The Role of Non-Structural Carbohydrates in Simulations of Ecosystem Carbon Fluxes

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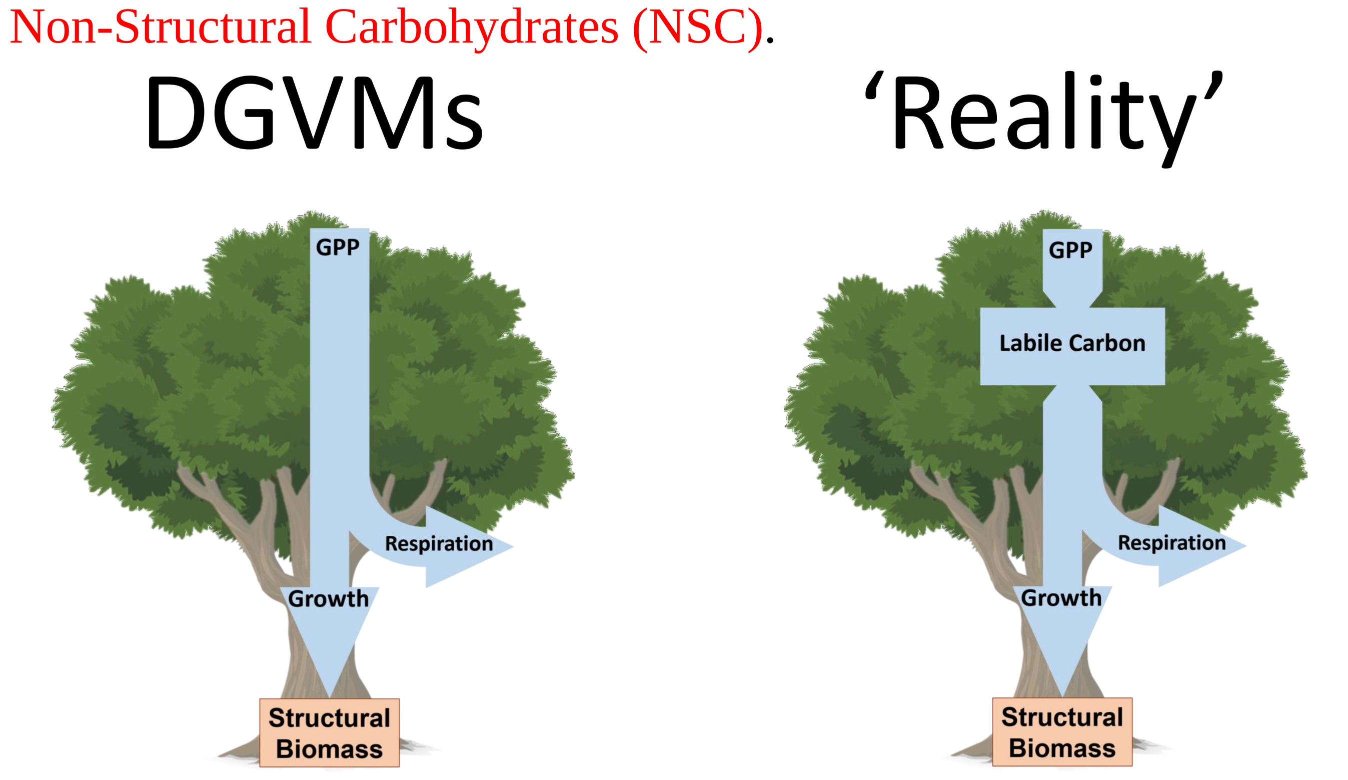
1. Introduction

- Most Dynamic Global Vegetation Models (DGVM) simulate growth (G) and respiration (R_p) as equal to instantaneous photosynthesis (GPP).
- In reality, plants regularly experience periods when the supply of carbon from photosynthesis does not equal the demands of respiration and growth.
- This asynchrony is facilitated by pools of labile carbon known collectively as Non-Structural Carbohydrates (NSC).



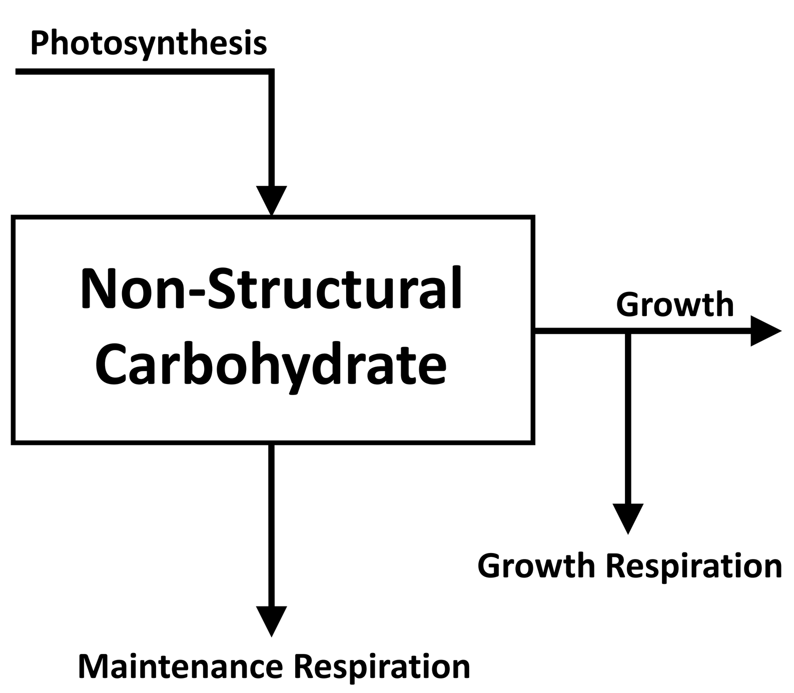
$$R_p + G = GPP \qquad R_p + G \neq GPP$$

Demand = Supply **Demand ≠ Supply**

Figure 1: Carbon allocation in most DGVMs vs. a more realistic system. Most DGVMs use all assimilated carbon in a single timestep so rate of utilisation (demand) is always equal to rate of photosynthesis (supply). In reality, plants store labile carbon that allows instantaneous carbon utilisation to diverge from instantaneous carbon assimilation over periods of up to hours or days.

2. Model Description - SUGAR

Substrate Utilisation by Growth and Autotrophic Respiration



The SUGAR model simulates a single pool of NSC at a grid box scale.

Assimilated carbon from photosynthesis (GPP) is collected by the NSC pool.

Respiration and growth depend on temperature and carbohydrate availability.

Inputs: GPP, Temperature.

3. Simulating Ecosystem Fluxes

Methods

- We drive the SUGAR model over the Amazon with satellite constrained GPP data (*Parazoo et al. 2014*) and temperature data from CRUNCEP for the period 2009/06 to 2015/12.
- The model is initialised using the first year of driving data and biomass data for the Amazon (*Avitabile et al. 2016*). The initial NSC content in each grid cell is varied from 0 to 8% of the total biomass in that grid cell. The effect of increasing NSC on predicted Plant Carbon Expenditure (PCE = R_p+G) is then analysed.

Key Results and Discussion

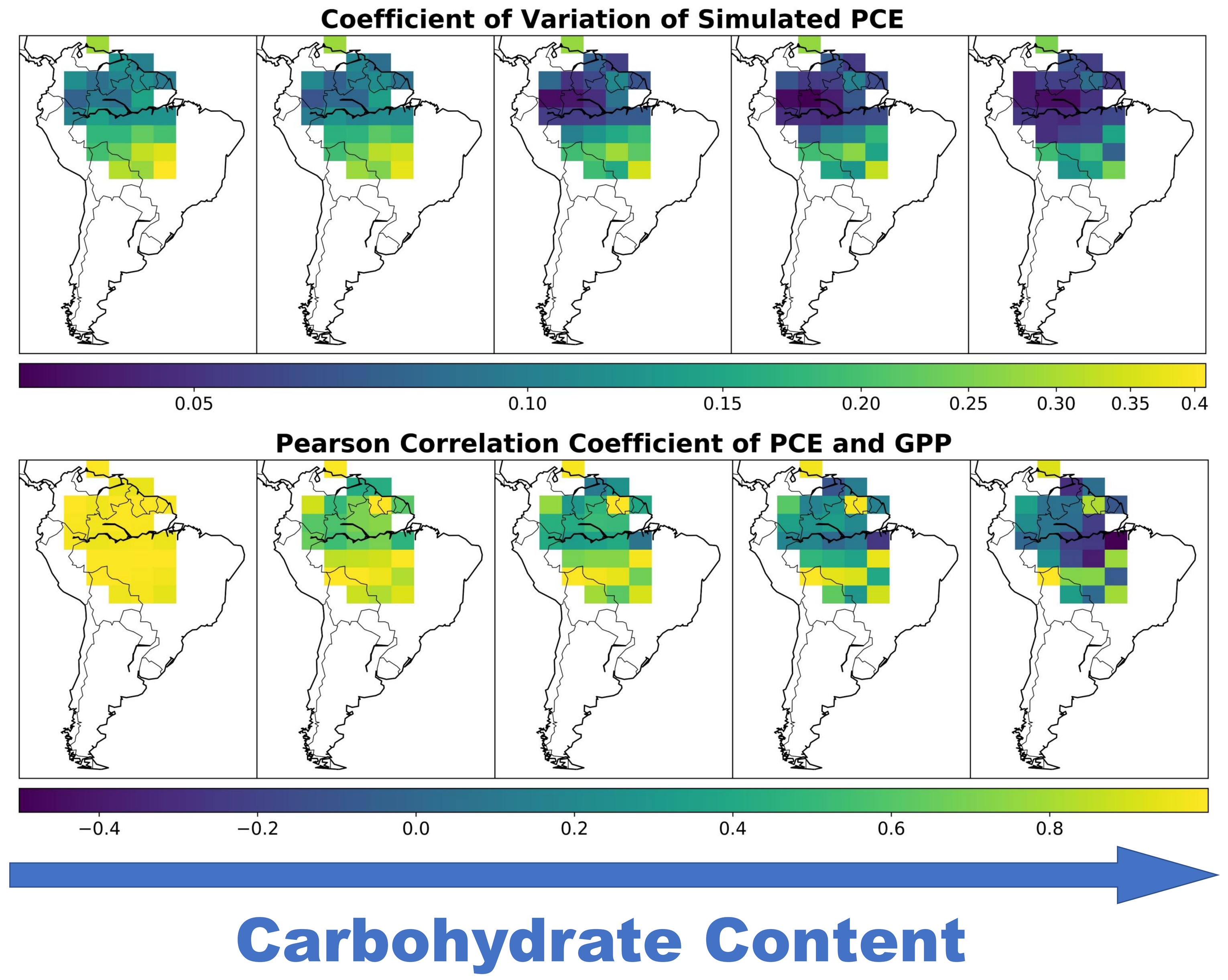


Figure 3: The effect of increasing NSC content on the coefficient of variation of predicted PCE time series (top panel) and the Pearson correlation coefficient of PCE and the driving GPP time series (bottom panel). From left to the right, the initialised NSC pool size as a percentage of grid cell biomass is 0.0%, 0.05%, 1.0%, 2.0%, 8.0%.

- The SUGAR model buffers the effects of seasonal variations in GPP on respiration and growth, maintaining a more constant (less variable) PCE (Fig. 3 top panel).
- This buffering effect is a consequence of the de-coupling of respiration and growth from GPP (Fig. 3 bottom panel).

References

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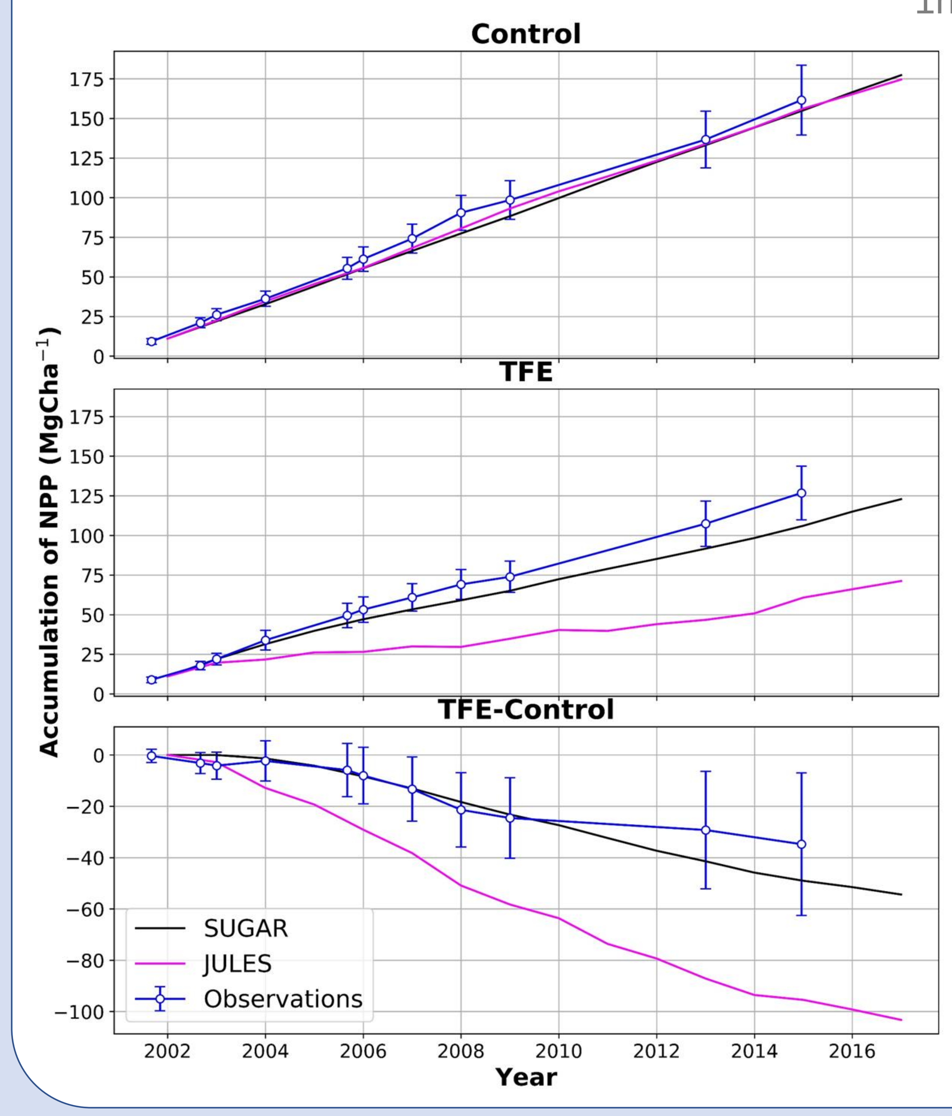
4. Extreme Drought - Caxiuanã

Caxiuanã Through Fall Exclusion

- Drought is a significant driver of asynchrony between photosynthesis and plant carbon expenditure.
- We use the Joint UK Land Environment Simulator (JULES) (*Clark et al. 2011*, *Best et al. 2011*) to simulate the first 16 years of the TFE experiment and non-droughted forest.
- SUGAR is driven with predicted GPP from JULES, and predicted growth (NPP) from each model is compared with observations.

Figure 4: The Through Fall Exclusion experiment (TFE) in Caxiuanã National Forest, Brazil allows the study of extreme drought on a tropical forest by preventing c. 50% of rainfall from entering the soils in a 1ha plot.



Key Results and Discussion

- Both JULES and SUGAR accurately capture NPP in the control forest.
- JULES underestimates NPP in the TFE forest.
- SUGAR significantly improves predictions of NPP in the TFE plot.

Figure 5: Accumulated NPP predictions by JULES (Pink) and SUGAR (Black) against observations (Blue). Observations are the sum of observed biomass increment and local litterfall (Rowland et al 2015, 2018).

5. Conclusions

- Modelling Non-Structural Carbohydrates is an essential component in correctly modelling ecosystem carbon fluxes.
- Our simple model of Non-Structural Carbohydrates allows respiration and growth to de-couple from photosynthesis within a large-scale DGVM, allowing more accurate simulations of responses to seasonal and longer-term changes in climate.
- SUGAR can produce significant improvements in the prediction of carbon flux responses to severe drought.