The impact of non-structural carbohydrates in simulations of tropical plant respiration

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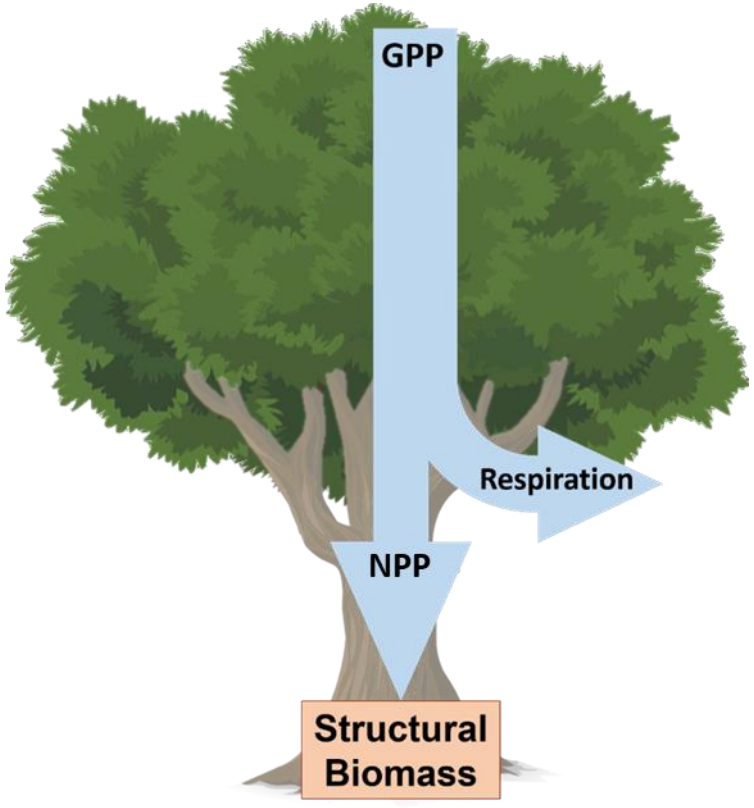
International Human Frontier Science Program Organization

Plant respiration in JULES



- Plant respiration is a key flux in determining the net land carbon sink
  - Roughly 50% of accumulated carbon is re-released by respiration

- Respiration in JULES is modelled using the **growth-maintenance respiration** paradigm:

$$R_p = R_m(T, B) + R_G(P)$$

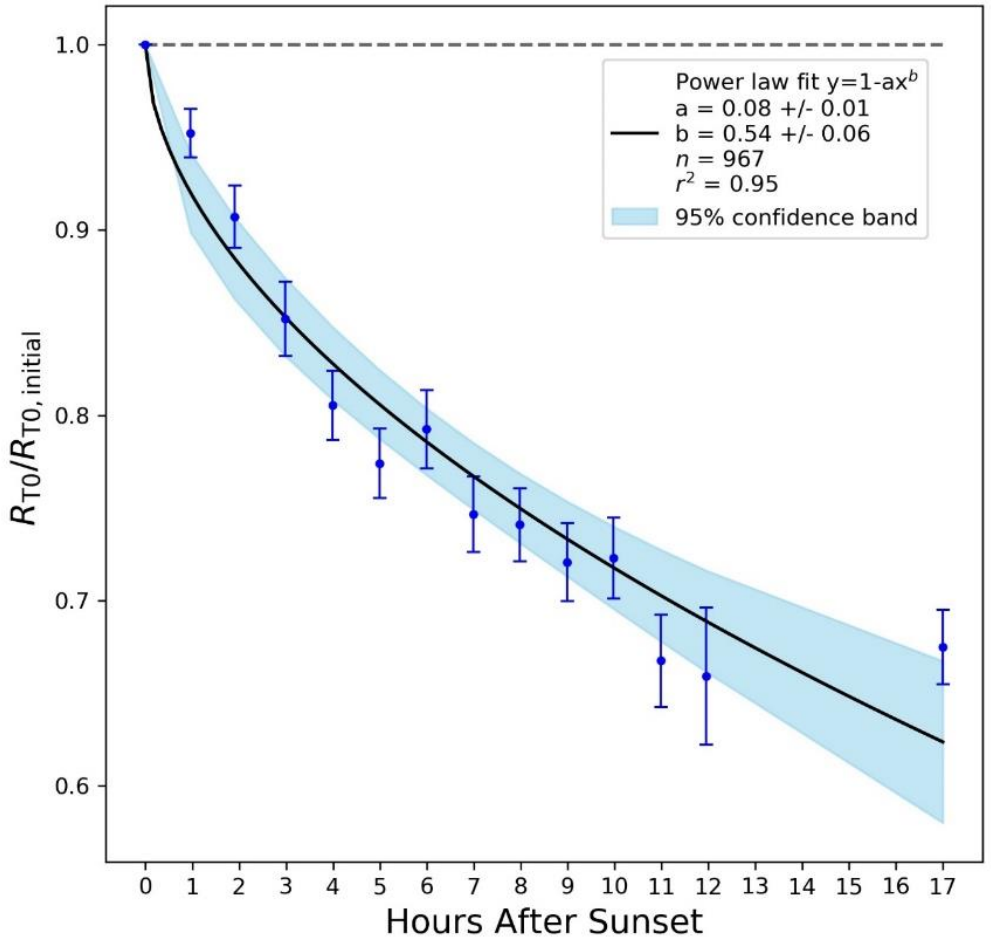
- R_g depends on photosynthesis
- R_m depends on temperature and biomass

Nocturnal plant respiration is under strong non-temperature control

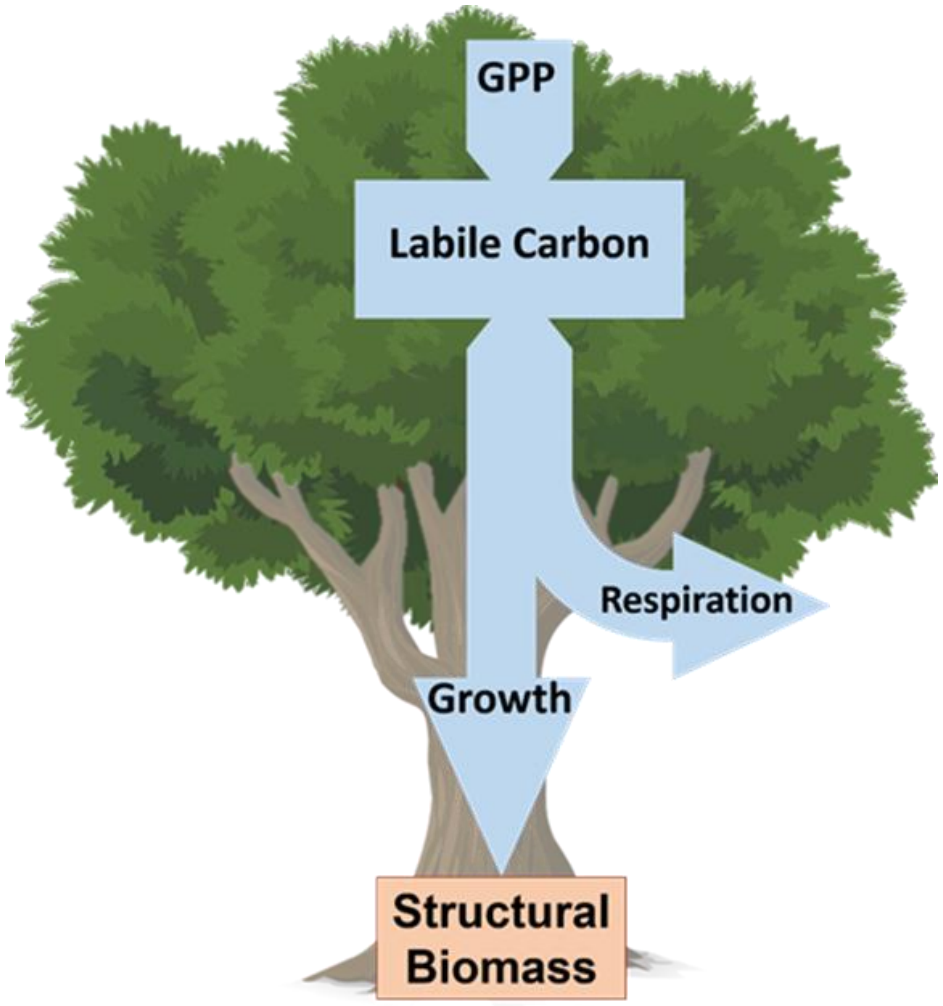
$$R = R_m(T, B) + R_G(P)$$

GMR prediction:
Under constant temperature, nocturnal plant respiration should remain constant.

- Bruhn et al., 2022 found significant variation in nocturnal respiration under constant temperature conditions
- This contradicts current the representation of respiration in most land surface models
- The result was consistent across multiple species and biomes

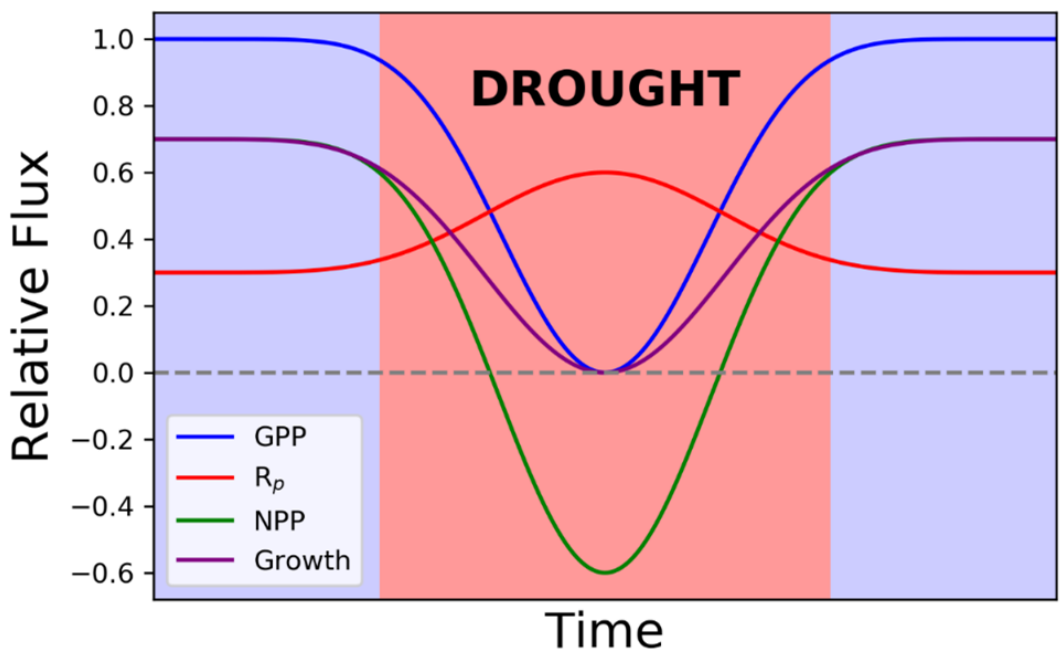


What are non-structural carbohydrates?



- NSC are labile carbon compounds that support growth and respiration in plants when the supply of C from photosynthesis is reduced.

- E.g. during drought – photosynthesis is inhibited by water availability.



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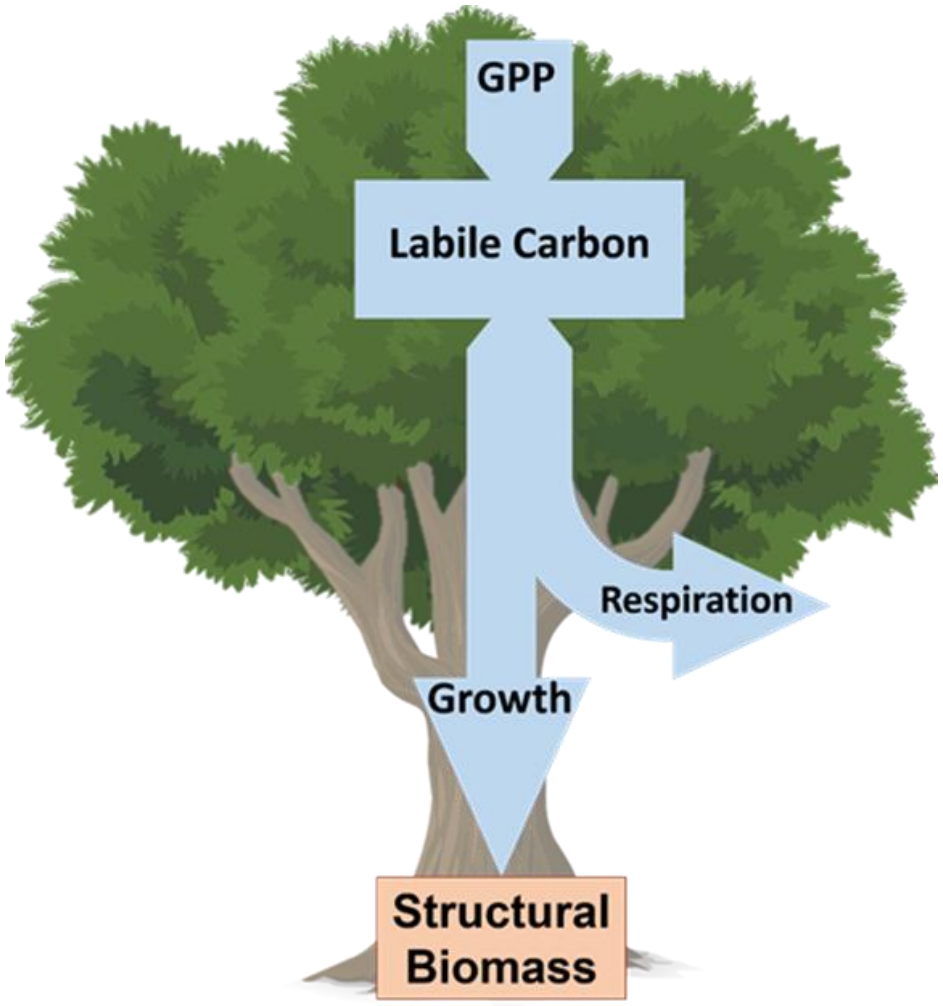

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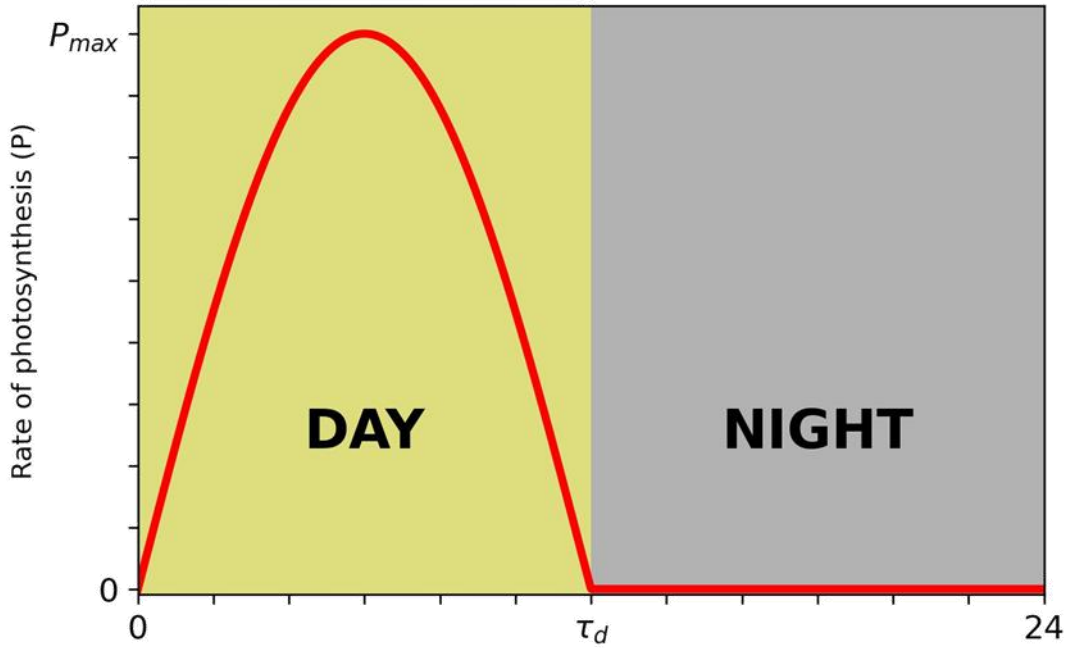


The role of substrate in plant respiration

Hypothesis: the decline can be explained by the depletion of NSC that fuels respiration.

We test this using a simple two pool model of carbohydrate dependence in plant respiration with the following assumptions:

1. Respiration depends on the availability of 'fast' substrate.

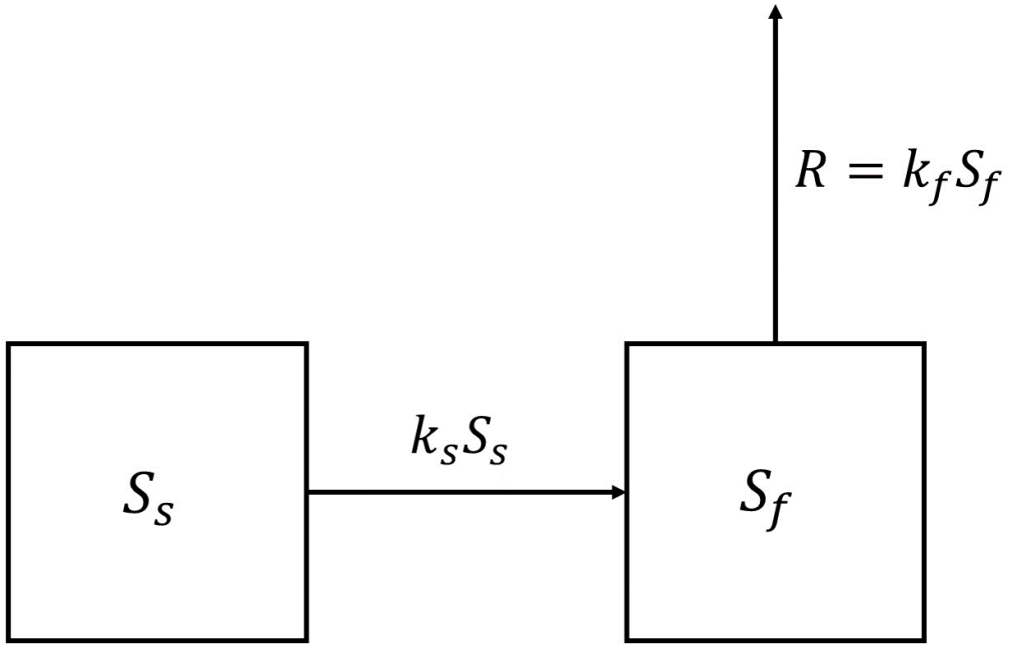
2. The 'fast' pool is replenished by a 'slow' pool.

$$\frac{R}{R_0}(t) = re^{-k_s t} + (1-r)e^{-k_f t}$$

Related to the ratio of the two substrate pools

Slow pool turnover rate

Fast pool turnover rate



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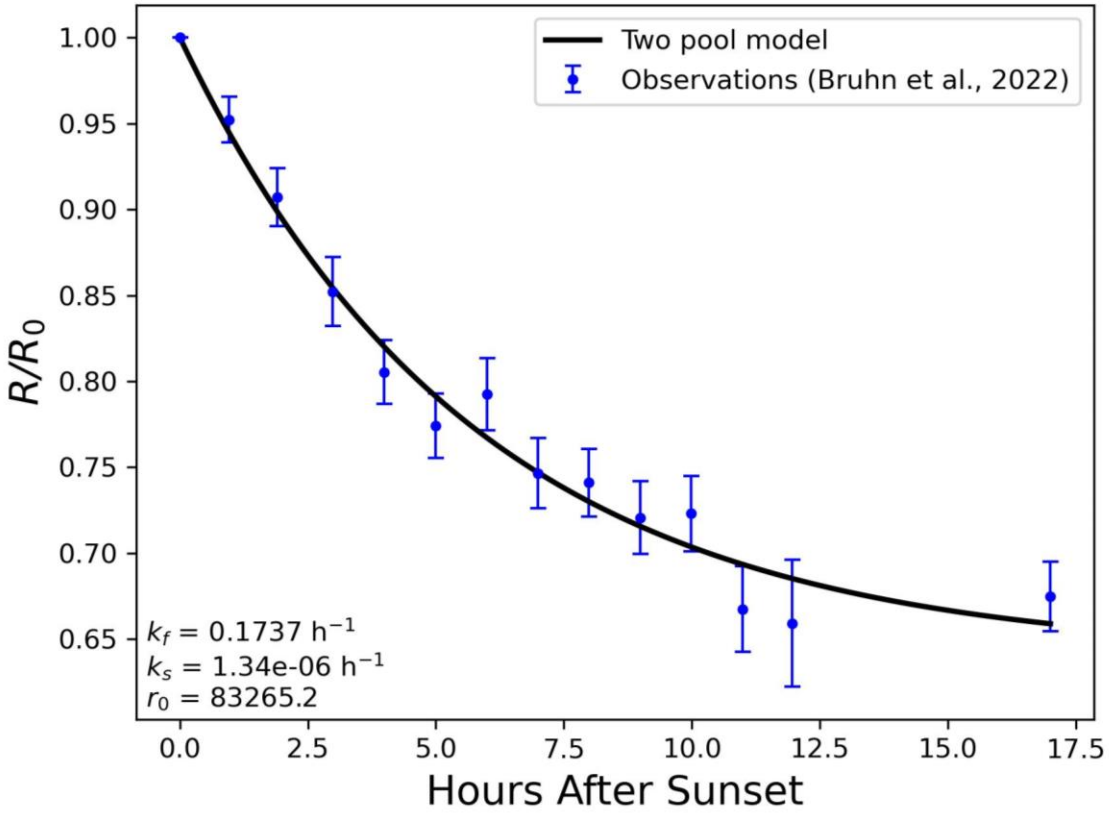


JULES-SUGAR (vn2)

- We have recently implemented the SUGAR model into JULES
- SUGAR simulates the role of NSC in plant growth and respiration
- Version 2 includes a new structural biomass turnover process based on Thornley (2011)
- This produces more realistic predictions of carbon use efficiency (CUE) and NSC concentrations in growing forests.
- **Structurally comparable to the two pool model**
- **We can use the data from Bruhn et al., (2022) to evaluate the parameters in SUGAR**

#1344 sci/tech_review enhancement

Opened 5 months ago
Last modified 3 days ago

SUGAR implementation

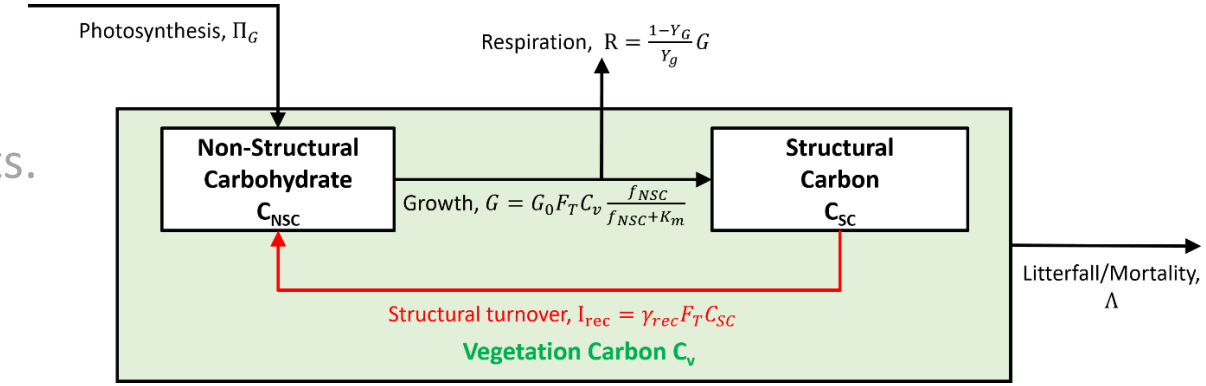
Reported by:	simonjones	Owned by:	eddyrobertson
Priority:	normal	Milestone:	JULES Feb-23
Keywords:	macro um LFRic meta_jules-shared	Cc:	andywiltshire, eddyrobertson

Description (last modified by eddyrobertson) Δ

Adding non-structural carbohydrate model (SUGAR, Jones et al., 2019 https://doi.org/10.5194/bg-17-3589-2020).

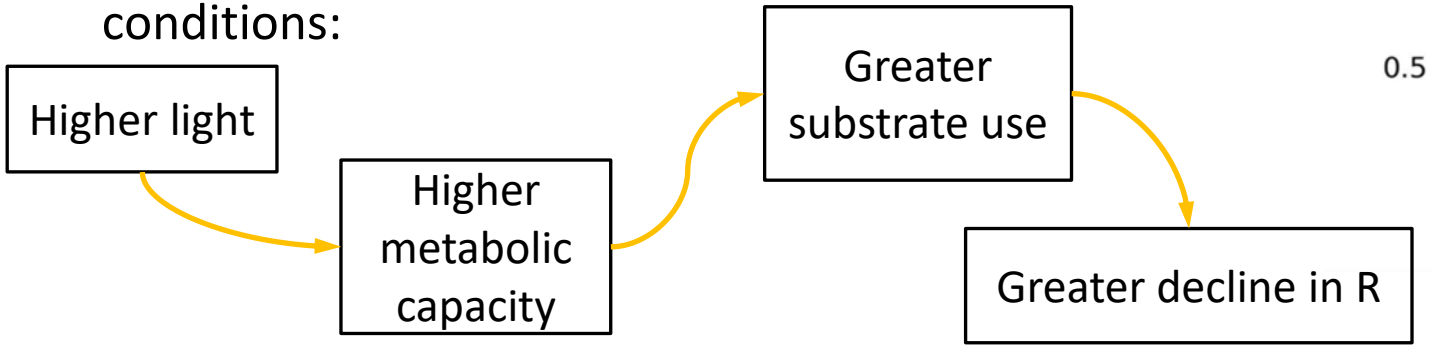
Linked UM Ticket: https://code.metoffice.gov.uk/trac/um/ticket/7108
Dev branch: vn7.1_jules-sugar
Test Branch: r24985_vn7.1_jules-sugar_test
Doc Branch: []

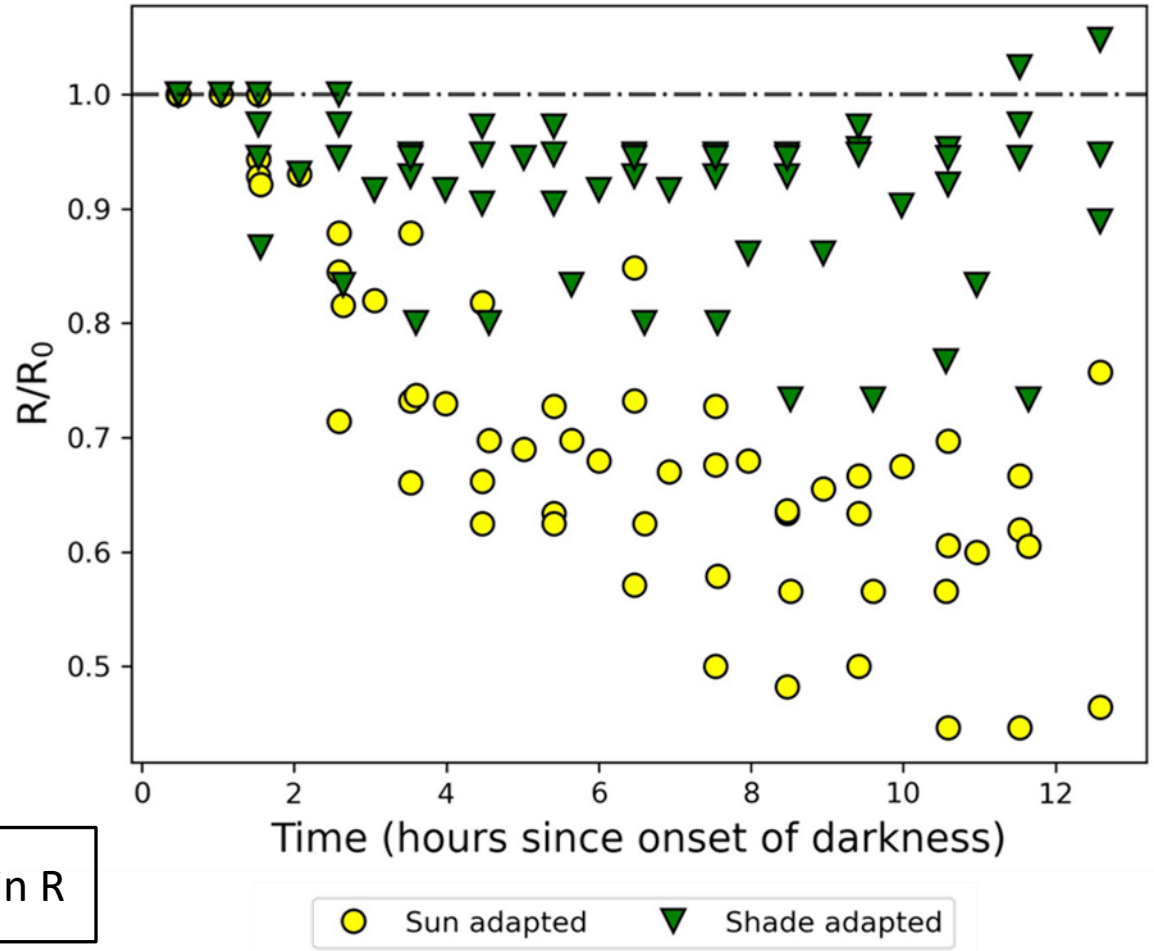
TicketSummary



The impact of environmental growing factors on nocturnal respiration

- (Unfortunately) the observed decline in nocturnal respiration is not as simple as it seems…
- Bruhn (2023) found a strong dependence on growing light conditions
- We hypothesise that this is related to the coordination of leaf metabolic capacity with growing light conditions:





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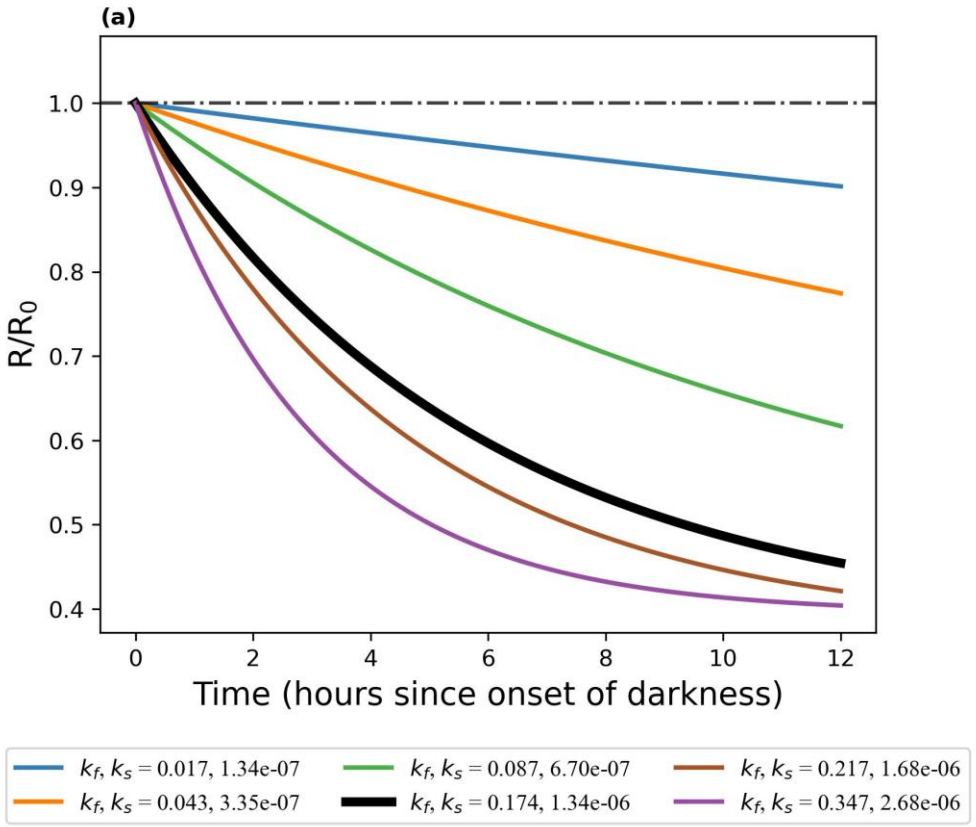
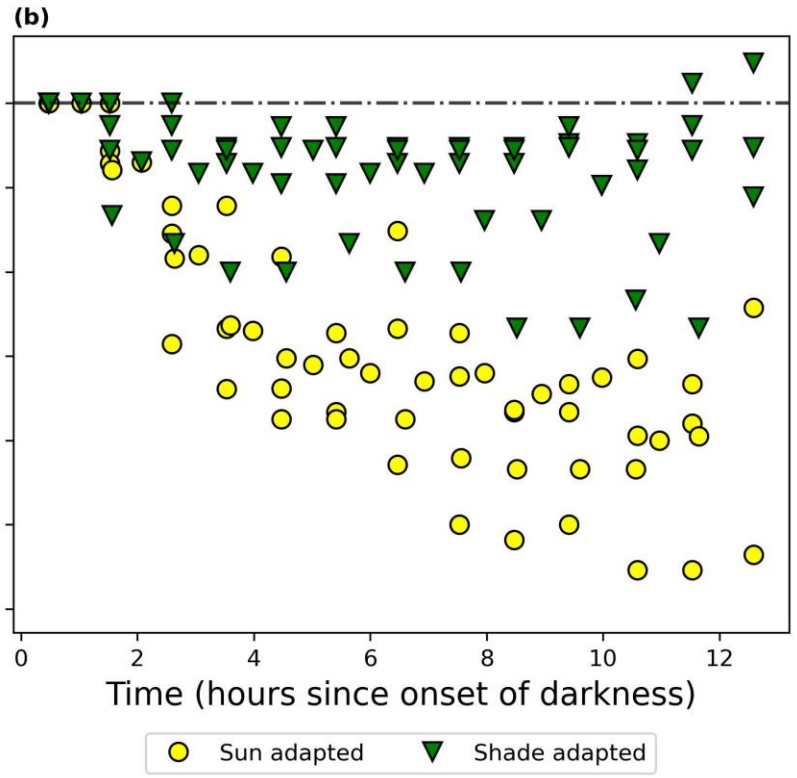




This is only a qualitative comparison!

There is still a lot we don't understand about this!

Summary

- The growth-maintenance respiration paradigm is unable to explain short term behaviour of plant respiration
- The depletion of labile substrates provides a simple explanation of nocturnal respiration decline
- There is still a lot we don’t understand about this
- The impact on long term predictions of the global land carbon sink is unclear
- The recently developed JULES-SUGAR model will allow us to examine this

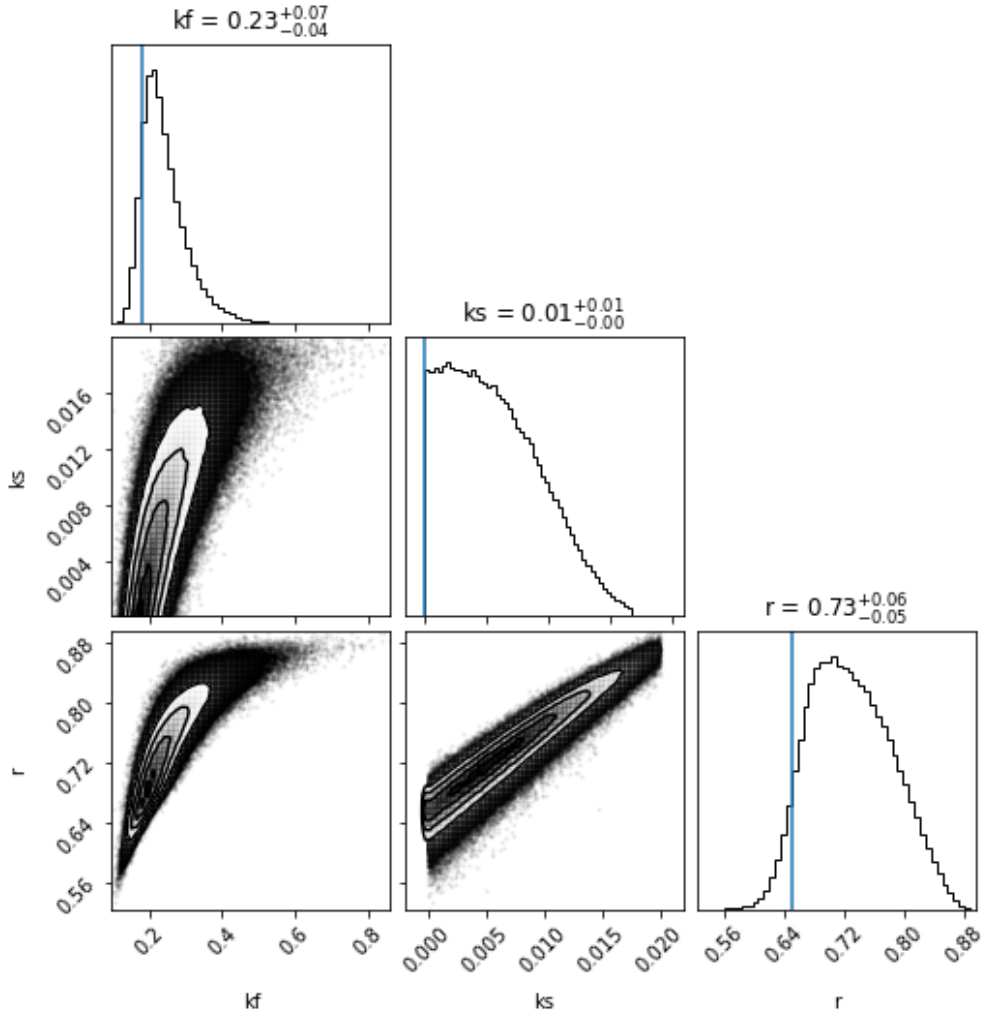
Thank you for listening
Any questions?

Substrate depletion can explain observed declines in nocturnal respiration under constant temperature

- The fast pool is well constrained by the nocturnal respiration data.
  - Interestingly, the fitted turnover rate (k_f) is consistent with observed turnover rates of sugars.

- However the slow pool is not well constrained.
  - We find that any turnover time > ~3 days is sufficient to describe the data

What is the impact of the slow pool turnover on long term respiration?



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