Vegetation Demography and Dynamics in a Next-Generation Biogeochemical Scheme

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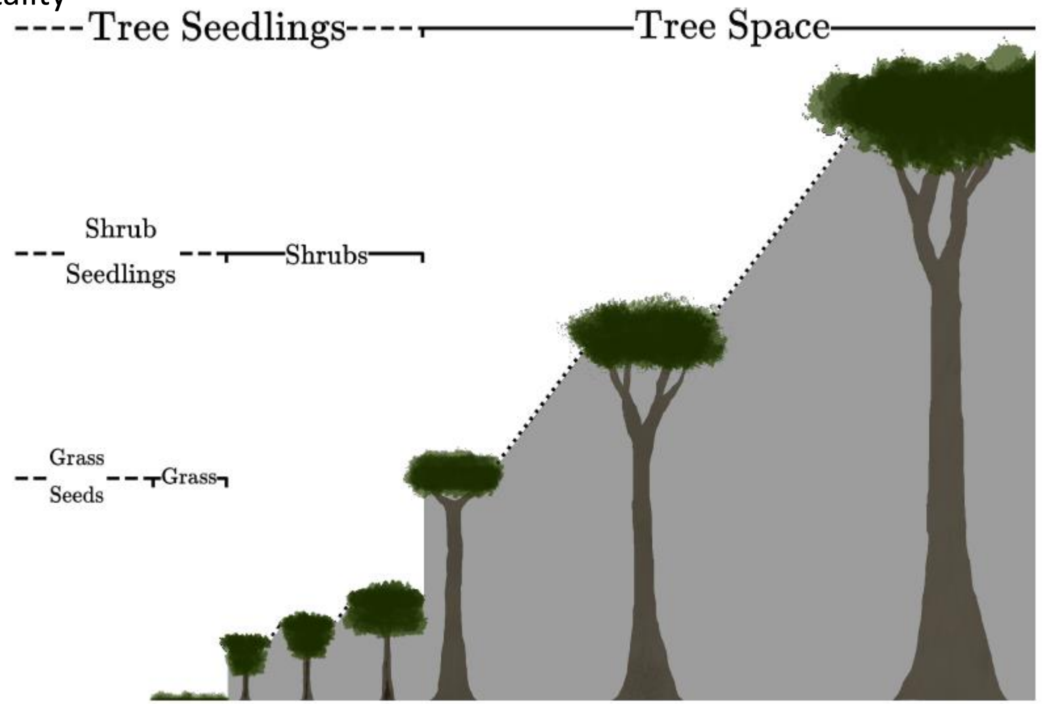
A quick introduction to RED

- The Robust Ecosystem Demography (RED) dynamic vegetation model simulates one demographic dimension – number density across plant mass using the Von Foerster equation:

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

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



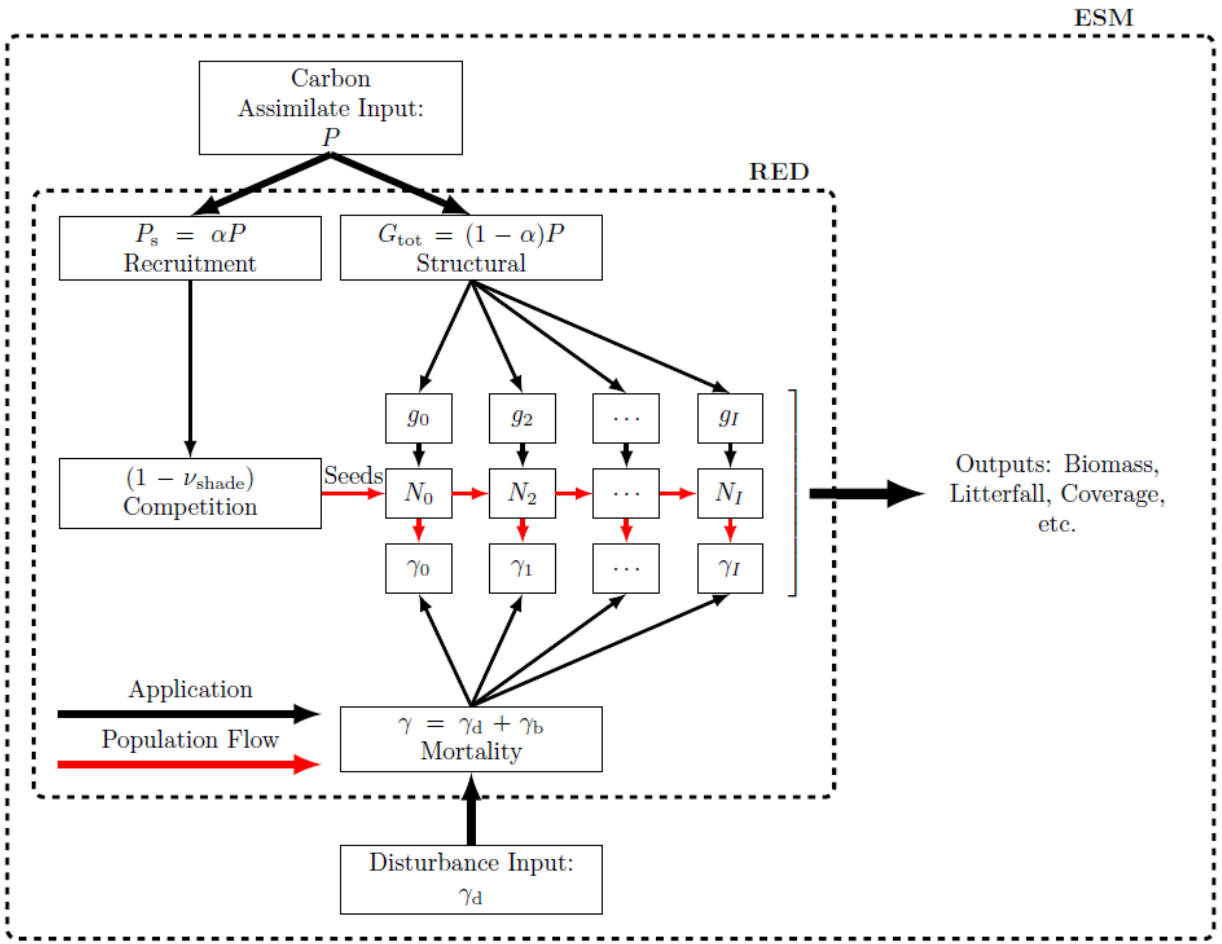
In RED version 1, competition for PFT l is conducted only on the seedling level:

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

$\alpha =$ 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)

JULES-RED coupling



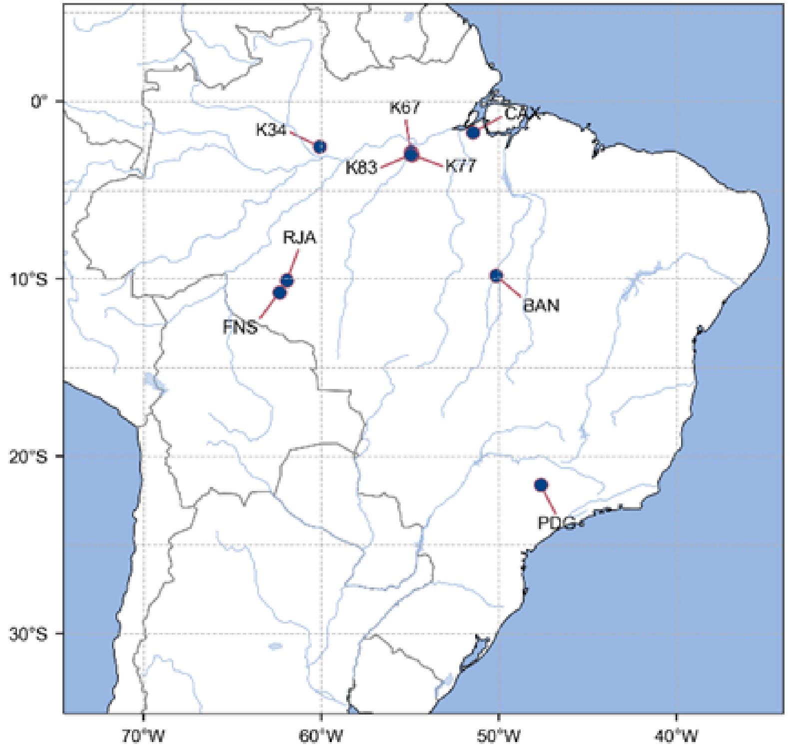
JULES gives RED the Grid-Box total assimilate (NPP – Local Litterfall), and any additional disturbance mortality. Assimilate is then disaggregated onto size classes by using metabolic scaling theory of growth (rearranging for g_0):

$$G_{tot} = \sum_i N_i g_i = g_0 \sum_i N_i \left(\frac{m_i}{m_0}\right)^{\frac{3}{4}}$$

JULES-RED in Brazil

- One of the firsts tests we did with the model!
- For u-cg855 we turned on dynamic vegetation with RED with a prolonged model spin-up (max: 400 year) to evaluate the regrowth. Initial number density was related to the minimum vegetation fraction as: $\frac{\nu_{\min}}{a_0} = N_0$
- Our version of JULES allowed for PFT number density to be outputted as a diagnostic (r21746_test_vn6.2_add_pND_diagnostic in the Net Office code repository)

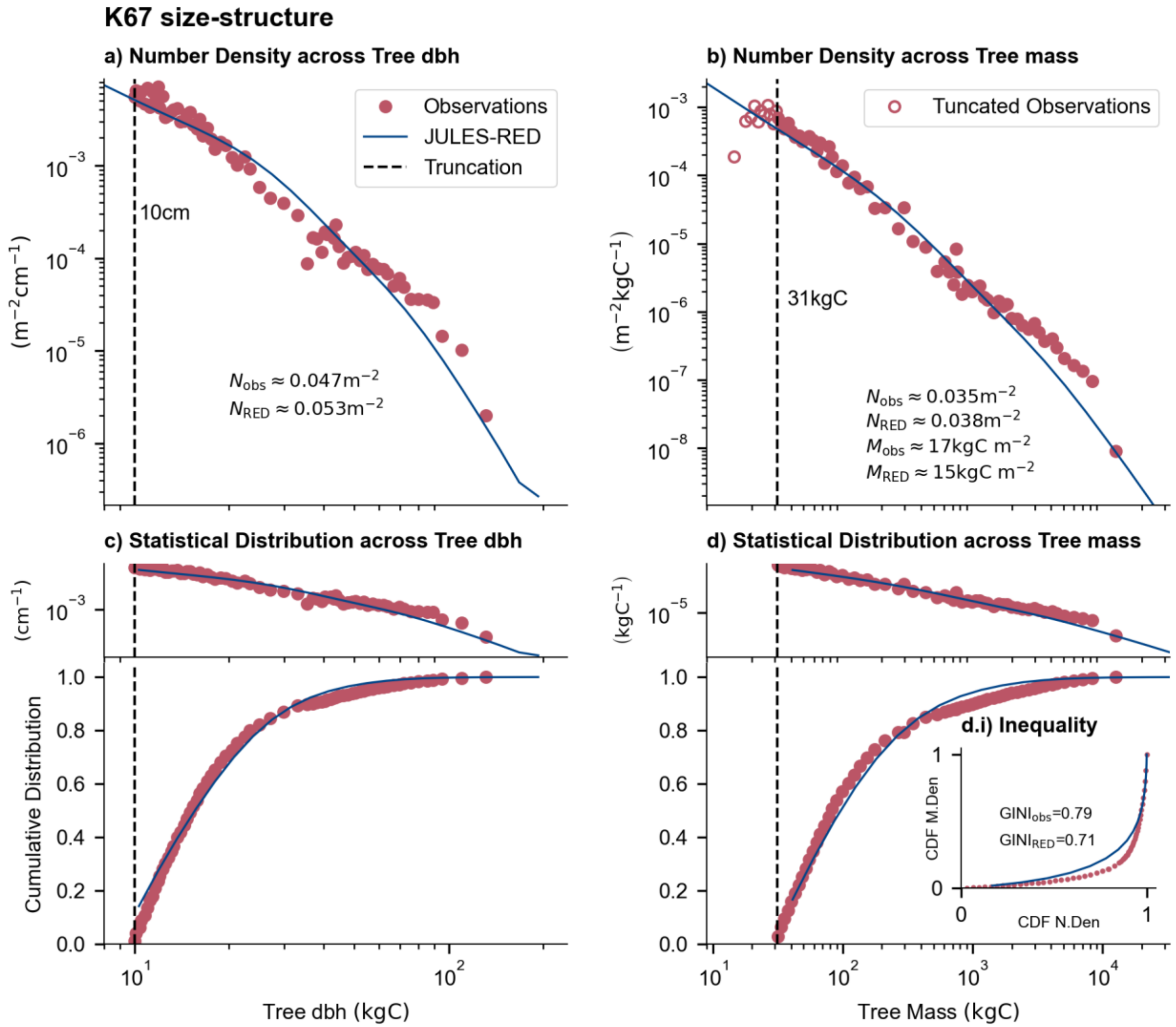
LBA Site Locations



Shows the geographic locations of the LBA sites across Brazil, including the shorthand codes for each site (see Saleska, et al., 2013).

JULES-RED size structure dynamics

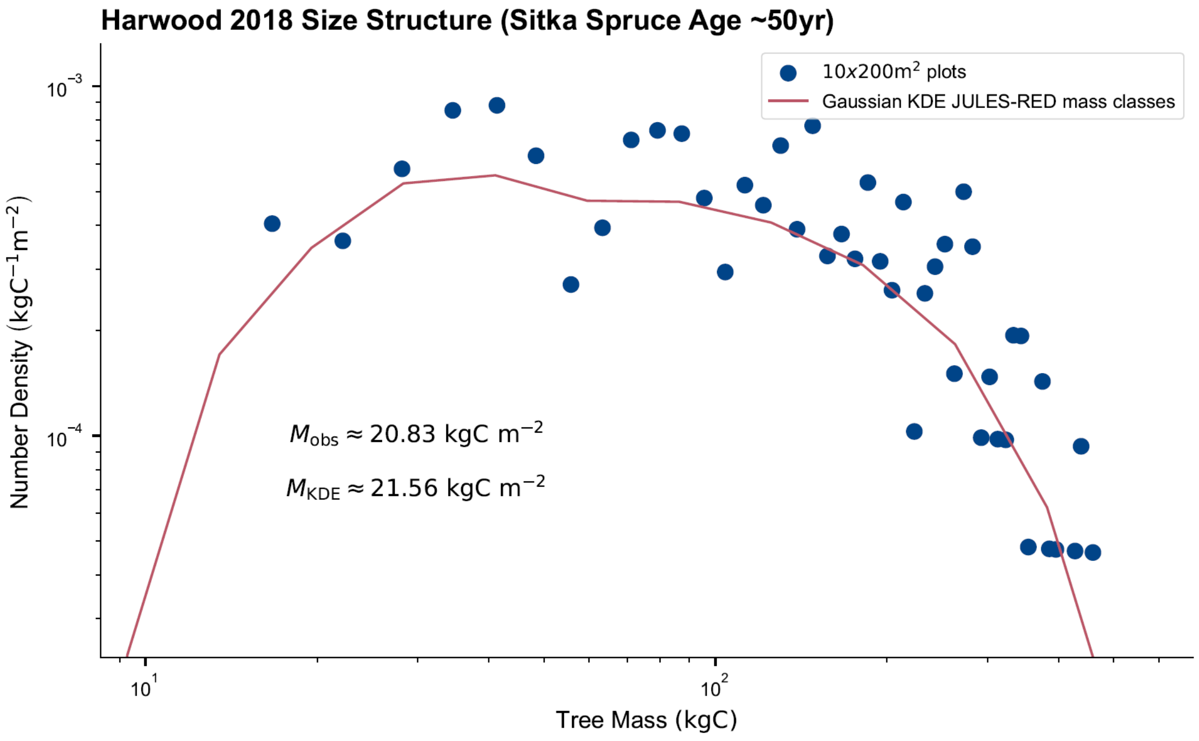
- The right plot shows how the JULES-RED BET-Tr number density spin-up performs against the observations (Chambers, et al. 2013)
- The left column is RED transposed into dbh space, while the right is in standard mass classes. The upper row is in absolute number density, while the bottom is the PDF and CDF.
- We can also compare the GINI coefficient of the biomass distribution.



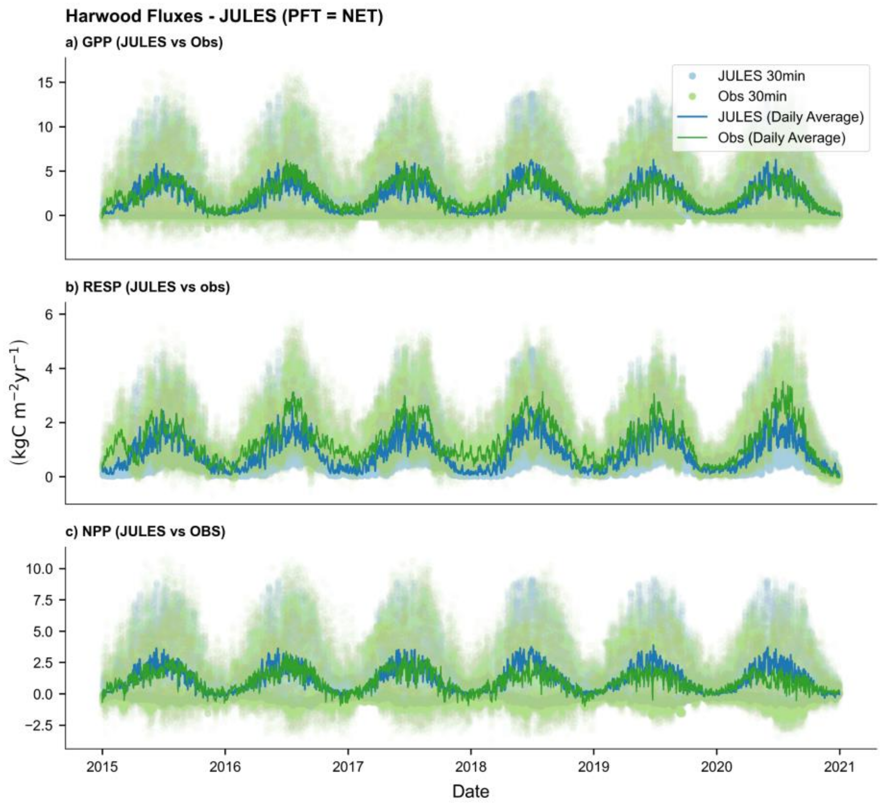
JULES-RED at a Sitka Spruce plantation

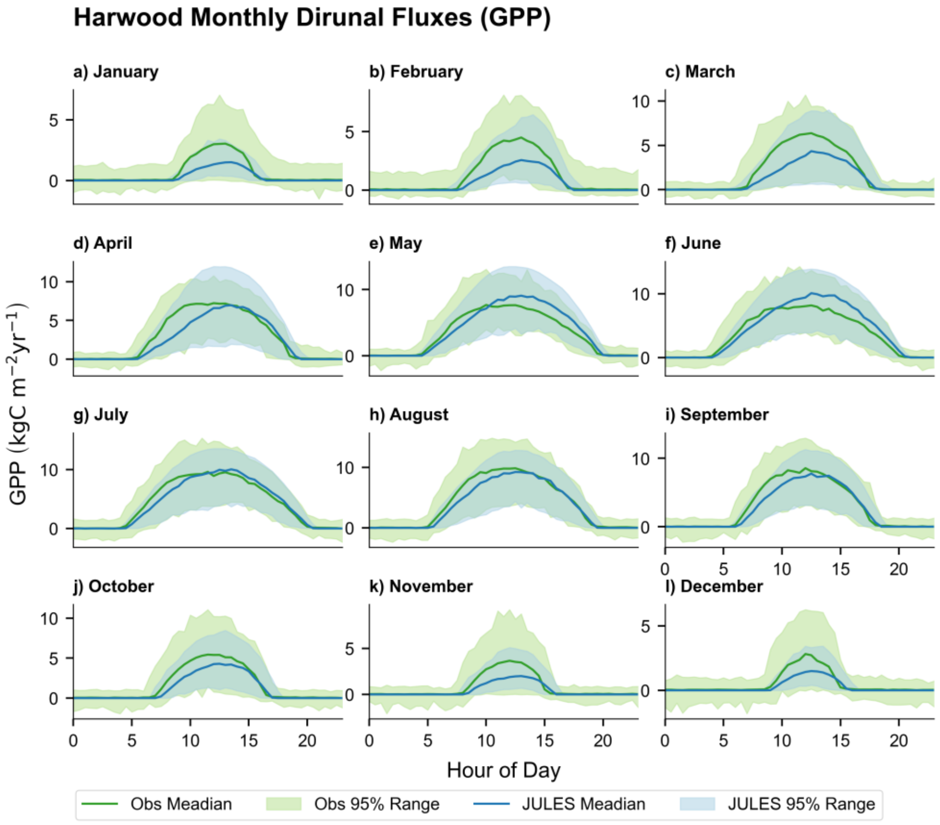
Managed forests provide a useful method of understanding vegetation dynamics:

- Densely packed -> limits of metabolic scaling theory with respect to light competition.
- All initial saplings are roughly the same size in neat packed rows.
- A lot of empirical understanding (Yield classes) and data out there.
- Afforestation a useful method for achieving climate adaptation and mitigation.



JULES-RED Evaluation of Fluxes at Harwood

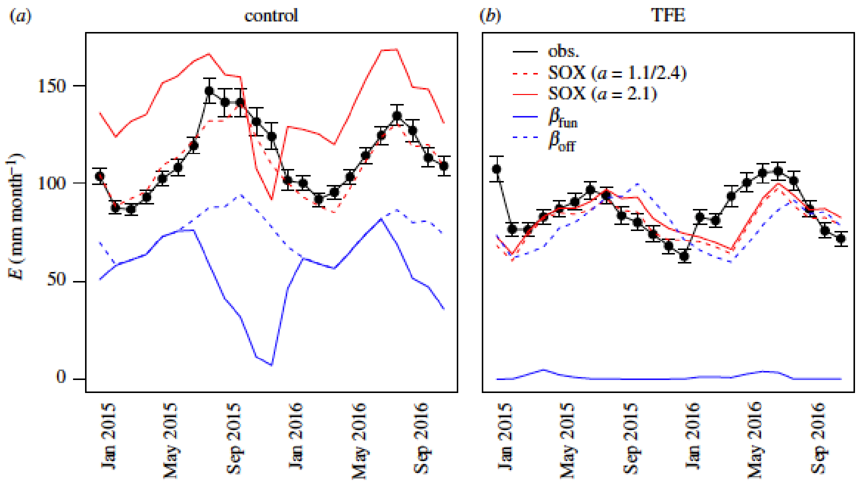




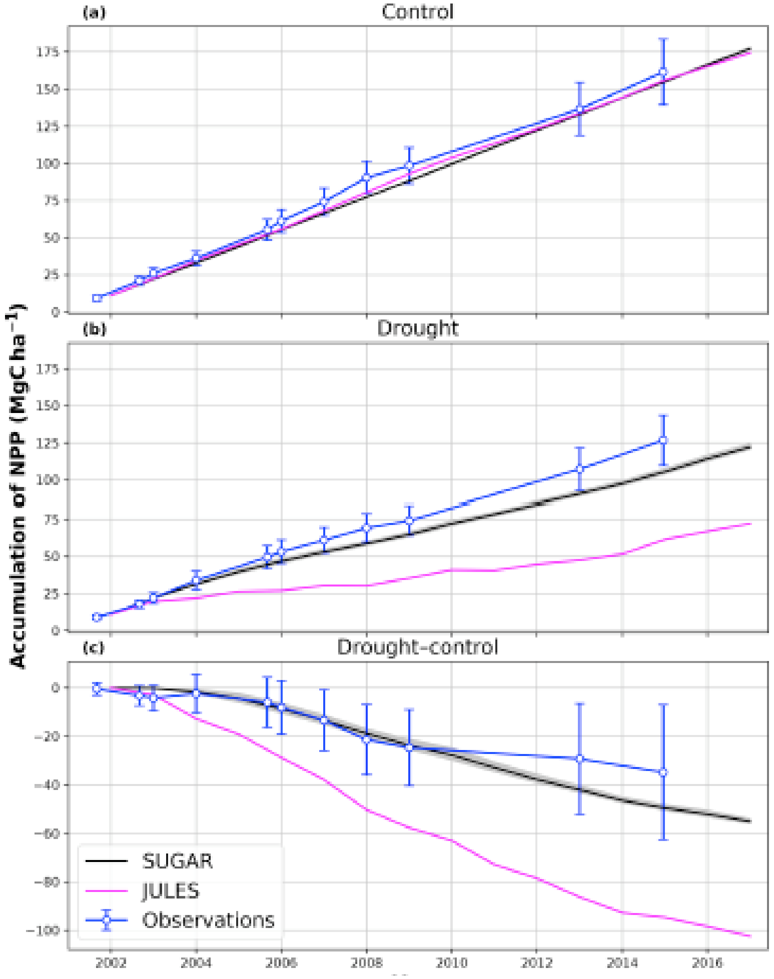
Fixing the size structure/veg dynamics in JULES-RED allows us to see how the model differs due to phenology/photosynthesis/allometric reasons.

Introducing JULES-VEGY

- Currently RED sits (**alone**) in a new JULES vegetation call routine, independent of TRIFFID, “veg3”.
- In the future we will want to include:
    1. SOX (xylem/drought mortality)



Sapflow Measurements from Caxiuana (Eller et al. 2018)



Comparison of Accumulated NPP SUGAR to JULES in Caxiuana (Jones et al. 2020)

```
!CALL Allocation/Nitrogen/NSC

!Work out growth

! Use the accumulated npp from sf_expl. Copy to new variable for driving
! veg dynamics
```

SUGAR

```
_per_day * veg3_ctrl%triffid_period)
: this can be used to pass a negative flux back to
` testing
per_day)! * veg3_ctrl%triffid_period)
. disturbance term on mass classes
'e
is the disturbance term to maintain a
:ed multiple calls but then the order matters.
RED
ndex_pts,veg_index,veg3_ctrl,land_pts,     &
state,
t
)
```

Summary

- JULES-RED simulates the size-structure of a forest assuming a constant mortality rate and the metabolic scaling of growth and using a Von Foerster equation.
- RED takes disturbance mortality (still needs development!) and assimilate (NPP – Local litter) as inputs.
- Integrates parameters across mass space to provide the average canopy height, leaf area index, and carbon density at the gridbox level. After which model partitions carbon into leaf, root and wood pools.

Job Opportunity!

- Postdoc with the Net Zero + project for 18 months at the University of Exeter.
- Develop JULES-RED to find the best place to afforest in the UK for Net Zero -> and help develop the mode for eventual integration into UKESM!

https://jobs.exeter.ac.uk/hrpr_webrecruitment/wrd/run/ETREC107GF.open?VACANCY_ID=368868bA5q&WVID=3817591jNg&LANG=USA

NetZero
PLUS

Appendix: JULES-RED - Canopy Height, and LAI

- The PFT fraction is estimated by the sum product of number density and crown area (a):

$$\nu = \sum_i N_i a_i \,, \qquad a_i = a_0 \left(\frac{m_i}{m_0}\right)^{\frac{1}{2}}$$

- Currently, after simulating the size structure RED updates the canopy height (H) and the “balanced” Leaf Area Index (LAI, L_b) by estimating the mean height and lai across the PFT coverage:

$$L_b = \frac{1}{\nu} \sum_i N_i a_i h_i \,, \qquad l_{b,i} = l_{b,0} \left(\frac{m_i}{m_0}\right)^{\frac{1}{4}}$$

$$H = \frac{1}{\nu} \sum_i N_i a_i h_i, \qquad h_i = h_0 \left(\frac{m_i}{m_0}\right)^{\frac{1}{4}}$$

Appendix: JULES-RED – Carbon Pool Partitioning

The gridbox carbon density (M) is given by the sum product of mass and number density. Dividing by the PFT fraction gives us the carbon density for the PFT area (C).

$$M = \sum_i N_i m_i \,, \qquad C = \frac{M}{\nu}$$

Partitions carbon pools into wood ($\mathcal{W}$), leaf ($\mathcal{L}$), and root ($\mathcal{R}$) carbon pools by using original JULES equations for leaf area index (L) and Leaf Mass Area (LMA):

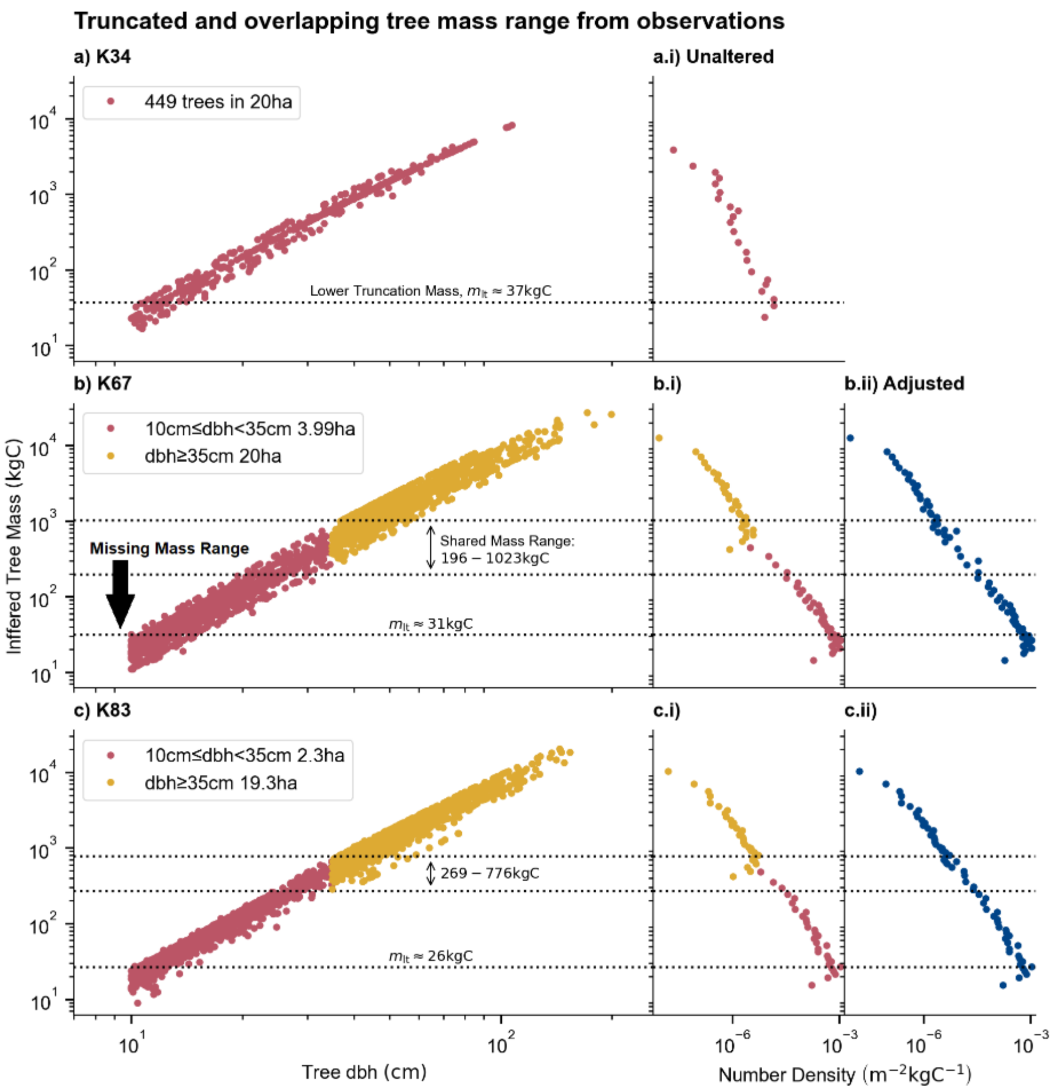
$$\mathcal{L} = \mathrm{LMA} \cdot L$$
$$\mathcal{R} = \mathrm{LMA} \cdot L_{\mathrm{b}}$$

We implicitly estimate the wood pool by taking the difference:

$$\mathcal{W} = C - \mathcal{L} - \mathcal{R}$$

Appendix: Observations at LBA sites

- In addition to previous experience on the suite. Some of these sites (Through LBA-ECO) have small scale species, wood density (also found through the DRYAD database) and dbh data.
- Observations give us the number density if we divide through by the area of the study. Sites with multiple surveys need reweighting to equate small area (~2ha) to large area (~20ha) by resampling.



Sources: Wofsy, et al., 2008 (K34), Menton, et al., 2011 (K83), Chambers, et al., 2013 (K67), and Zanne, A. E., 2009 (DRYAD).

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RED model + DET papers + JULES:

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