JULES-RED simulations of forest demography and resilience in Brazil and RED version 2

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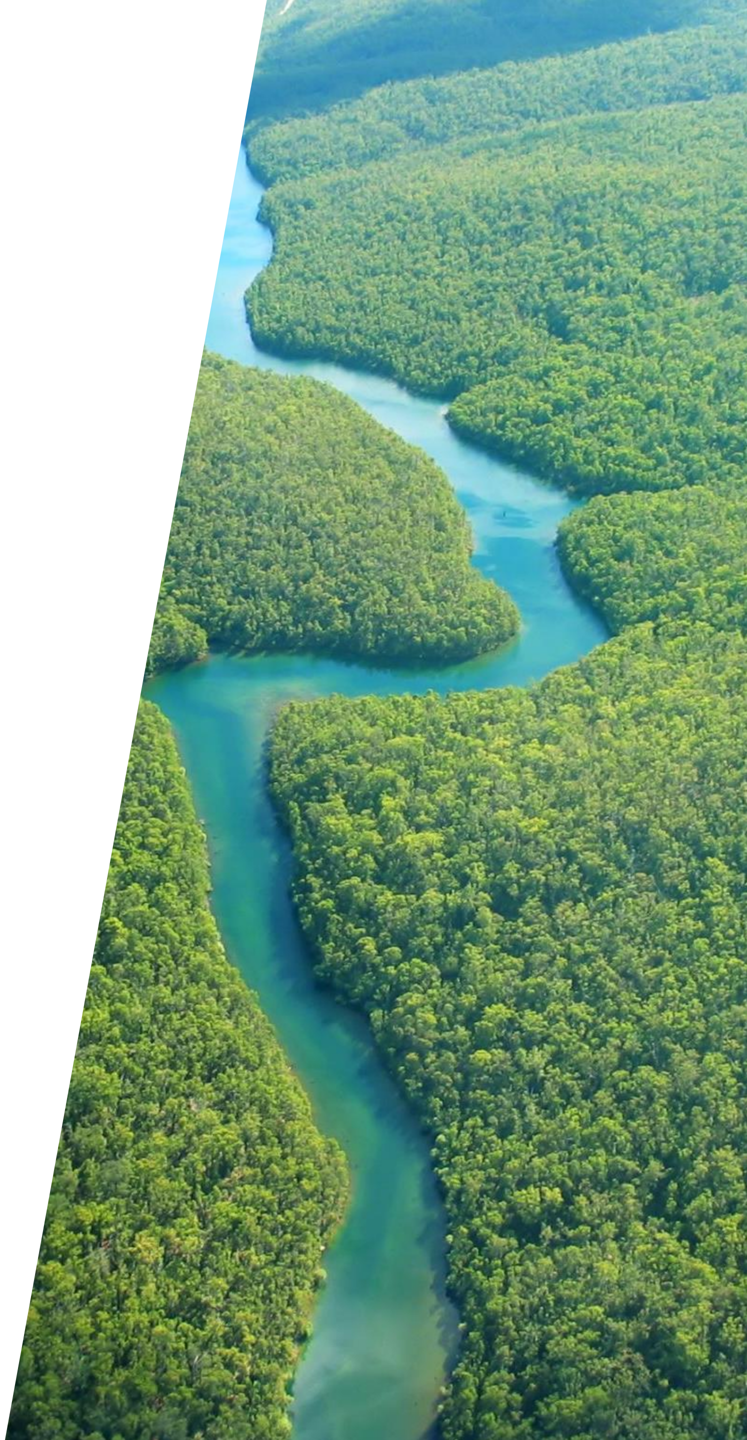


A quick introduction

- The Robust Ecosystem Demography (RED) dynamic vegetation model is being introduced into JULES (target is 6.2!) to introduce plant size as a new dimension:

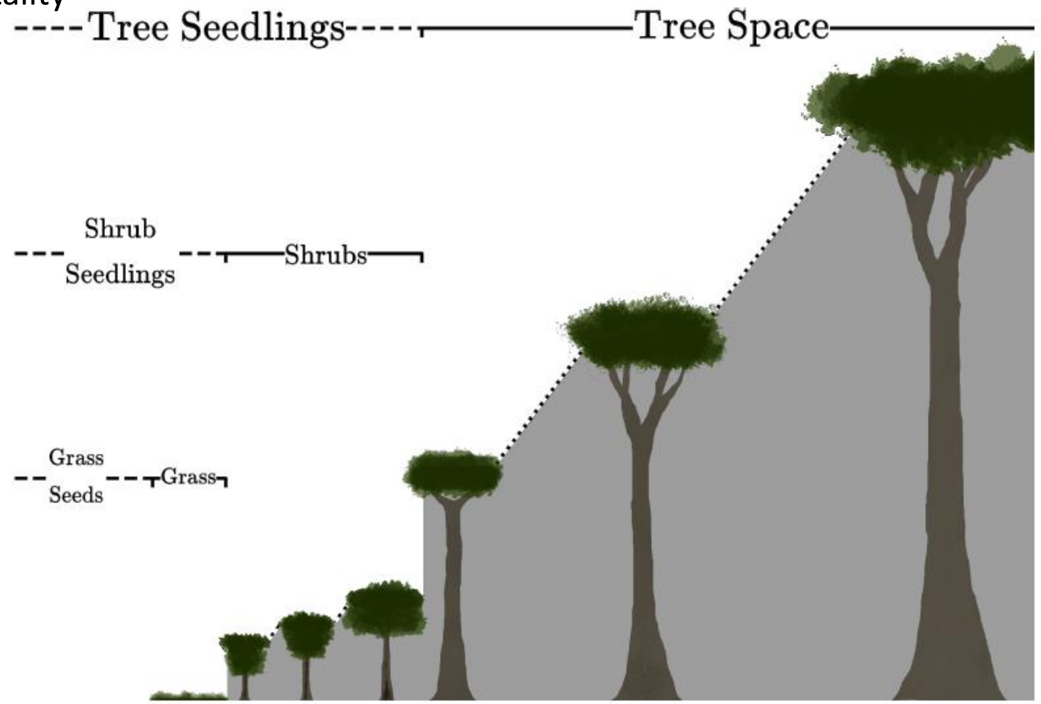
$$\frac{\partial n}{\partial t} + \frac{\partial}{\partial m}[ng] = -\gamma n$$

n = number density, m = plant mass, g = plant growth and γ = plant mortality

In RED version 1, competition for PFT l is conducted only on the seedling level:

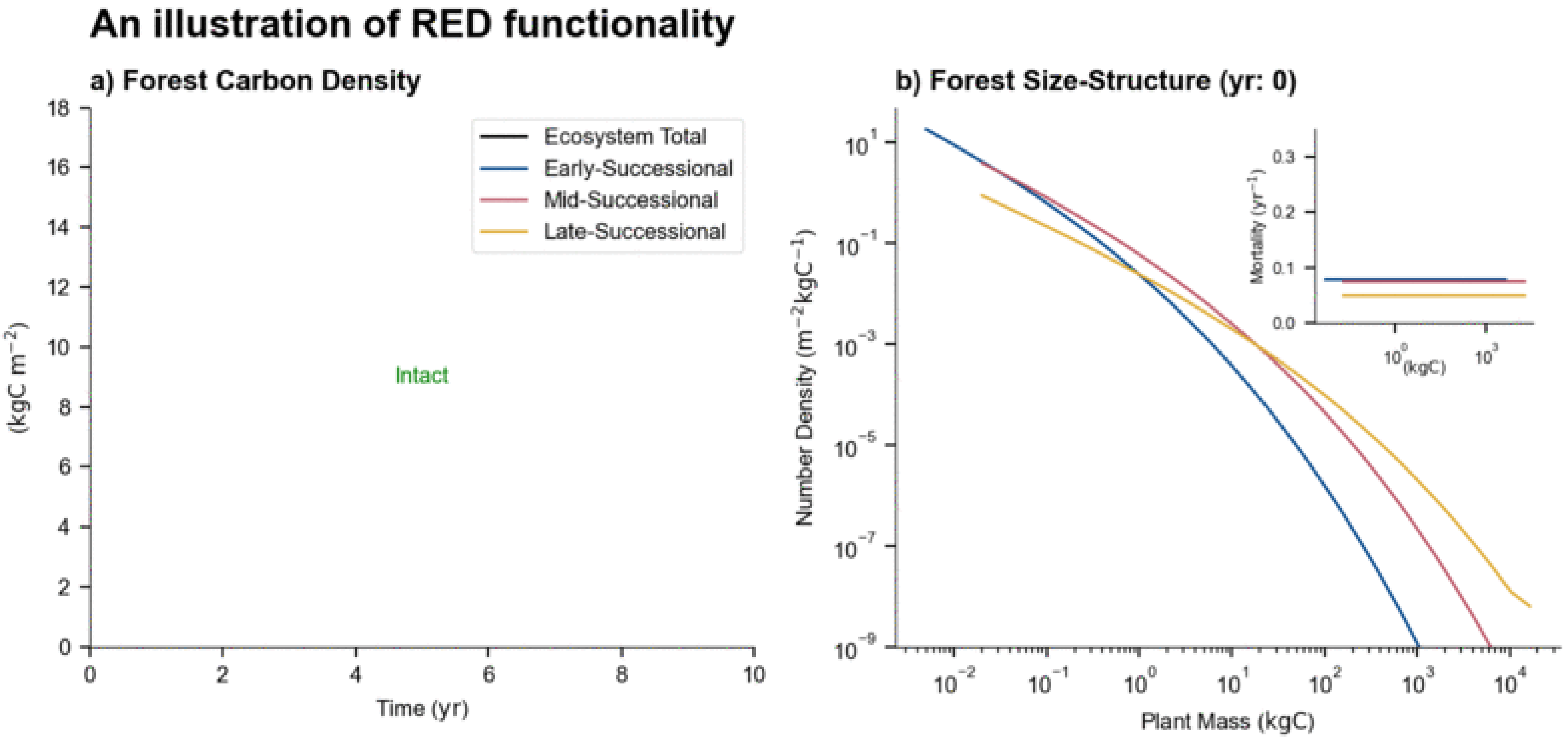
$$n_0 g_0 \Big|_l = \frac{\alpha P}{m_0}\Big|_l s_l, \qquad s_l = 1 - \sum_k c_{l,k}\, \nu_k$$

α = assimilate for reproduction, P = total plant grid-box assimilate, s = shading and c =competition coefficients.



Model Paper: (Argles et al 2020). Other literature: (Moore et al 2019 & 2020)

Size-dependent Dynamics



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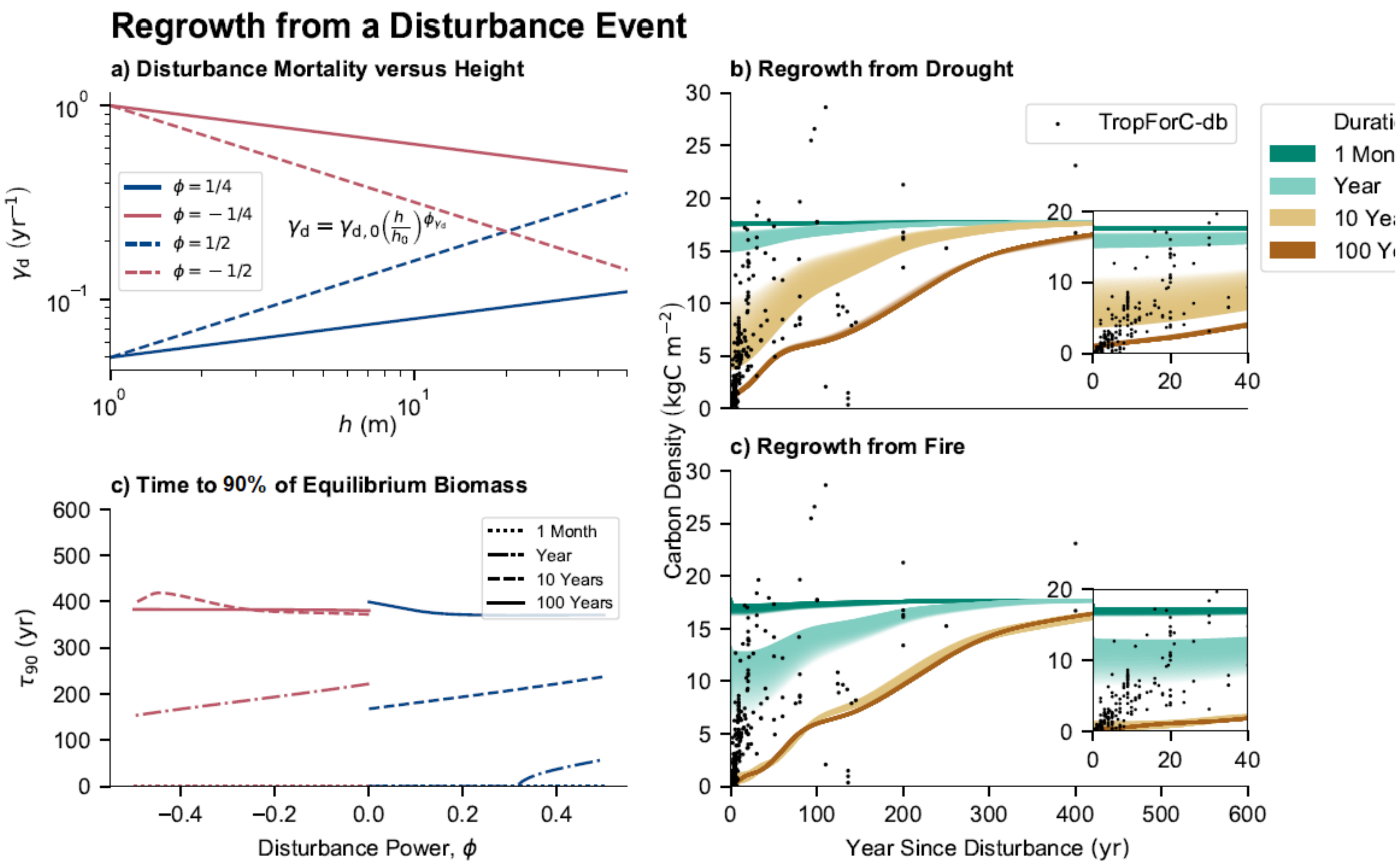


Here we assume a simple power-law for a disturbance:

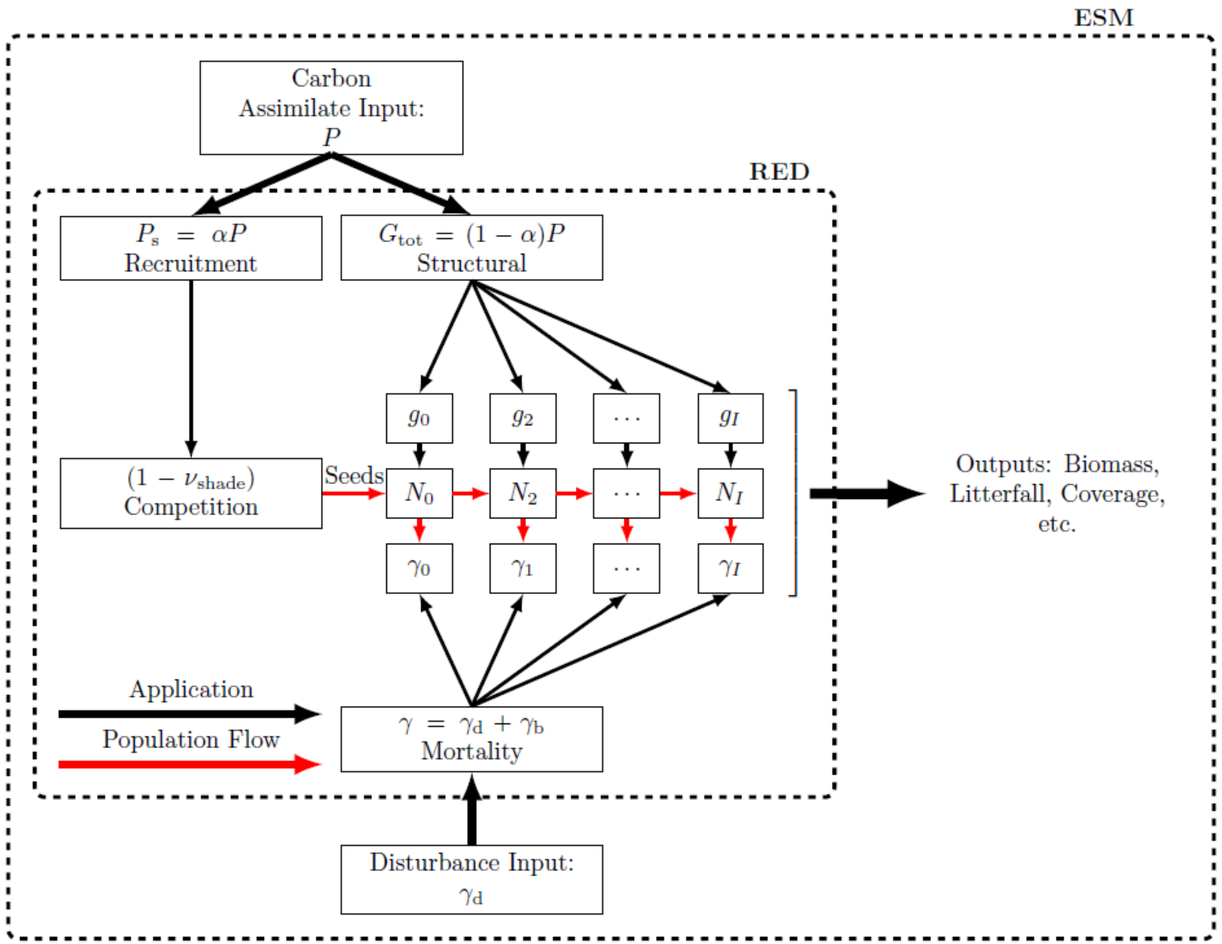
$$\gamma_d = \gamma_{d,0}\left(\frac{h}{h_0}\right)^{\phi_\gamma}$$

A positive power could be relating to a disturbance such as drought.

A negative power could be representative of fire.

TropForC-db contains carbon density and site age from pan-tropical locations (Anderson-Teixeira et al. 2016)

JULES-RED coupling



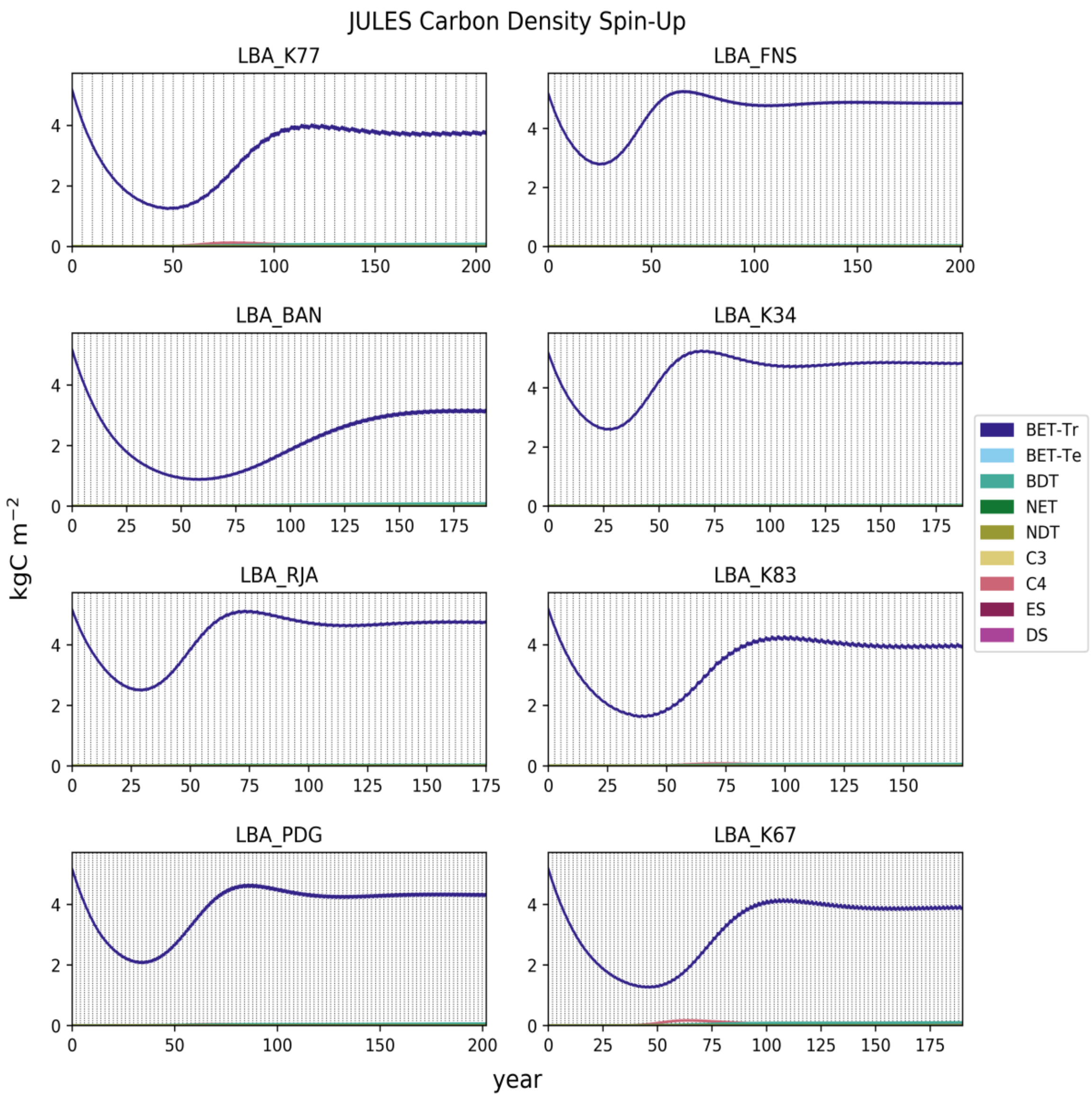
JULES gives RED the Grid-Box total assimilate (NPP – Local Litterfall), and any disturbance mortality

RED updates the plant number density through mass classes and therefore the vegetation carbon, height and other important parameters.

Additional modules (Fire & Drought) can be developed for the RED framework allowing for important size-dependent processes.

JULES-RED spin-ups

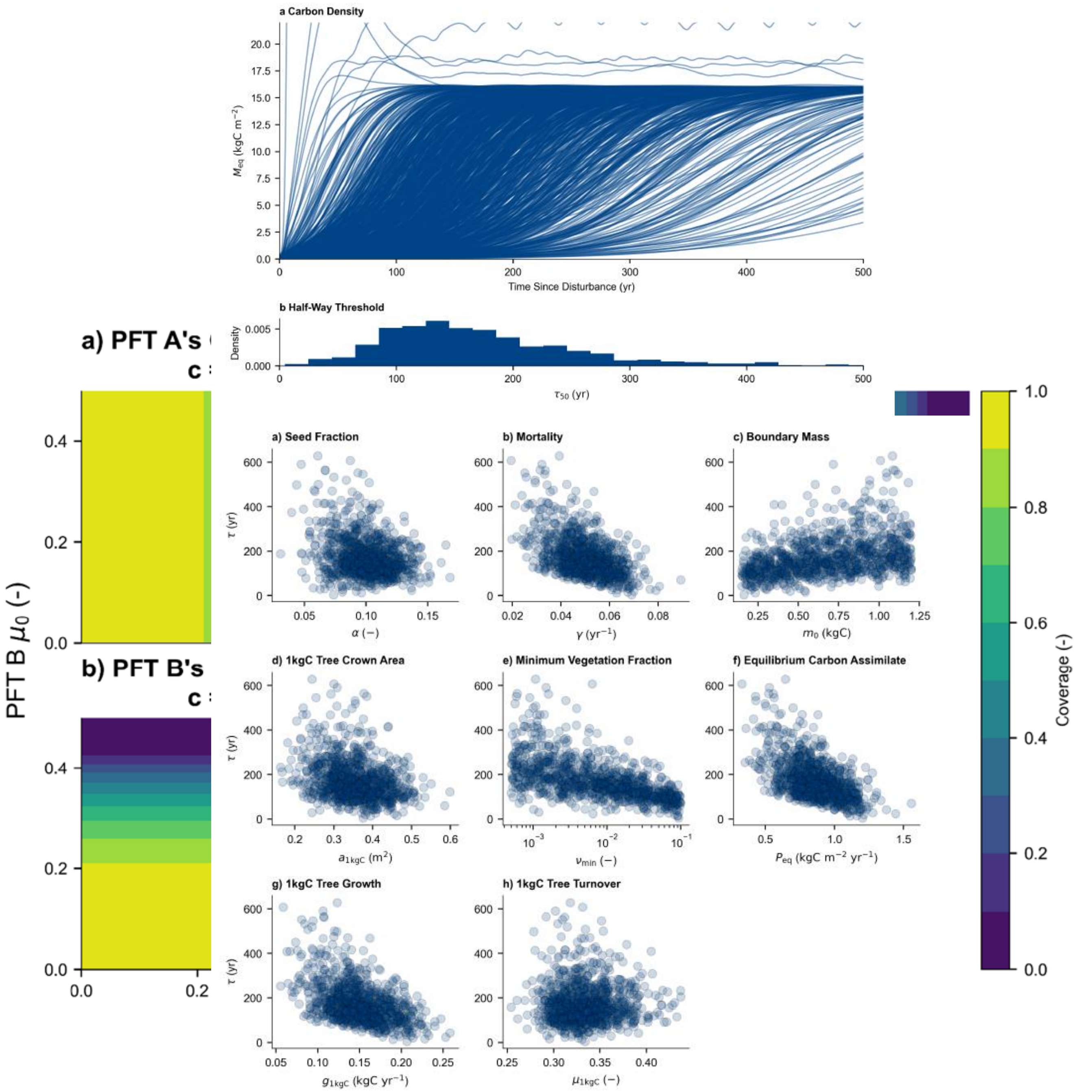
- Current testing of the JULES-RED branch has been done with a copy of u-al752 for the LBA sites.
- Figure on the right we have assumed a mortality rate of $\gamma_b = 0.05\ \mathrm{yr}^{-1}$ for BET-Tr and an arbitrary initial number density distribution.
- We have a target submission for JULES 6.2 into the trunk, there will be a switch between TRIFFID and RED.
- For CSSP-Brazil we would like to do resilience runs (N216 resilience runs) for South America, with other JULES components (INFERNO, SOX and SUGAR).



RED version 1 issues.

- There are currently two principal issues with RED version 1. Firstly, there is a dependence on regrowth time-scales on arbitrary parameters such as the minimum vegetation fraction, $\nu_{\min}$ and the choice of seedling mass m_0.

- Secondly, achieving diversity among PFTs in the same competitive tier (i.e. tree vs tree or shrub vs shrub).



RED version 2 Seed Pool

- RED version 2 removes now includes an explicit seed pool, N_s at a seed mass m_s. Seeds germinate into plants of the same mass $m_s \rightarrow m_0$ and enter the size structure at a rate of $\frac{g_s}{m_s} s$, (s being the shading). The recruitment flux now becomes:

$$\frac{\partial N_s}{\partial t} = \frac{\alpha P}{m_s} - \gamma_s N_s - \frac{g_s}{m_s} N_s \, s$$

Seeds do not contribute to the shading competition. Therefore, this allows us to set a minimum seed density without arbitrarily compromising regrowth time-scales.

RED version 2 Diversity

- We assume a new competitive matrix for Grasses, Shrubs and Tree PFTs with a shared inter-group coefficient c, having $c < 1$ allows for PFT overlap in space.

Old RED

c_{kl}	Trees	Shrubs	Grasses
		l	
Trees	1	0	0
Shrubs	1	1	0
Grasses	1	1	1

RED v2

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	Trees	1	0	0
k	Shrubs	c	1	0
	Grasses	c	c	1

- The new fraction JULES sees is the “top-down” coverage, which is simply $\nu_{\mathrm{TD}} = c\nu$.

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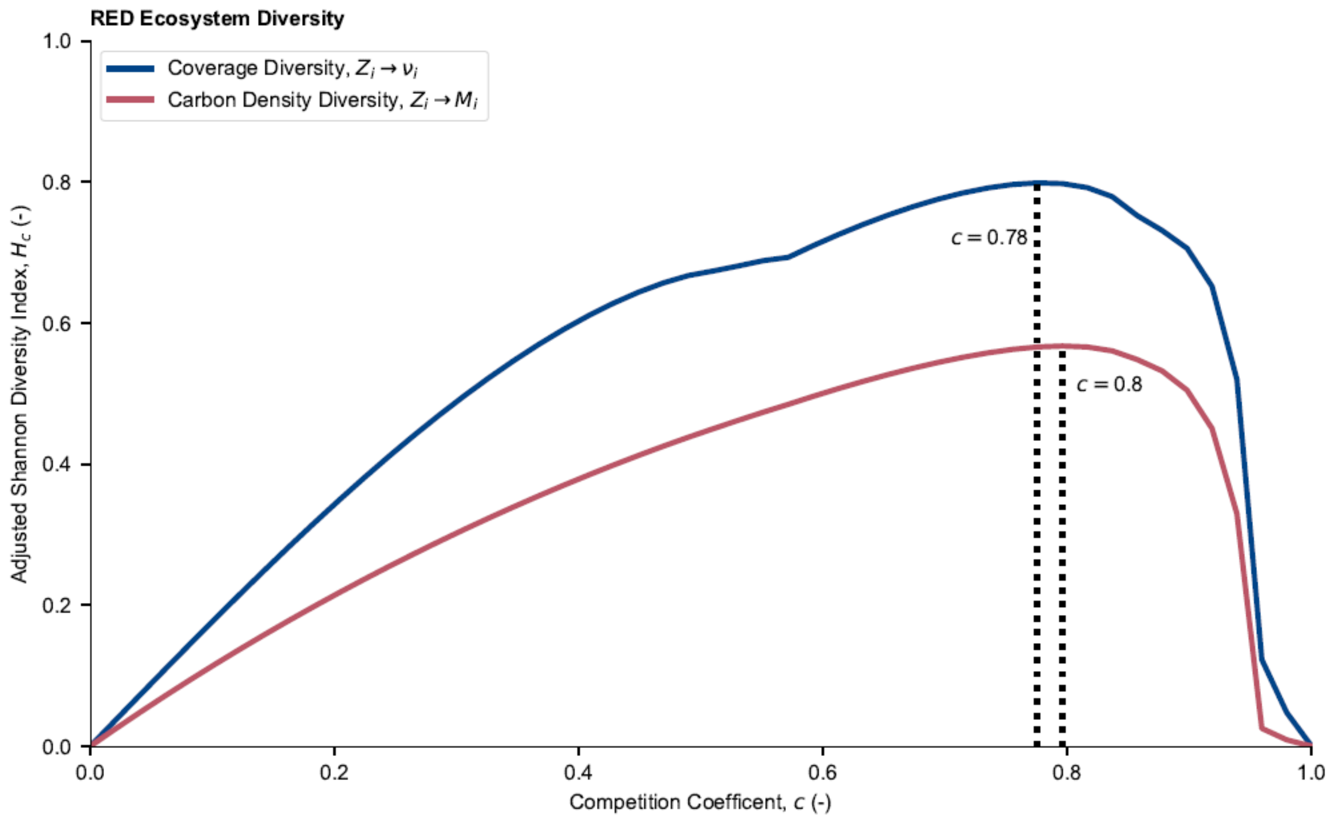
RED version 2 Diversity

To mimic the Maximum Entropy Theory of Ecology (Harte, 2011), we pick a c value to maximise our diversity function:

$$H_c = -c \sum_i \left(\frac{Z_i}{Z_{\mathrm{tot}}}\right) \ln\left(\frac{Z_i}{Z_{\mathrm{tot}}}\right),$$

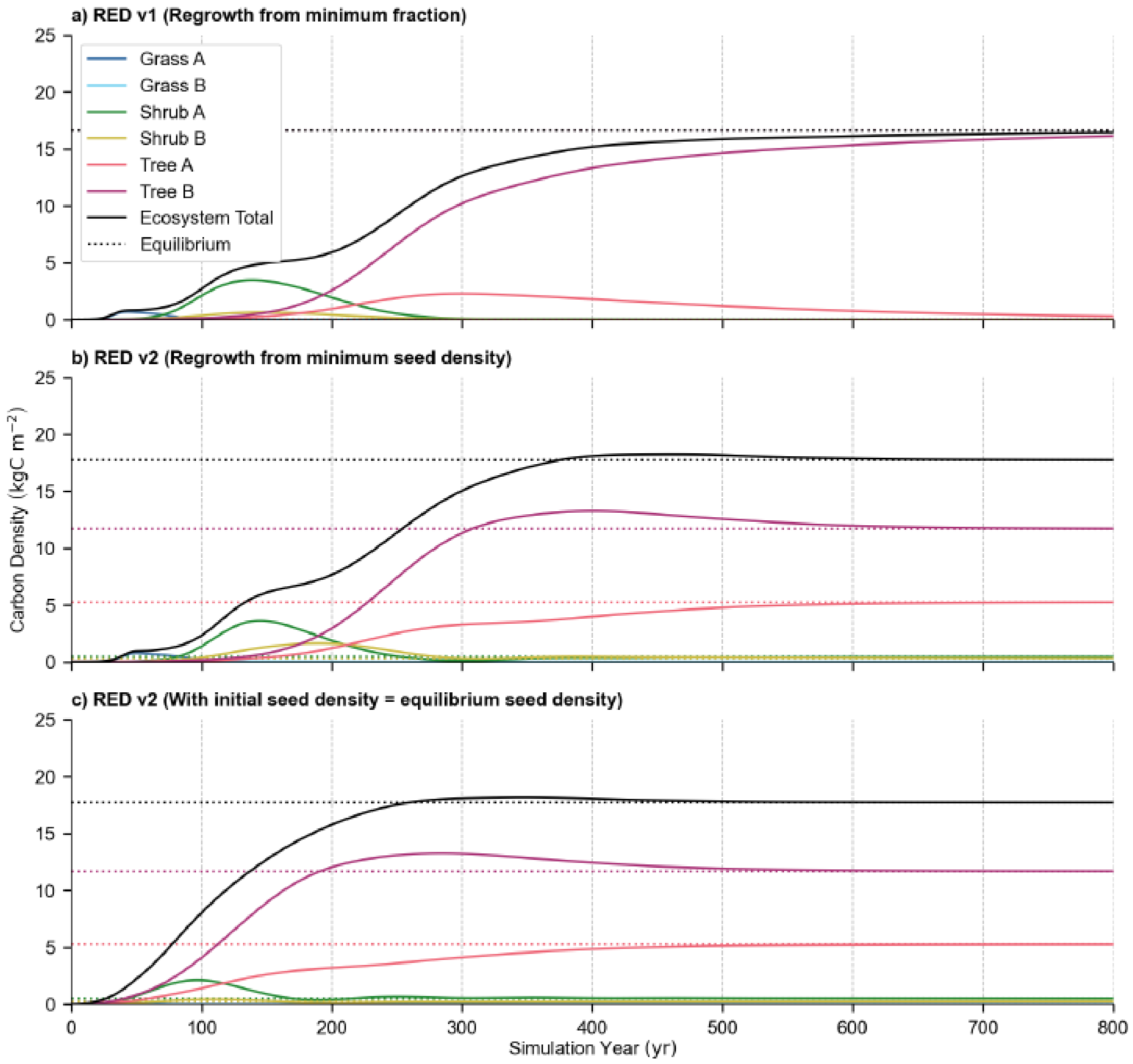
$$\mathrm{Z_{tot}} = \sum_i Z_i$$

Z_i is an ecosystem PFT property such as coverage or carbon density.



RED version 1 versus version 2.

Here we have selected 6 Arbitrary PFTs meant to represent a distribution of mortality and growth rates.



Any Questions?