Complete or overcompensatory thermal acclimation of leaf dark respiration in African tropical trees

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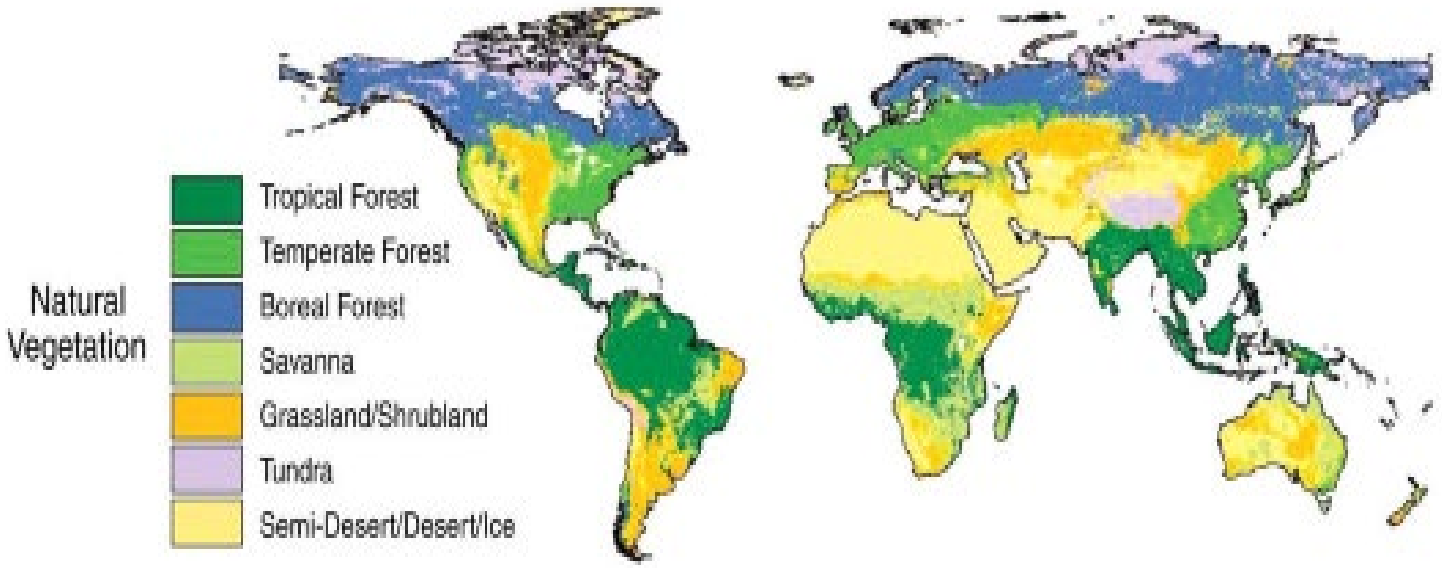
WeCLISH and PARTAKE Africa's Climate Café on Zoom, February 28, 2025

Mujawamariya et al. 2021, New Phytologist

Why tropical mountain forests ?



- Account for 32-36% of terrestrial net primary productivity (NPP) (Clark 2004)
- Store about 55% of the carbon in the world's forests (Pan et al. 2011)
- Hydrological and biophysical interactions with the atmosphere
- Provide livelihood for many people & host great biodiversity by supporting >60% of all known species (Martino, 2015).

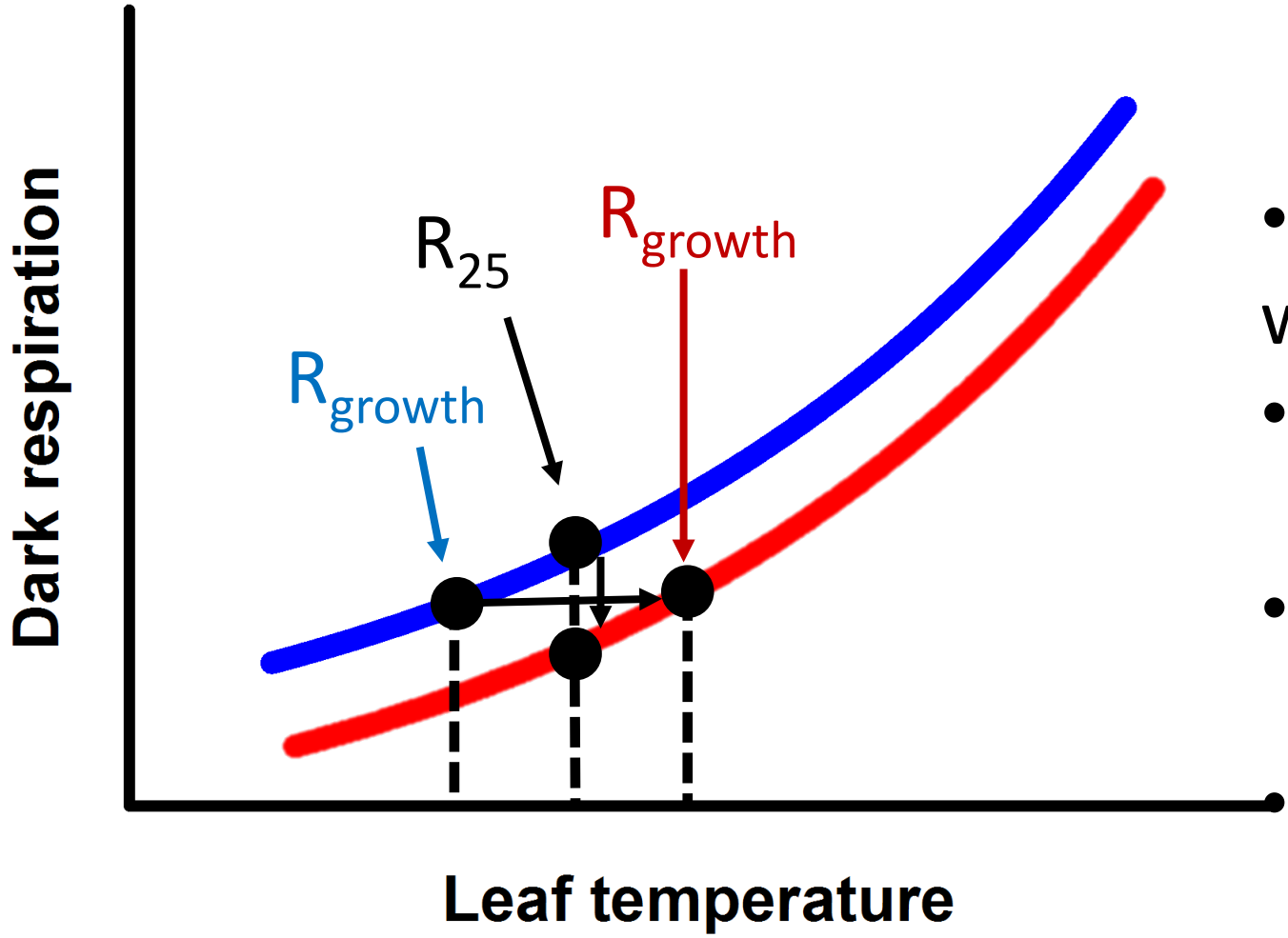
Context and Knowledge gap

Tropical climates are getting warmer, with pronounced dry periods in large areas.

The productivity and climate feedbacks of future tropical forests depend on the ability of trees to acclimate their physiological processes, such as leaf dark respiration (Rd), to these new conditions.

However, knowledge on this is currently limited due to data scarcity.

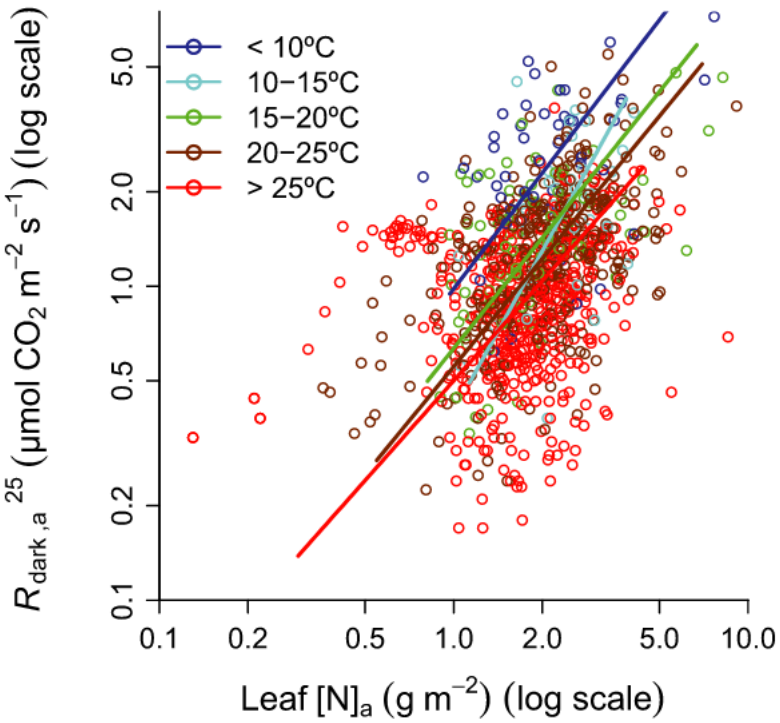
Thermal acclimation of respiration



- Decreases at warmer T_{growth} when measured at common T
- Equal when measured at T_{growth}
- Decreases in leaf Nitrogen
- Decreases in leaf mass area

Owen and Tjoelker 2003. *Trends in Plant Science*
Crous et al. 2017. Tree Physiology
Aspinwall et al. 2017. *Functional Plant Biology*

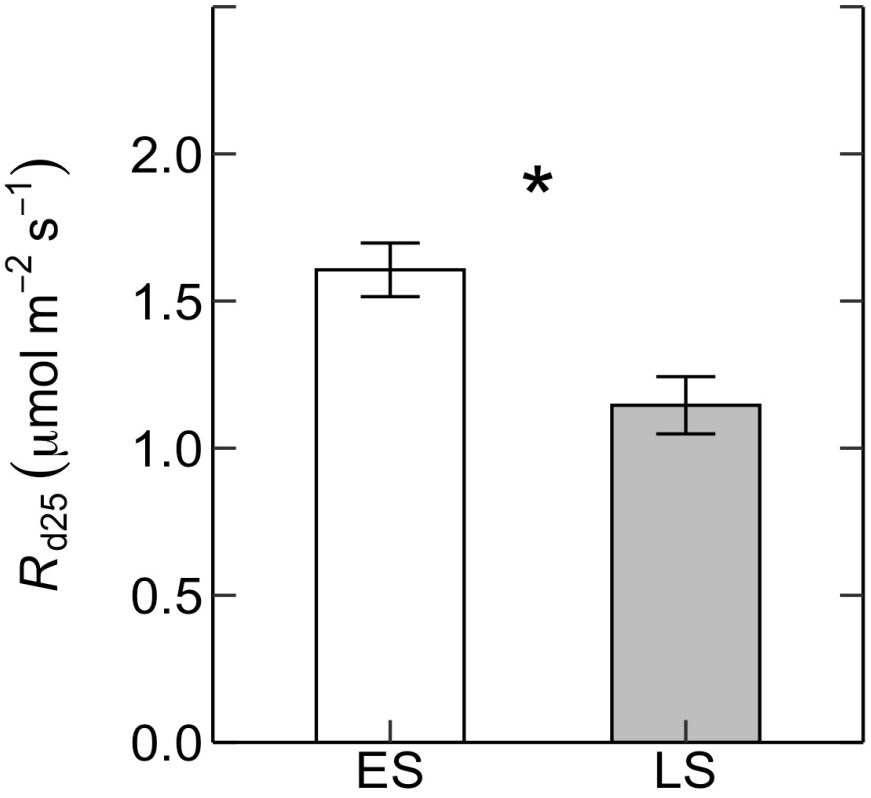
Mechanisms (physiological and biochemical) underlying thermal acclimation of R_d are not well known



Even at the same leaf N, R_d is still lower in warm grown trees

Atkin et al. 2015. New Phytologist

R_d varies among and across Plant Functional Types



At a common leaf temperature:

- Early-successional species have higher R_d than late-successional tree species

Ziegler et al. 2020. Front. Plant Sci

Less is known regarding the thermal acclimation of R_d in tropical species, and variation among species

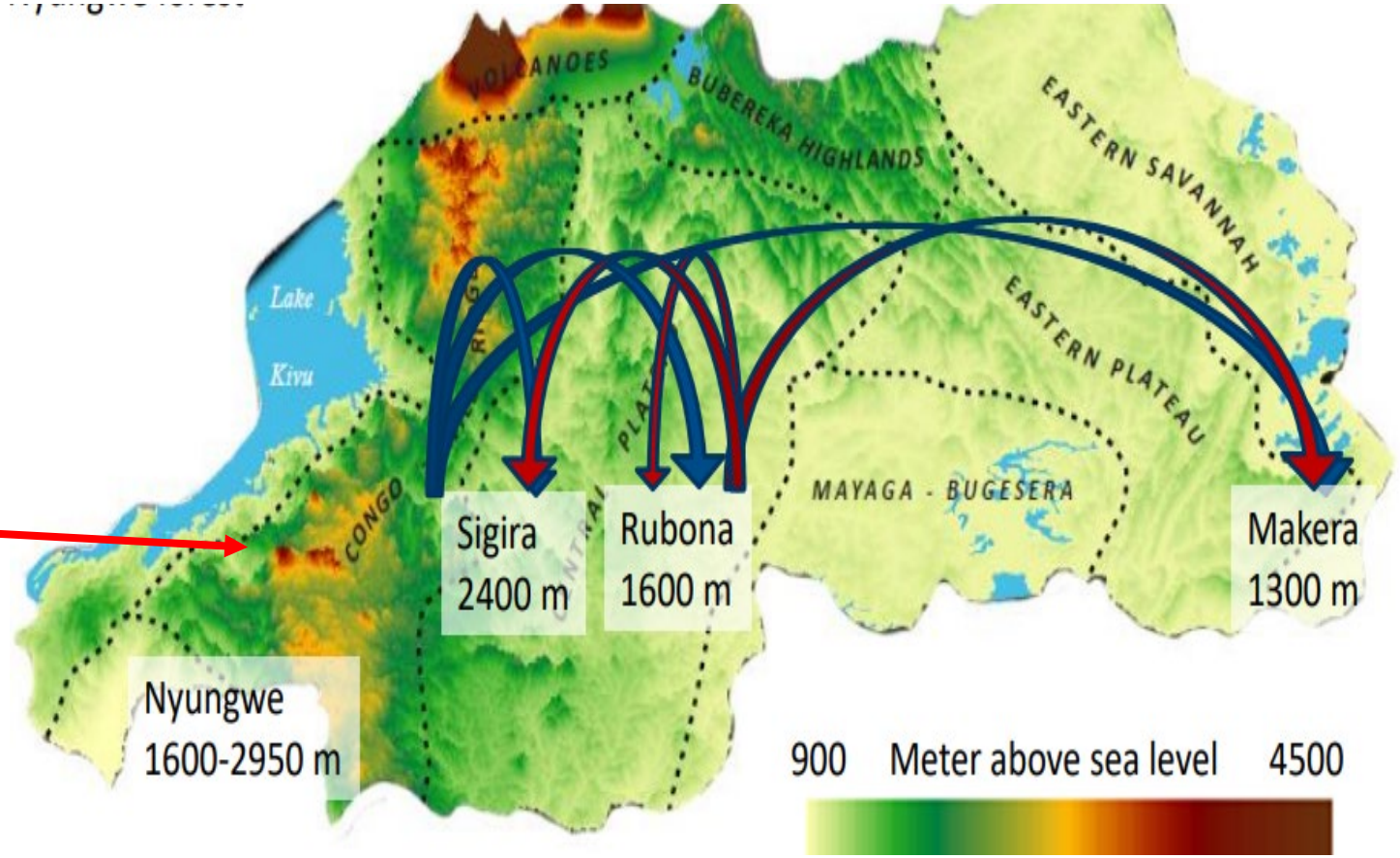
Hypotheses

- Plants grown at warmer sites acclimate R_d
- Net photosynthesis is a stronger predictor of thermal acclimation of leaf respiration than leaf nutrients or LMA
- Given that photosynthesis (and thus substrate availability) may decrease under drought, rates of leaf R_d at a common leaf temperature would be reduced by drought

STUDY DESIGN _ Rwanda Tropical Elevation Experiment (Rwanda TREE)

Elevation gradient to simulate future climate

Plantations of 20 native tree species from high and mid altitudes (10 early-successional, 10 late-successional) established along an elevation gradient in Rwanda



Site characteristics and treatments

6 treatments x 3 replicates = 18 plots at each site
20 species x 270 individuals = 5400 trees (+ side study with 150 potted plants)

Sigira/Nyamagabe
S 2° 30’ 54”; E 29° 23’ 44”
Montane rain forest
2400 m. a. s. l.
17.5/23.8 °C, 2100 mm

Treatments:

	HW	MW	LW
LN	**Control**	Shelter -500 mm	Shelter -900 mm
HN	Fertilizer	Shelter -500 mm -& Fertil.	Shelter -900 mm -& Fertil.

Rubona/Huye
S 2° 28’ 30”; E 29° 46’ 49”
Transitional rain forest
1600 m. a. s. l.
22.5/28.6 °C, 1600 mm

Treatments:

	HW	MW	LW
LN	Irrigation +500 mm	**Control**	Shelter -400 mm
HN	Irrigation +500 mm & Fertil.	Fertilizer	Shelter -400 mm -& Fertil.

Ibanda **Makera**/Kirehe
S 2° 6‘ 31“; E 30°51'16"E
Evergreen and semi-evergreen bushland and thicket
1300 m. a. s. l.
23.8/31.4 °C, 1050 mm

Treatments:

	HW	MW	LW
LN	Irrigation +900 mm	Irrigation +400 mm	**Control**
HN	Irrigation +900 mm & Fertil.	Irrigation +400 mm & Fertil.	Fertilizer

LN = low nutrient (control)
HN = high nutrient (fertilised)
LW = low water supply
MW = medium water supply
HW = high water supply

16 species were measured:

- 6 Late successional
- 9 Early successional

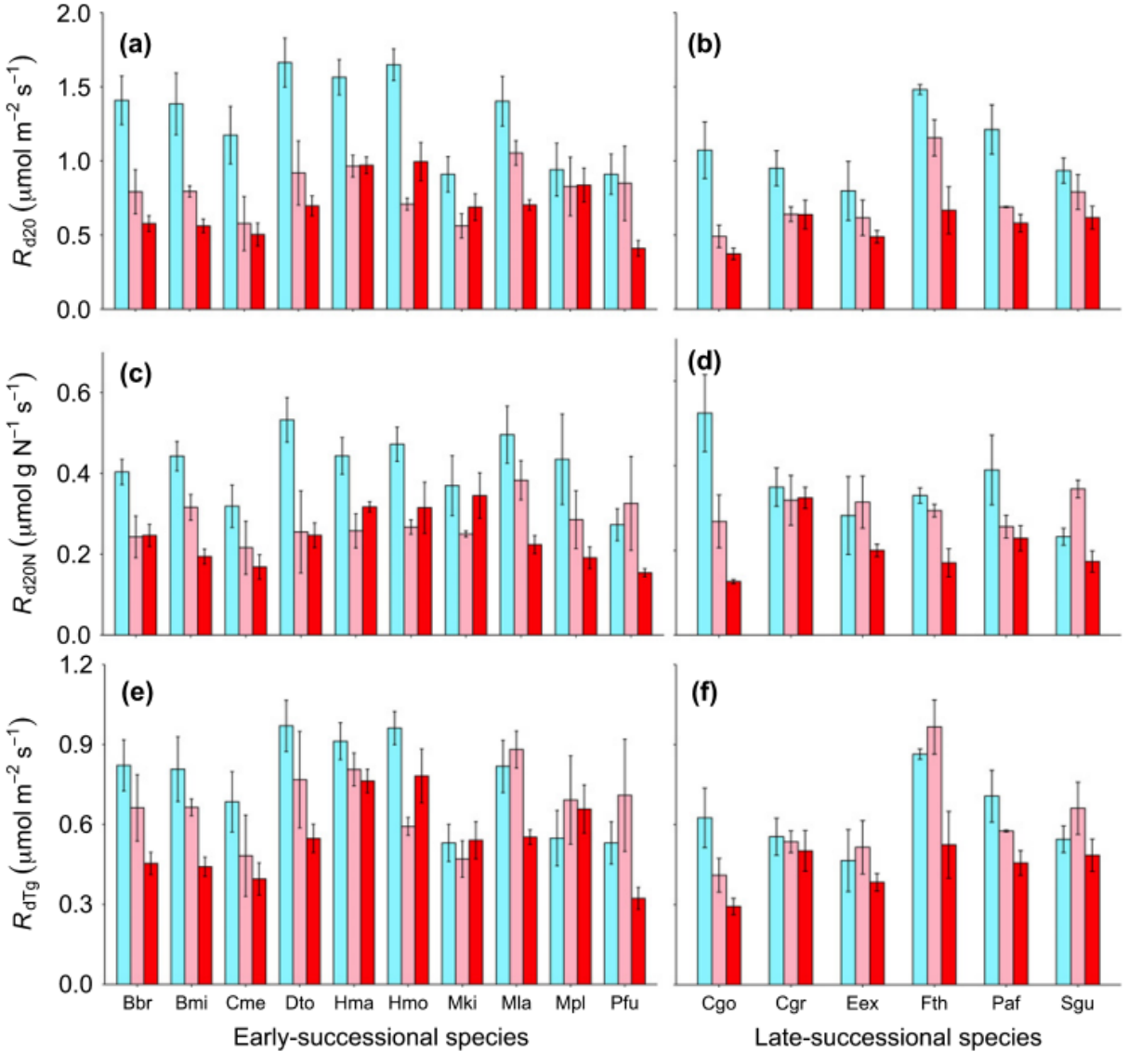
Gas exchange measurements

Measurements taken during both wet and dry seasons

Explaining photosynthesis measurements to students

- ❑ Taking gas exchange measurements using portable photosynthesis systems (LI6400 XT, Li-Cor Inc., Lincoln, NE, USA).
- ❑ In ES and LS species, at the three sites
- ❑ Night-time measurements taken between 7:00 and 11:00 PM

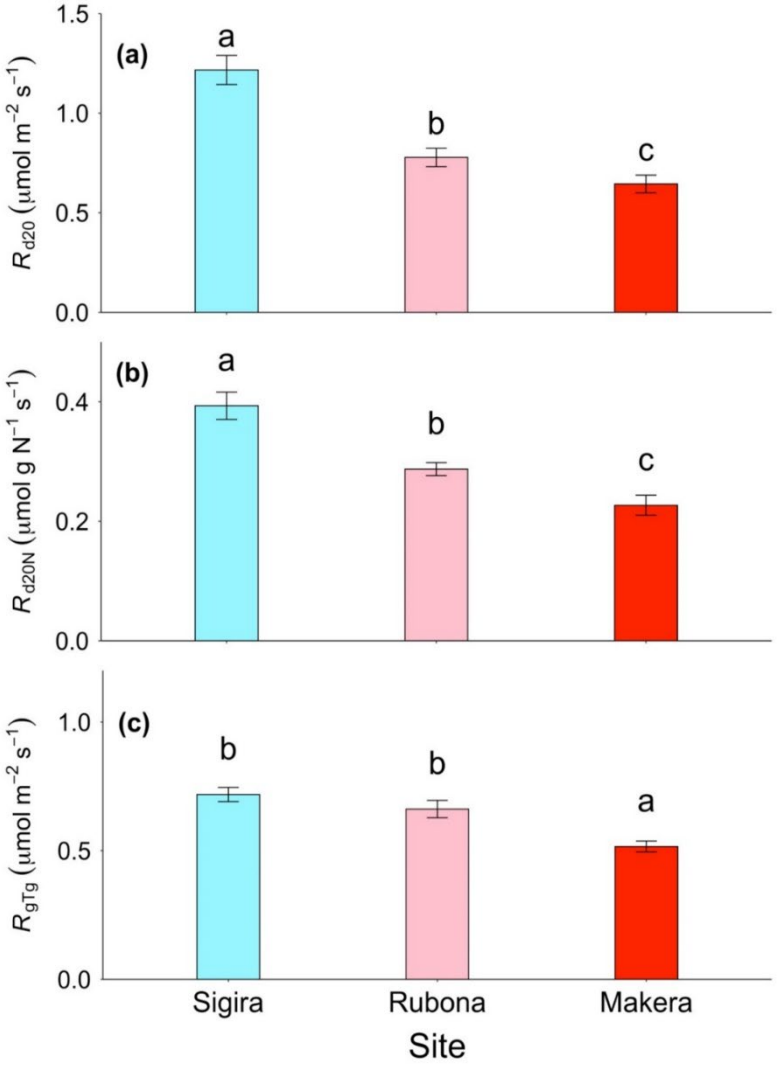
R_d strongly acclimates to warming across 16 tree species



- R_d at a common leaf temperature is progressively lower at warmer sites
- No difference between successional groups

Mujawamariya et al. 2021_New Phytologist

Thermal acclimation of leaf dark respiration



- R_d at a common leaf temperature is lower at warmer sites
- R_d normalized to leaf nitrogen is lower at warmer sites
- R_d at growth temperature; homeostasis or over-compensation

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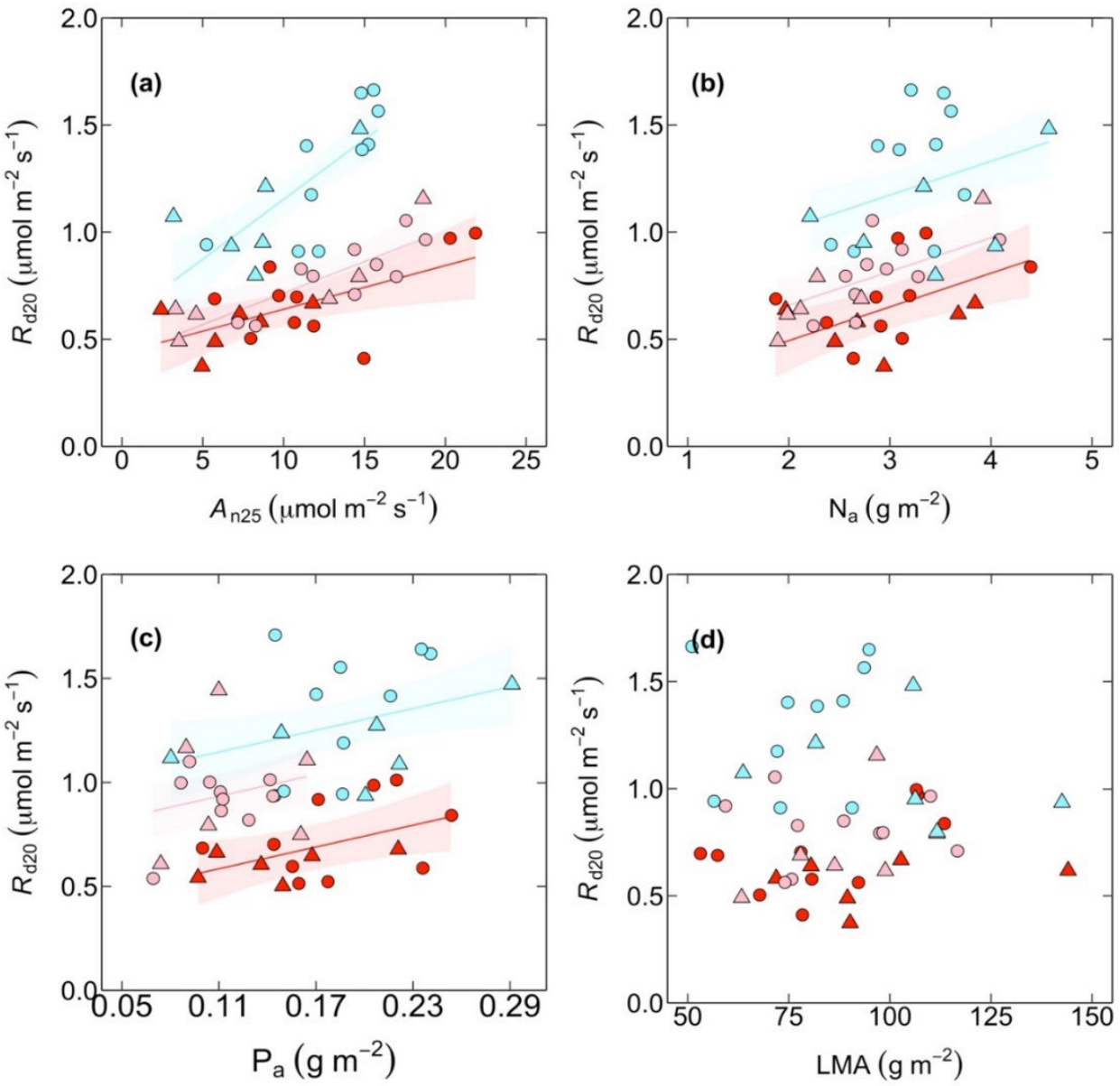
Respiration is correlated with other leaf traits



- R_{d20} was positively related to net photosynthesis (strongest), leaf nitrogen and phosphorus, but not leaf mass per area

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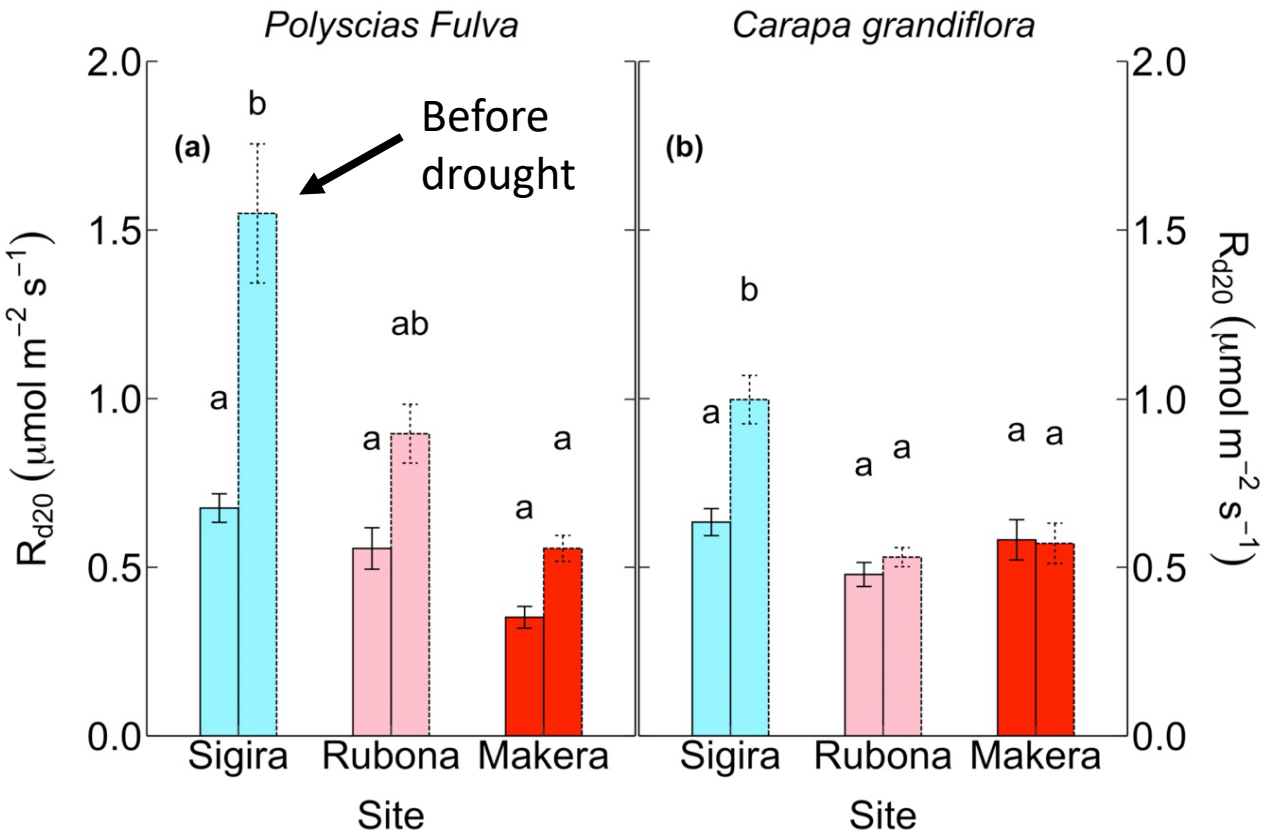
Respiration was reduced at end of drought season



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- R_{d20} decreased after drought, more so at the coolest site and for an early- (*Polyscias fulva*) versus late- (*Carapa grandiflora*) successional species

Summary

- H1 - Plants grown at warmer sites acclimate Rd
  - YES (homeostasis acclimation and even over-acclimation)
- H2 - Net photosynthesis is a stronger predictor of thermal acclimation of leaf respiration than leaf nutrients or LMA
  - YES
- H3 - Given that photosynthesis may decrease under drought, rates of leaf R_d at a common temperature would be lower during late dry season compared to early dry season
  - YES, and particularly at the coolest site and in the early successional species

The strong thermal acclimation of leaf R_d in tropical tree species should be accounted for to avoid overestimation of the impact of global warming on autotropic respiration in tropical forests.

THANK YOU !

Partners:

UNIVERSITY OF GOTHENBURG

Rwanda Agriculture Board

Funders:

Vetenskapsrådet

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