New estimates of temperature response of leaf photosynthesis in Amazon forest trees.

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Introduction

- In many dynamic vegetation models, degradation of the tropical forests is induced because they assume that productivity falls rapidly when temperatures rise in the region of 30-40°C.
- This is due to the assumptions on the temperature optima of photosynthetic capacity, which are low and can differ widely between models.
- Hardly any empirical information is available for tropical forests, and even less on acclimation of photosynthesis to changing temperatures.

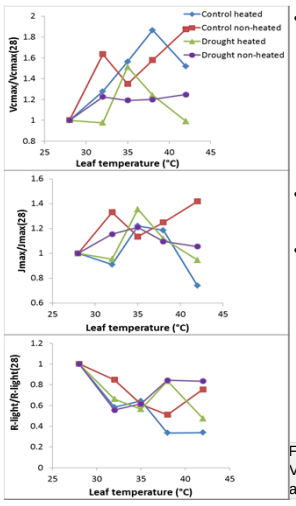
Methods

- CO_2 response curves were made in the Caxiuana reserve, Brazil in May-2013 and Oct-2013
- We used a more than 10 year old rainfall exclusion plot (da Costa et al, 2010) and the associated control plot.
- Sets of leaves were selected, with one leaf heated continuously by about 2˚C for up to one year with a heating plate (Doughty 2011; Fig 1)

Fig 1. Heating plate

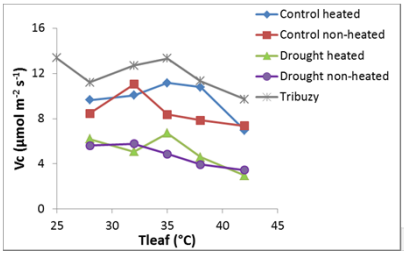
- CO_2-response curves collected at five temperatures (25-45˚C) using a Licor-6400.
- We also re-analysed a dataset collected by Felsemburgh in 2009 and by Tribuzy in 2005, in Cuieiras and Tapajos, Brazil.
- Vcmax and Jmax were calculated as a function of temperature and (long-term).
- Resulting temperature dependences were used to fit parameters in continuous temperature response functions used in various models.
- Carboxylation rates were back-calculated following the Farquhar model assuming a Ci of 400ppm, i.e., ignoring stomatal limitation.

Results



- Vcmax in the non-heated leaves show a increase with temperature, but with a dip in the mid-30 degree range (Fig 2). For the heated leaves, there is an optimum, for Vcmax at 38 °C for the control plot and at 35 °C for the drought plot.
- For Jmax, the optima are more pronounced and wider.
- An interesting feature of our data is that Rd tends to (weakly) decrease with temperature. In our experiments, Rd is, dark respiration in the light The results on Rd in this study are likely not significant and merely a 'rest term' of the regressions used to calculate Vcmax.

Fig 2. Normalised average temperature response of Vcmax, Jmax and R-light. Control non-heated data were averaged with cuieiras and Tapajos.



- Even though Vcmax may not, or hardly show a temperature optimum, re-calculated photosynthesis (here: carboxylation rate) itself does.
- The optimum temperature is clearly higher for heated leaves.

Fig 3. re-calculated carboxylation rates

- The combination of new parameter values do generate curves that are close to the measured ones.
- These parameters are in principle suitable to be inserted in code or parameter settings of the associated models.
- Fig 4 shows that in several cases (e.g. Jules, Orchidee) there is a large difference between the default parameterisations of these models and the fitted curves.

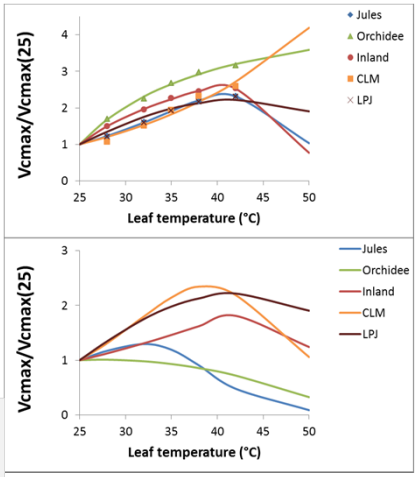


Fig 4. Normalized fitted Vcmax (25°C; top) and default model parametrization (below). Results from the control plot, non-heated were averaged with cuieiras and Tapajos data.

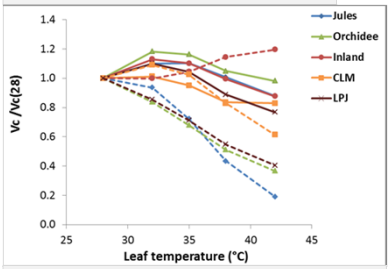


Fig 5. Calculated carboxylation rates using fitted Vcmax (solid line) and default Vcmax (dashed line). Normalized to 28°C.

The re-calculated carboxylation rates also show big differences in temperature dependence between the fitted curves and the default parameterization of the models.

- Vc for Jules, Orchidee and LPJ showed higher values.
- CLM showed no effect (or minor).
- Inland showed an increase in Vc.

Conclusions

- Temperature dependence of photosynthesis is rather weak. This is important for DGVM simulations for tropical forests, because the temperature dependence in these models is generally strong, with pronounced optima.
- The effects of leaf heating are inconclusive. Vcmax and Jmax didn't show an increased temperature optimum. For Vc, however, calculated from Vcmax there is an increase of the temperature optimum with leaf heating. Therefore we can conclude that there is some evidence that photosynthesis acclimates with environmental temperatures.
- The fitted temperature dependence markedly differs from those in especially the Jules, orchidee and LPJ models.

Literature

- da Costa, et al.,2010 : Effect of 7 yr of experimental drought on vegetation dynamics and biomass storage of an eastern Amazonian rainforest. New Phytologist, 187(3): 579-591.
- Doughty, C. E.. 2011. An in situ leaf and branch warming experiment in the Amazon. Biotropica, 43(6), 658-665.

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