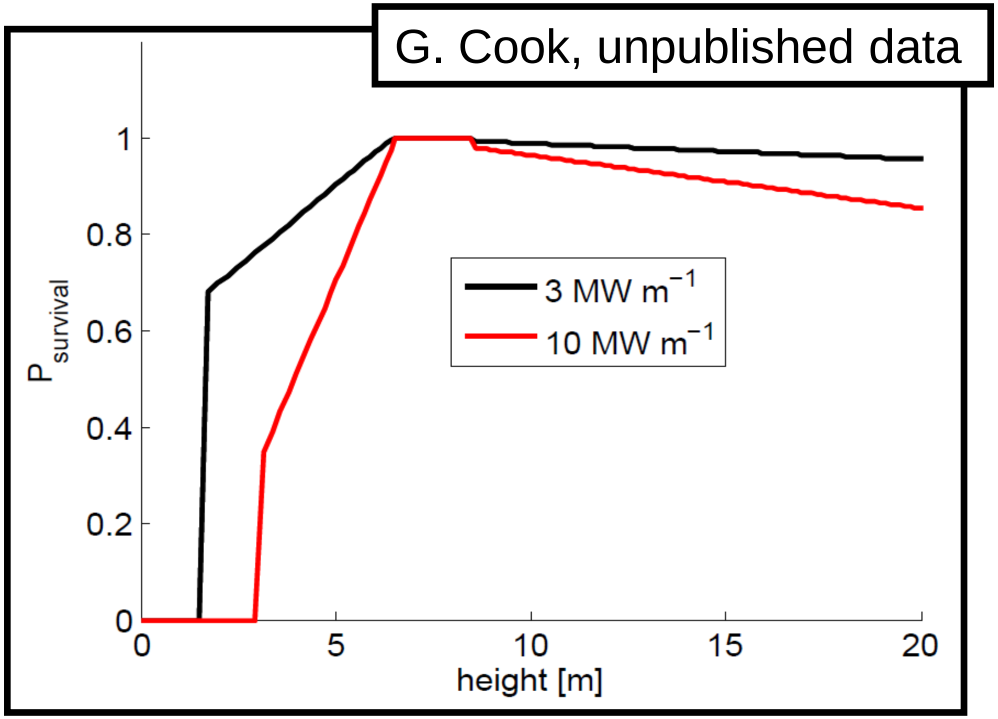
-Compute Fuel Load from overall biomass

-Determine Fire – Power

-Compute $P_{survival}$

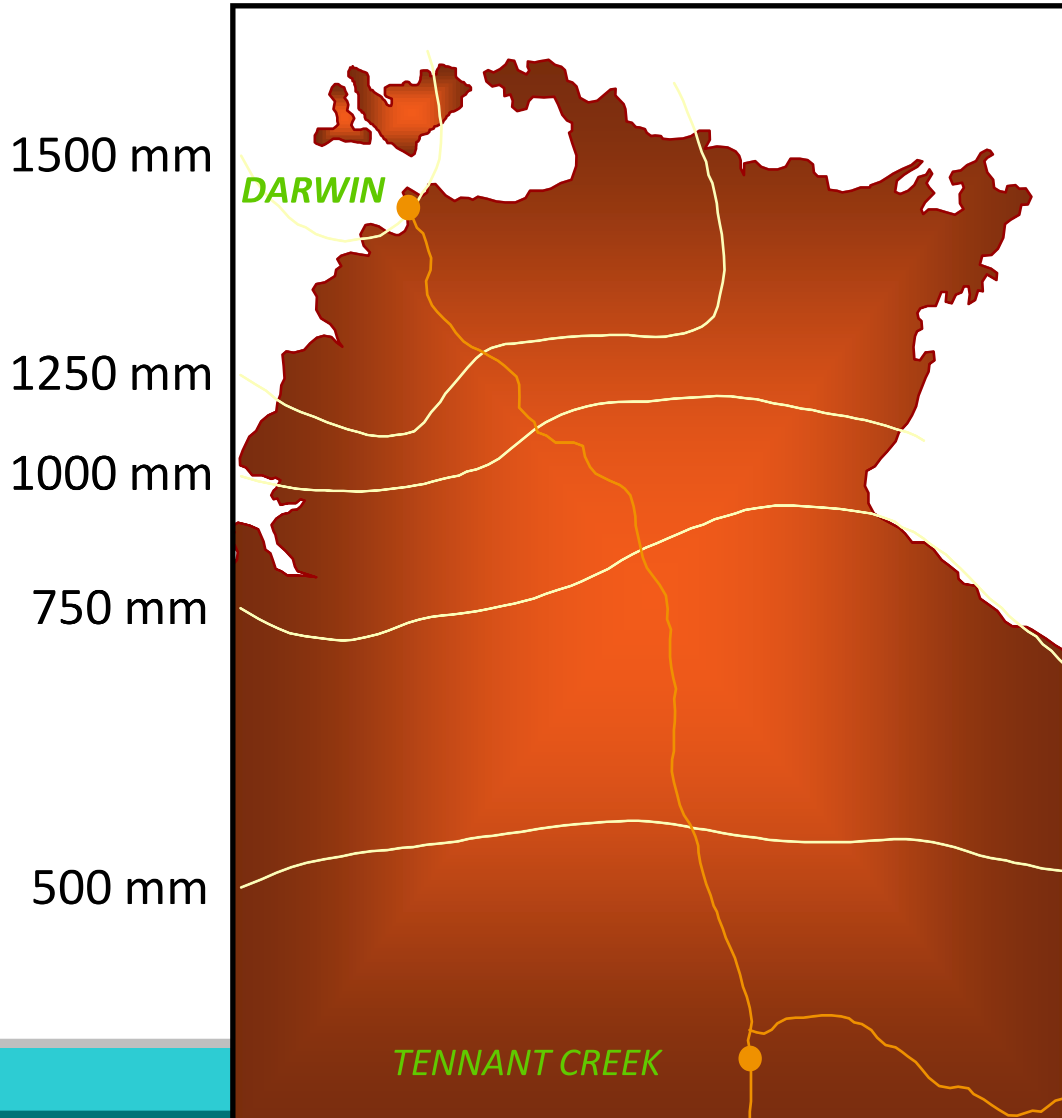
-Remove biomass

-Reset history



FIRST RESULTS

Study Site: Northern Australian Tropical Transect

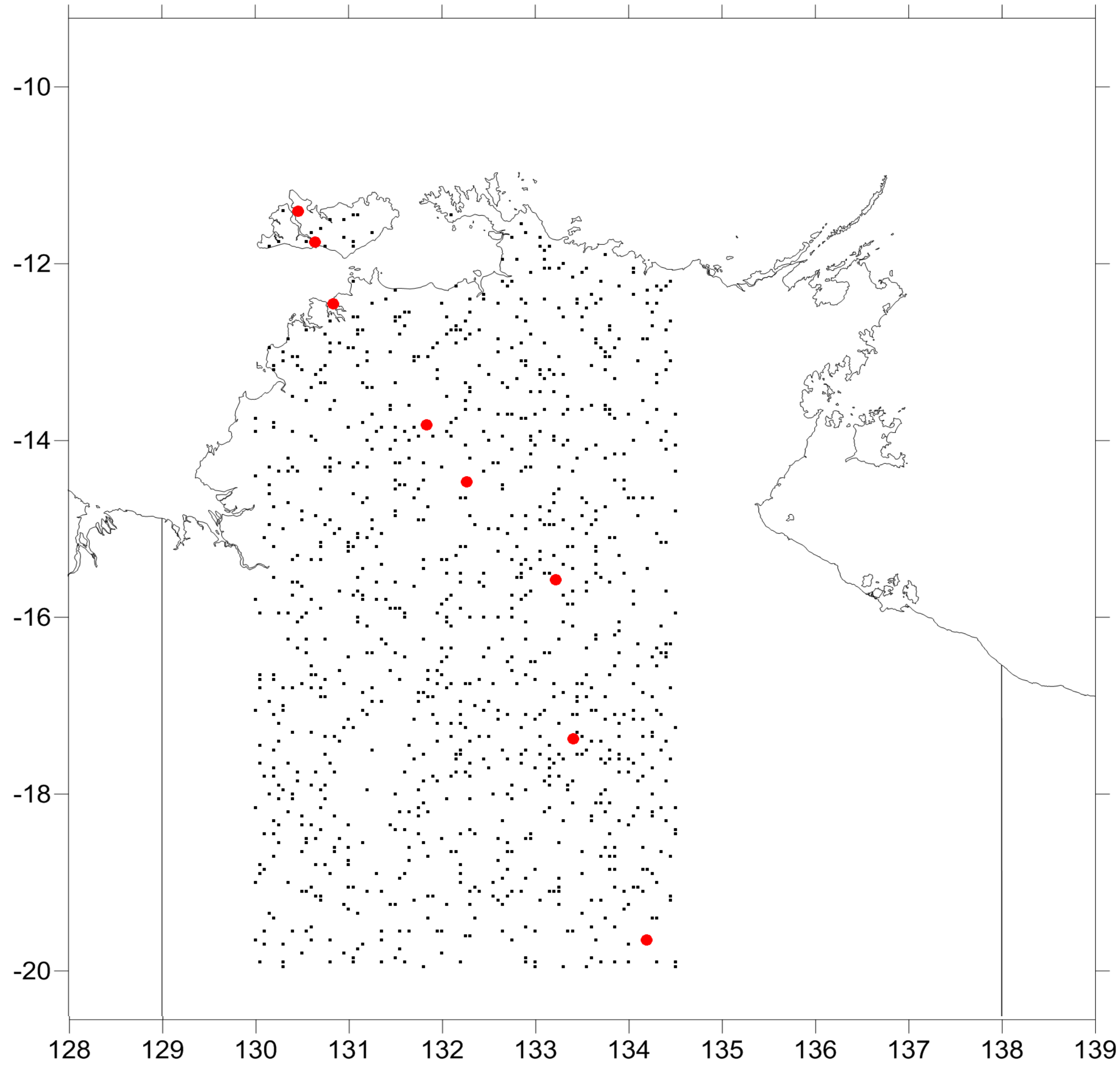


Photos by Adam Liedloff

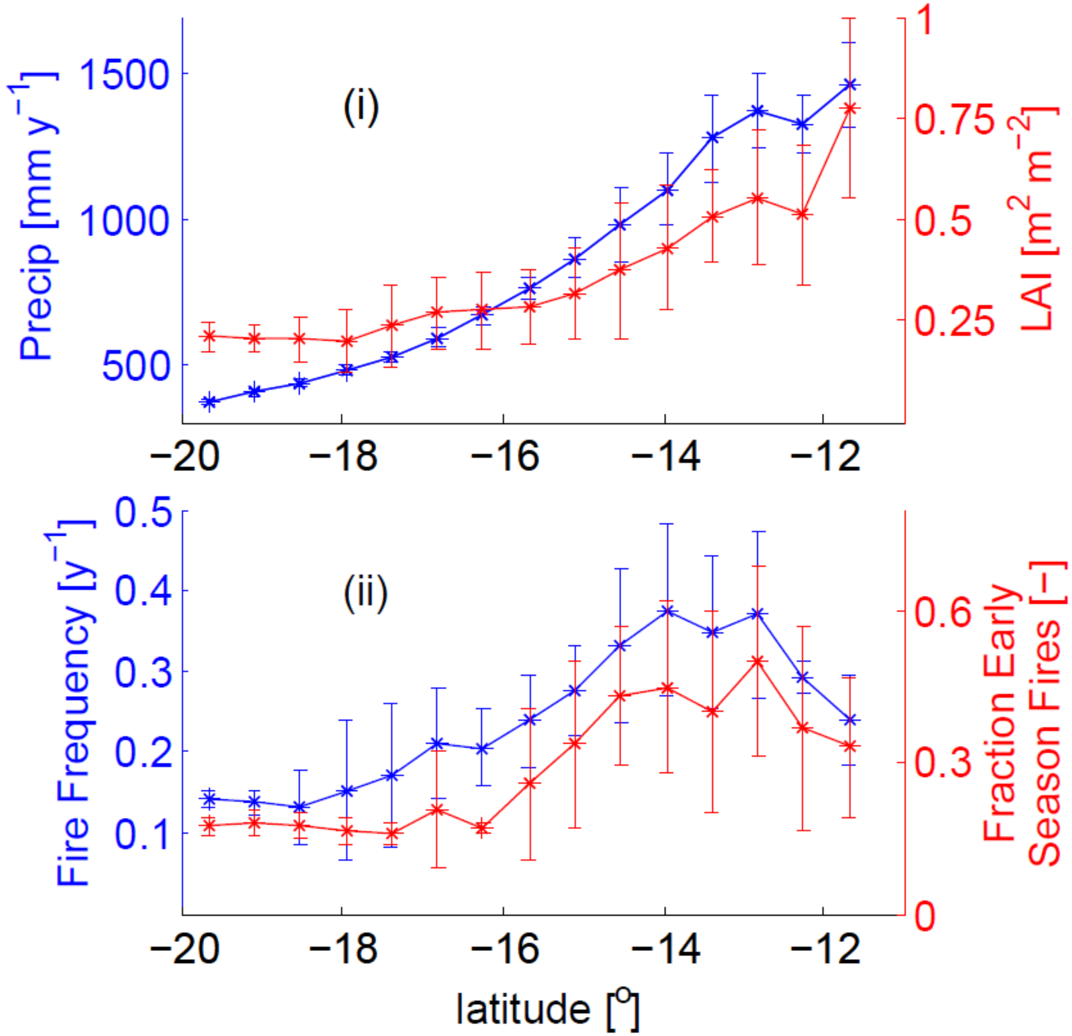
Sampling the NATT

8 NATT stations

1000 randomly generated pixels for CABLE



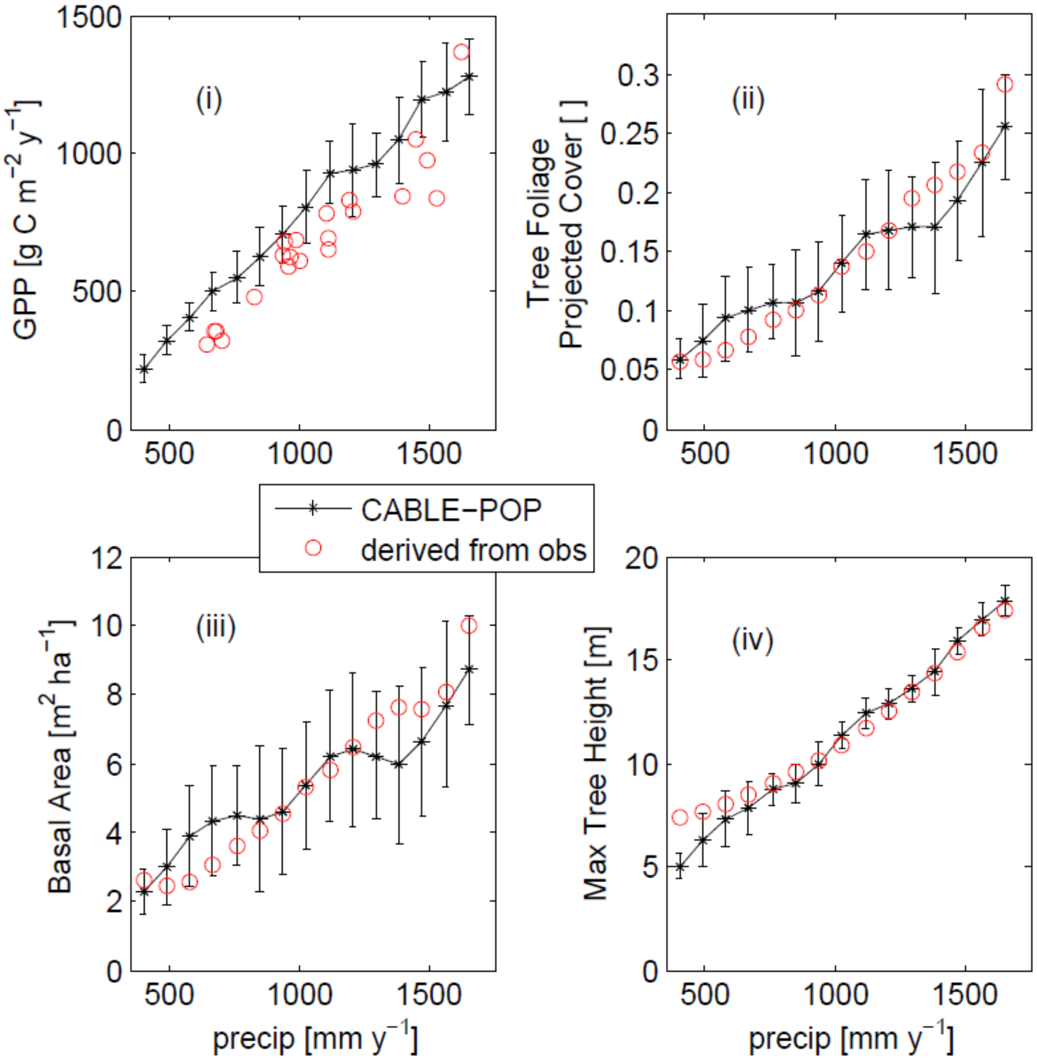
NATT Transect: gradients in rainfall, vegetation cover, fire.



Fire Data: Mick Meyer, pers. comm.

CABLE-POP vegetation function and structure predictions

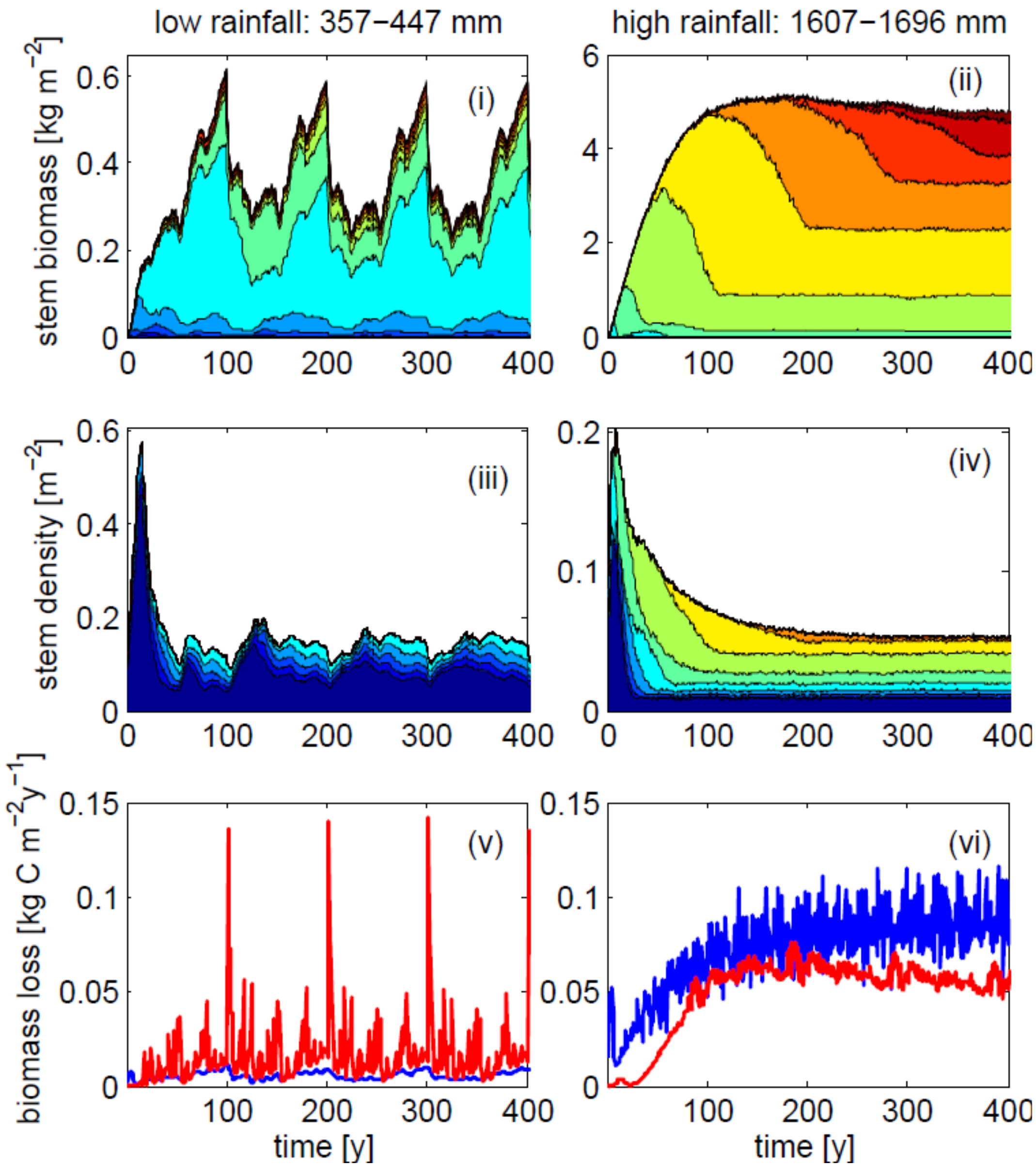
Obs-based estimates



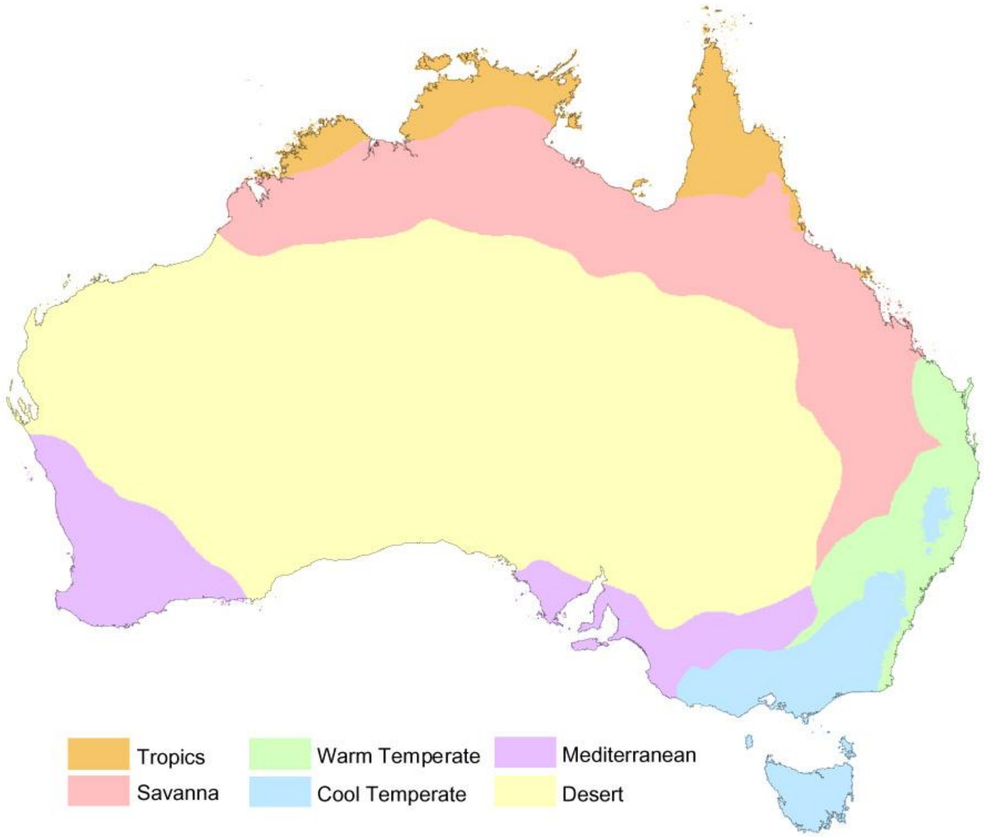
Kanniah, K.D., Beringer, J. and Hutley, L.B., 2011. Environmental controls on the spatial variability of savanna productivity in the Northern Territory, Australia. Agricultural and Forest Meteorology, 151(11): 1429-1439.

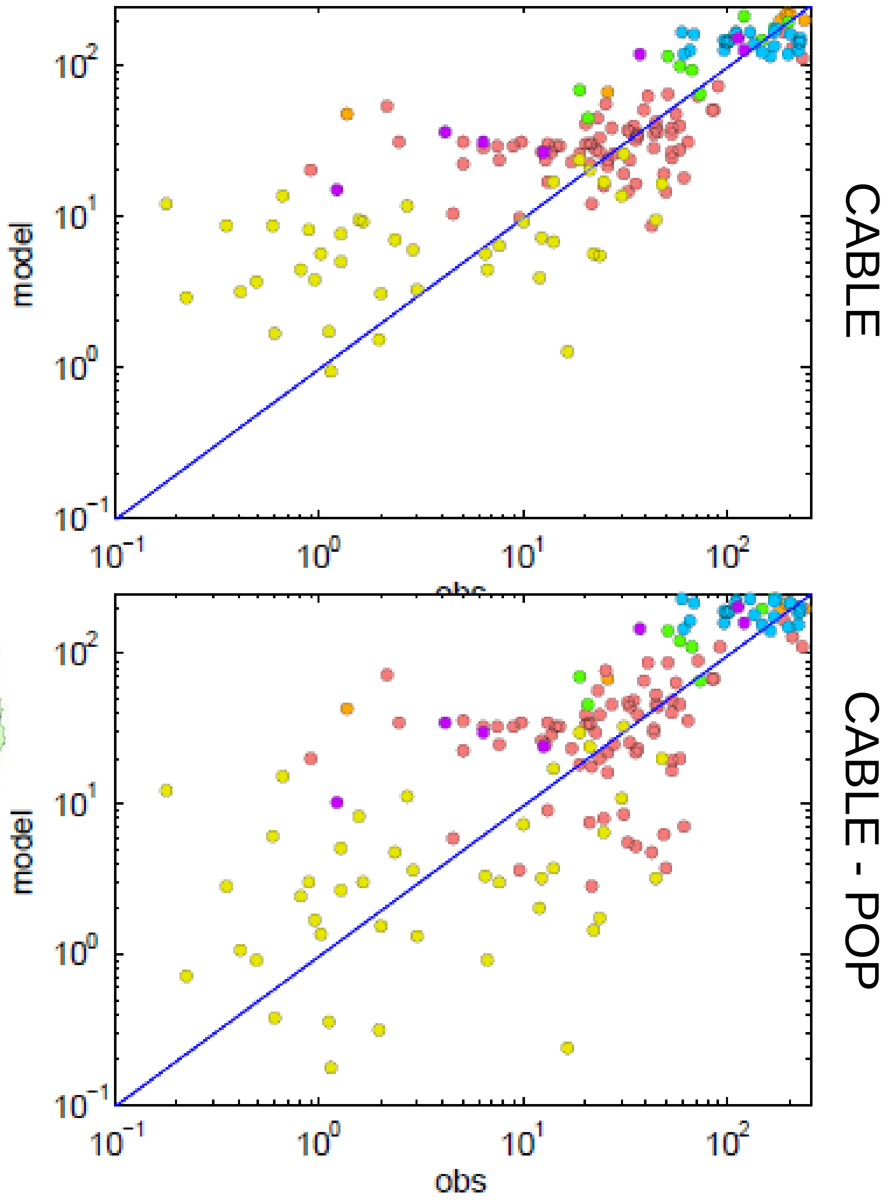
Williams, R.J., Duff, G.A., Bowman, D. and Cook, G.D., 1996. Variation in the composition and structure of tropical savannas as a function of rainfall and soil texture along a large-scale climatic gradient in the Northern Territory, Australia. Journal of Biogeography, 23(6): 747-756.

CABLE-POP tree population dynamics at low and high rainfall extremes



Above ground biomass (tC ha^{-1})





SUMMARY & OUTLOOK

Summary

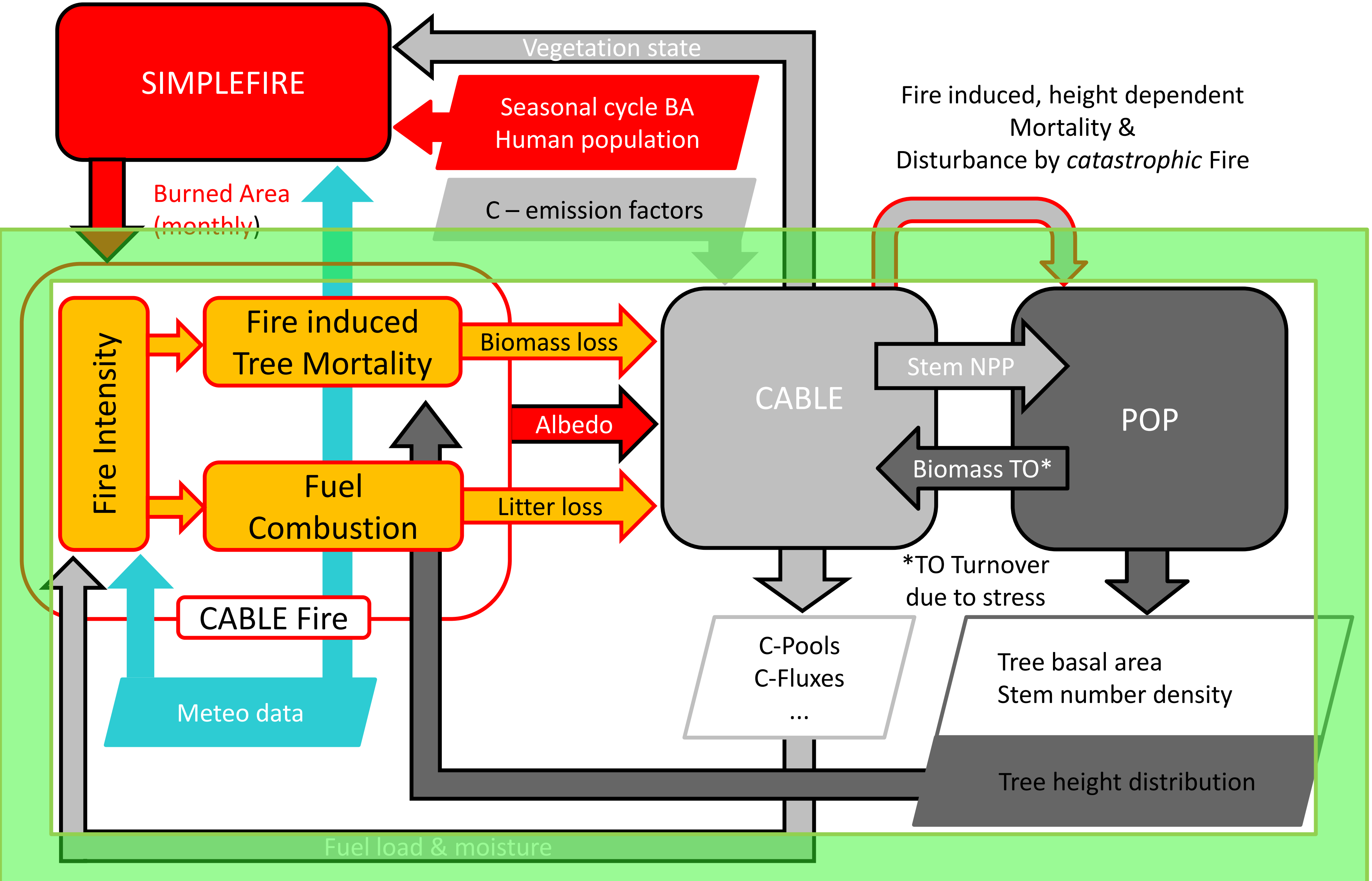
- POP has passed the (NATT-)test
- Most probably improves Carbon budget calculations
- Is sufficiently fast to be applied in large scale studies.

Future Directions using POP coupled to CABLE

- Testing against global forest allometry

- Australian continental applications
  - E.g. estimates of C-sequestration following tree-plantings on cleared land.

- Prognostic fire modelling


SIMPLEFIRE
Vegetation state
Seasonal cycle BA
Human population
C – emission factors
Burned Area
(monthly)
Fire induced, height dependent
Mortality &
Disturbance by *catastrophic* Fire
Fire Intensity
Fire induced
Tree Mortality
Biomass loss
Albedo
Fuel
Combustion
Litter loss
CABLE
Stem NPP
Biomass TO*
POP
*TO Turnover
due to stress
CABLE Fire
Meteo data
C-Pools
C-Fluxes
...
Tree basal area
Stem number density
Tree height distribution
Fuel load & moisture

Thank you

CMAR/ALOA
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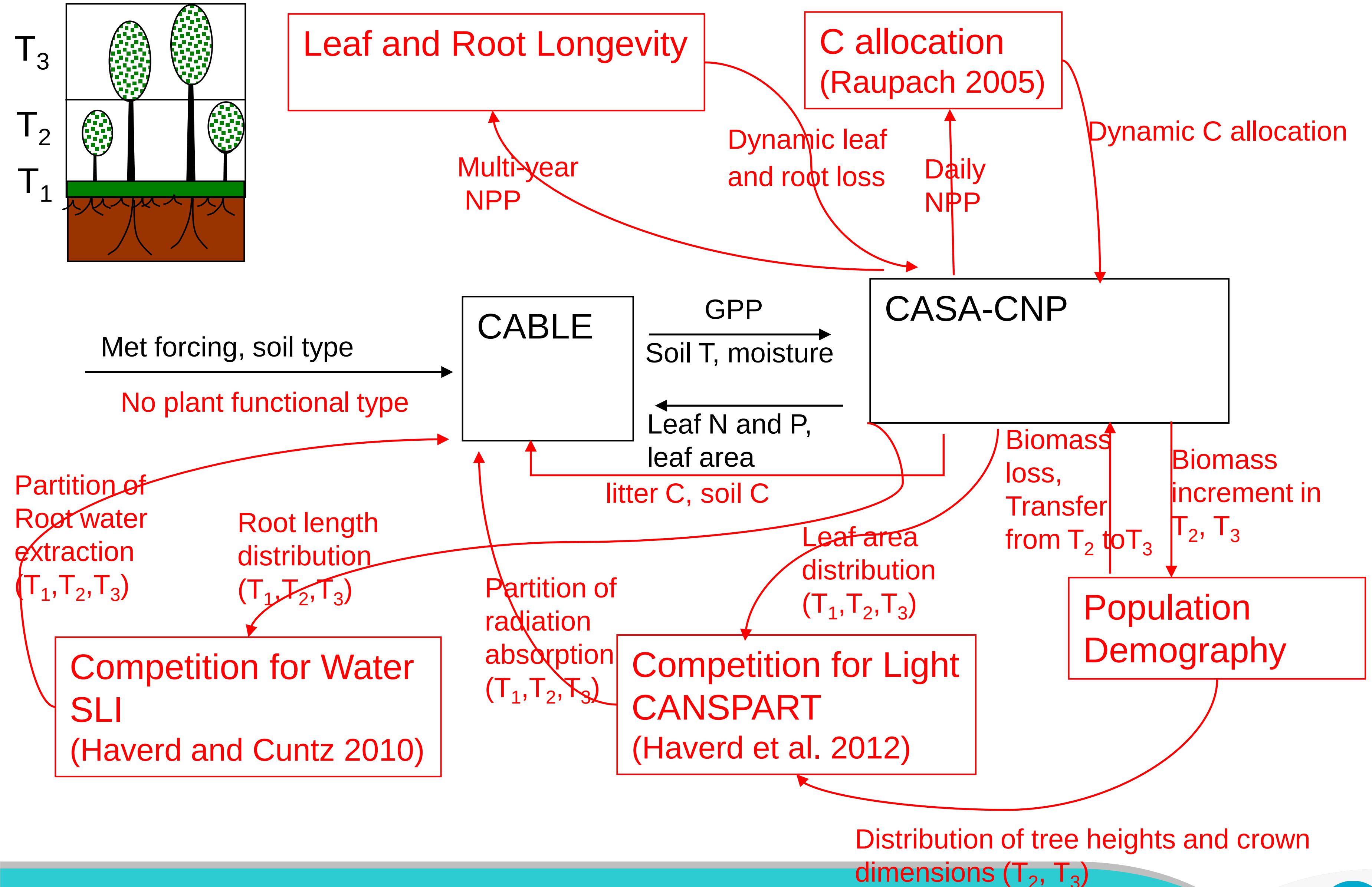
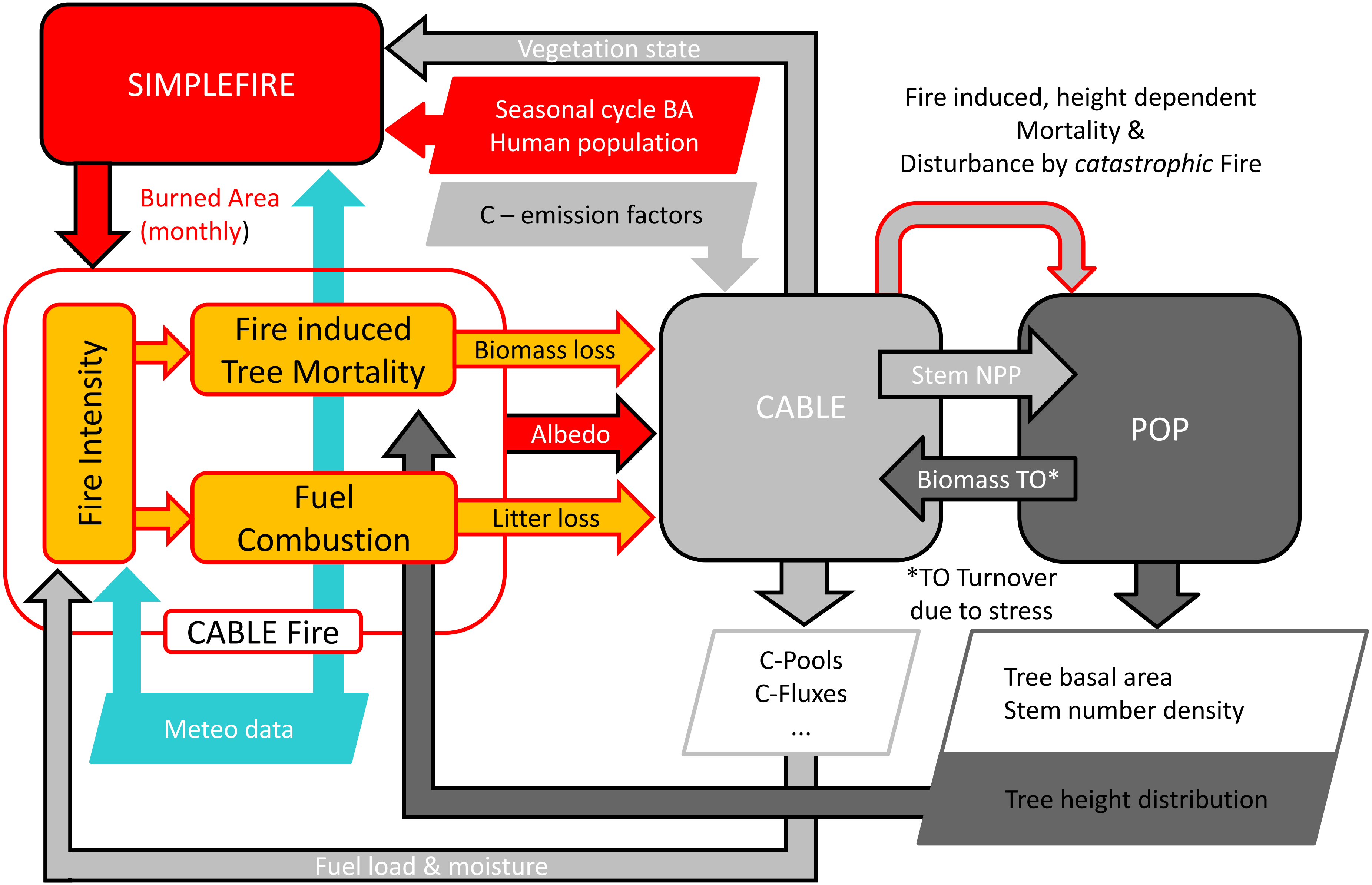
CABLE-POPOP: consistent vegetation structure and function

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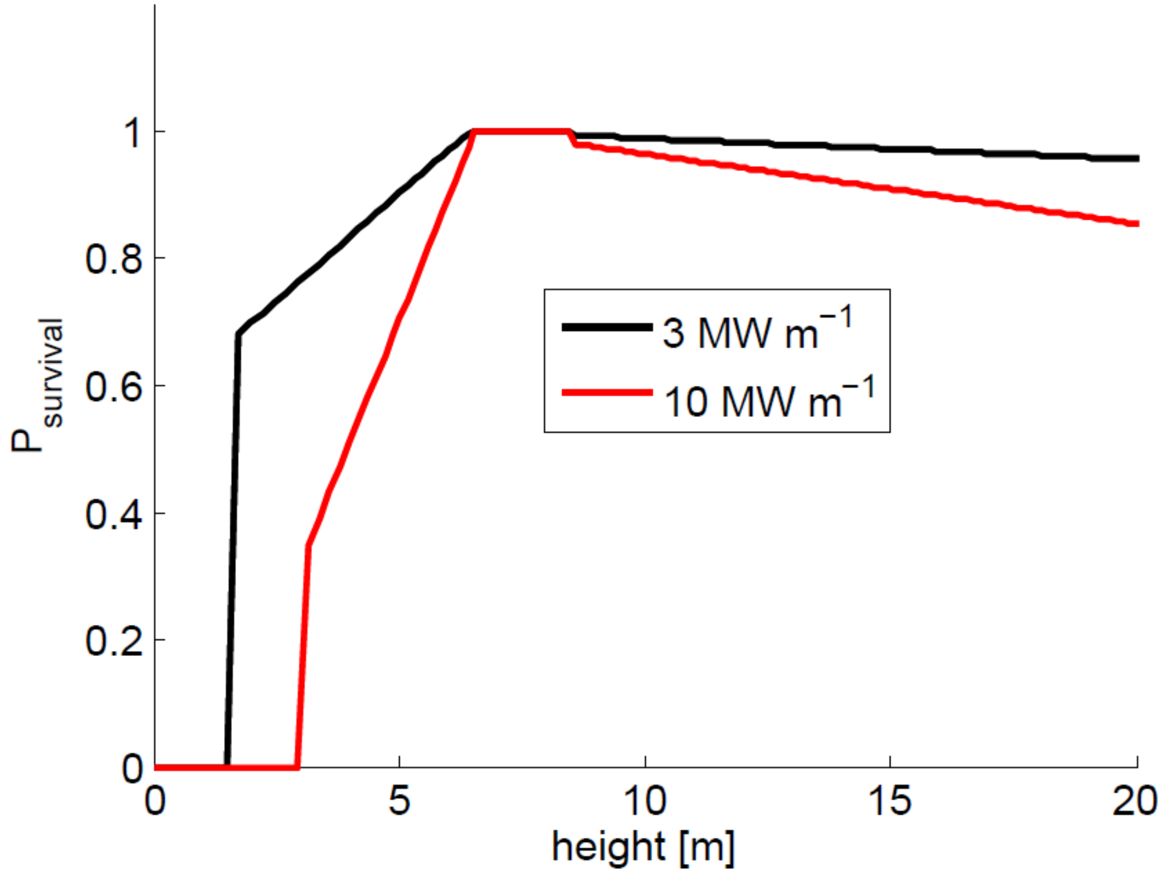
Motivation 2: Impact of Fire on Terrestrial Carbon Balance

Tree survival depends on height



G. Cook, unpublished data

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•Account)
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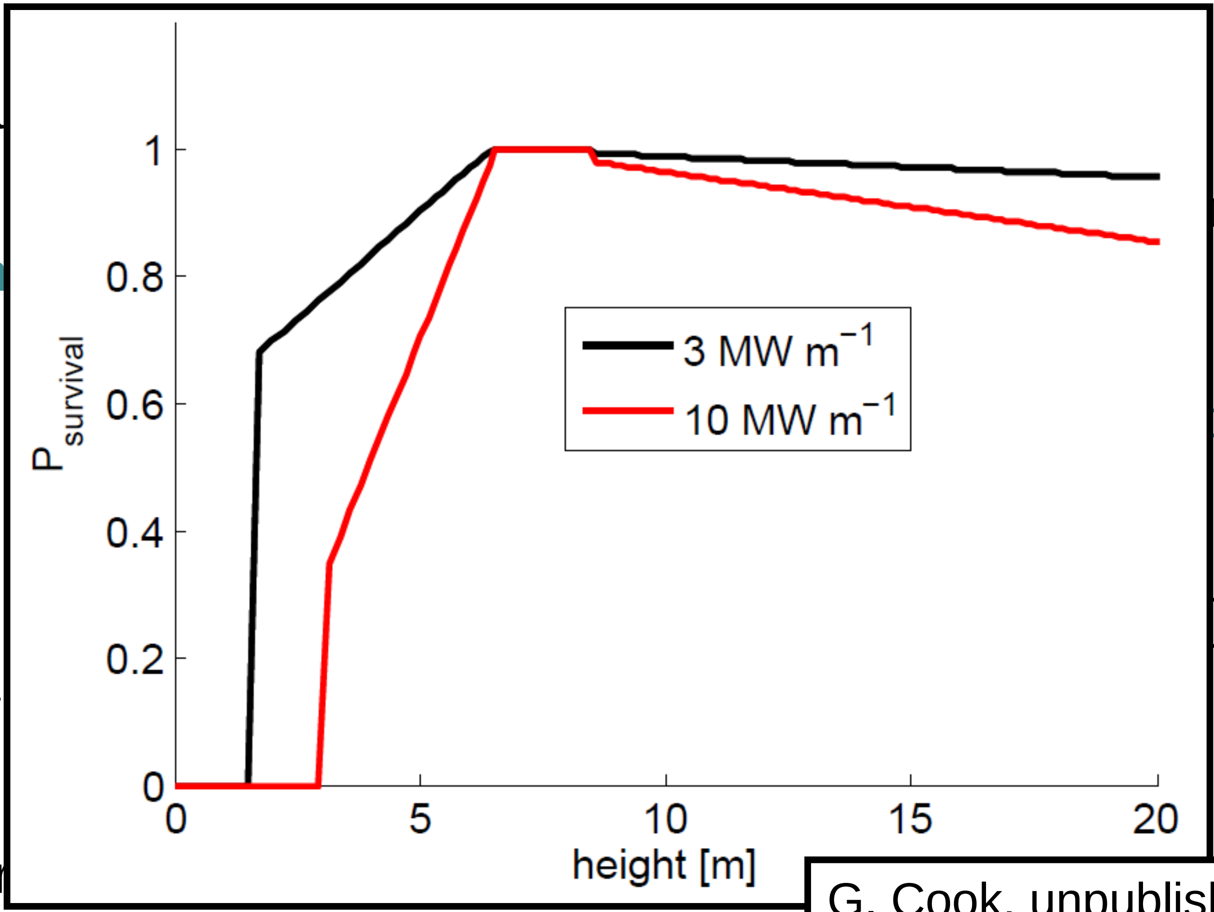

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