Does seasonal drought influence ecosystem transpiration and water use efficiency in a tropical rainforest ?

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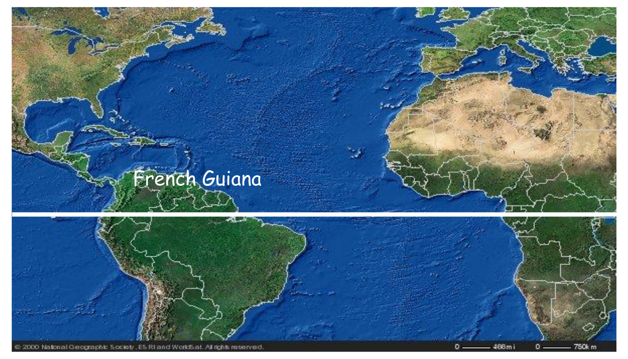
A. Introduction



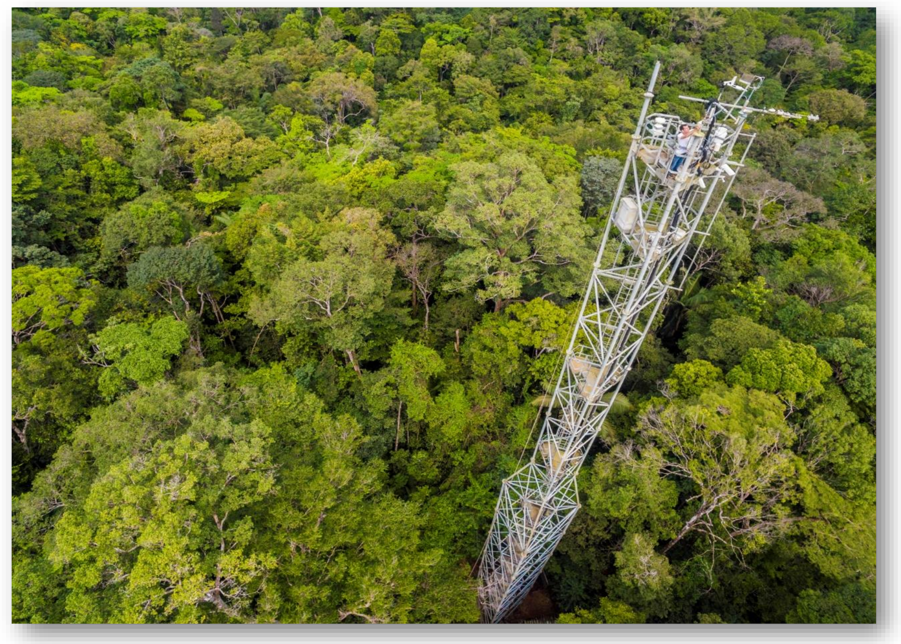
2 et 6° de latitude Nord; 52 et 55° de longitude Ouest

- Warmer and drier climates over eastern Amazonia have been predicted during the next several decades, with consequences on water and carbon cycles.
- Available literature on the long-term response of the coupled water and carbon cycles to these disturbances is highly limited.
- Here, we evaluated the ecosystem transpiration across an 11-year period (2004 – 2014) to capture interannual and seasonal changes and determine its key climatic drivers.
- We expected solar radiation to play a vital role to control evapotranspiration (ET) processes, without neglecting the restrictive role of soil water availability during drought period.
- We also hypothesized that the effect of drought on ET would be directly related to the severity of drought.
- Whether a reduction in evapotranspiration with drought will occur or not highlights the focus of this study.

B. Materials and Methods

Study site

- French Guiana, South America – a tropical wet
- forest 10 – 40 m above sea level
- Ave. rainfall is 3041 mm; ave. air temperature is 25.7°C
- Guyaflux experimental unit covers >400 ha of undisturbed forest
- 620 tree ha^{-1} tree density (DBH >0.1 m)
- Tree species richness is 140 species ha^{-1}
- Mean tree height is 35 m; emergent trees >40m


GuyaFlux tower in French Guiana

Flux and meteorological measurements

- CO_2 and H_2O concentrations
- Air temperature and humidity
- Global and infrared incident and reflected radiations
- Incident and reflected photosynthetic photon flux density
- Rainfall
- Wind direction and speed
- Atmospheric pressure
- Soil temperature
- Volumetric soil water content

Data were collected and compiled as 30-min averages or sums and processed following the standard flux data processing and analysis procedures.

Daytime evapotranspiration (ET)

ET at ecosystem level during day time was determined from values of the flow of *latent heat* (LE) obtained with the eddy flux system.

The soil water stress index (SWSI) and the drought period

SWSI is a dimensionless number that is calculated as the sum of daytime differences between the REW value and the 0.4, divided by 0.4 (*Granier et al. 1999*).

$$SWSI = \sum \frac{REW - 0.4}{0.4}$$

C. Results

Fig 1. Seasonal variations of ET

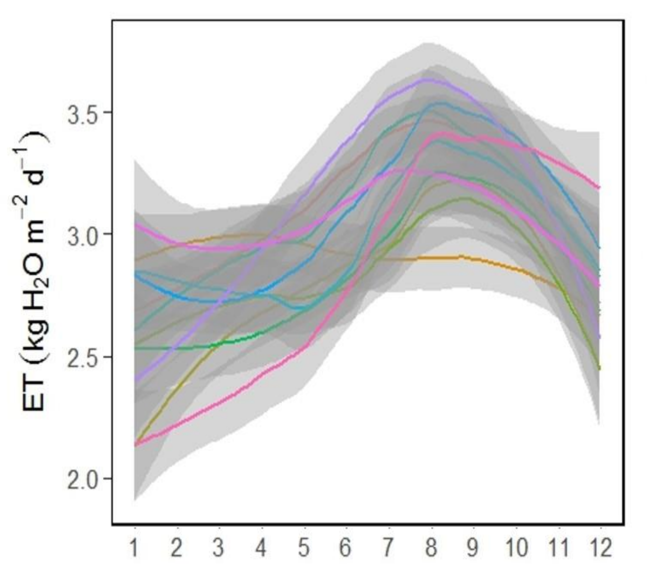


Fig 2. Climatic drivers

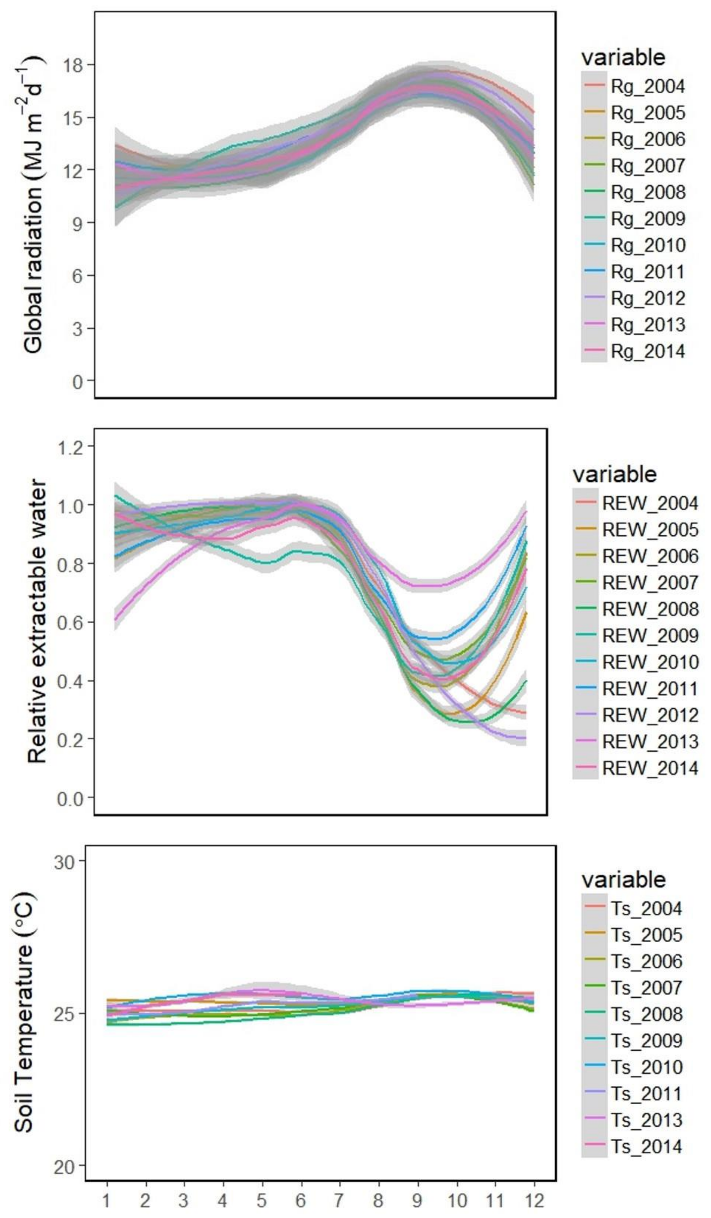
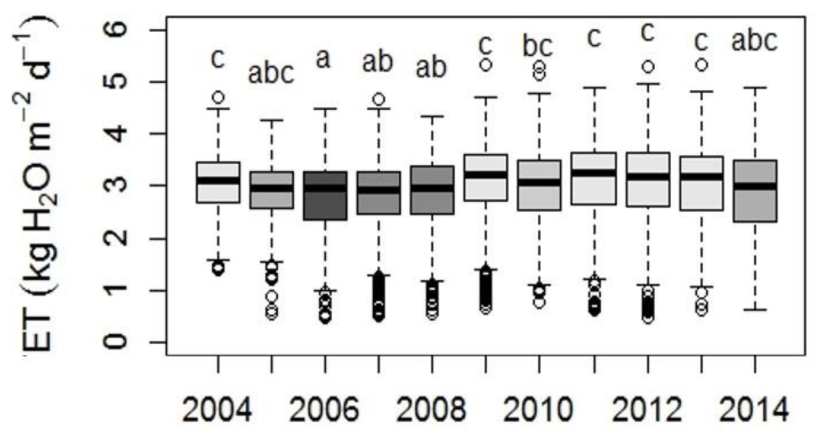


Fig 3. Interannual variations of ET



Drought effect on ET

Fig. 4 Comparison of ET and WUE for the whole year and during drought period

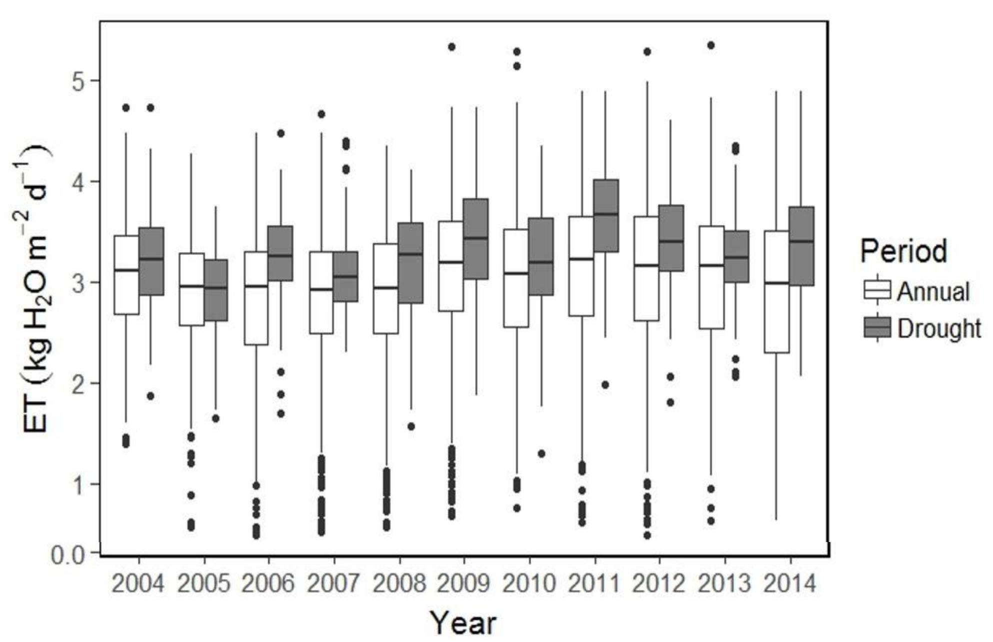


Table 1. Best climate predictors

Dependent variable	Best model predictors	Multiple R^2	Intercept	Coefficients 1	Coefficients 2	F value	P value
2004 - 2014							
ET		0.70	2.91				
	Rg			0.46	0.71	1136.4	< 0.0001
	REW			0.21	0.21	105.3	< 0.0001
	Ts			0.07	0.04	7.11	<0.0001
Soil water depletion							
ET		0.48	3.19				
	Rg			9.51	3.39	180.6	< 0.0001
	REW			1.01	2.20	105.3	< 0.0001
	Rg			0.56	0.12	5.18	<0.0001

Fig. 5 Interannual variation in soil water stress index (SWSI)

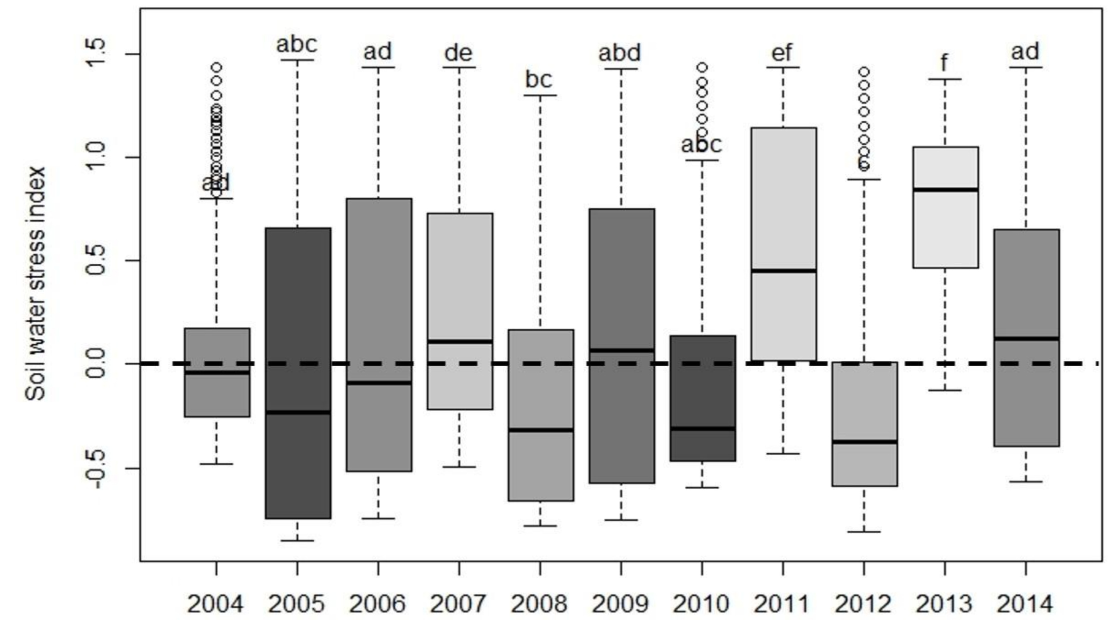


Fig. 6 Drought duration (gray shaded area) and the severity of water stress

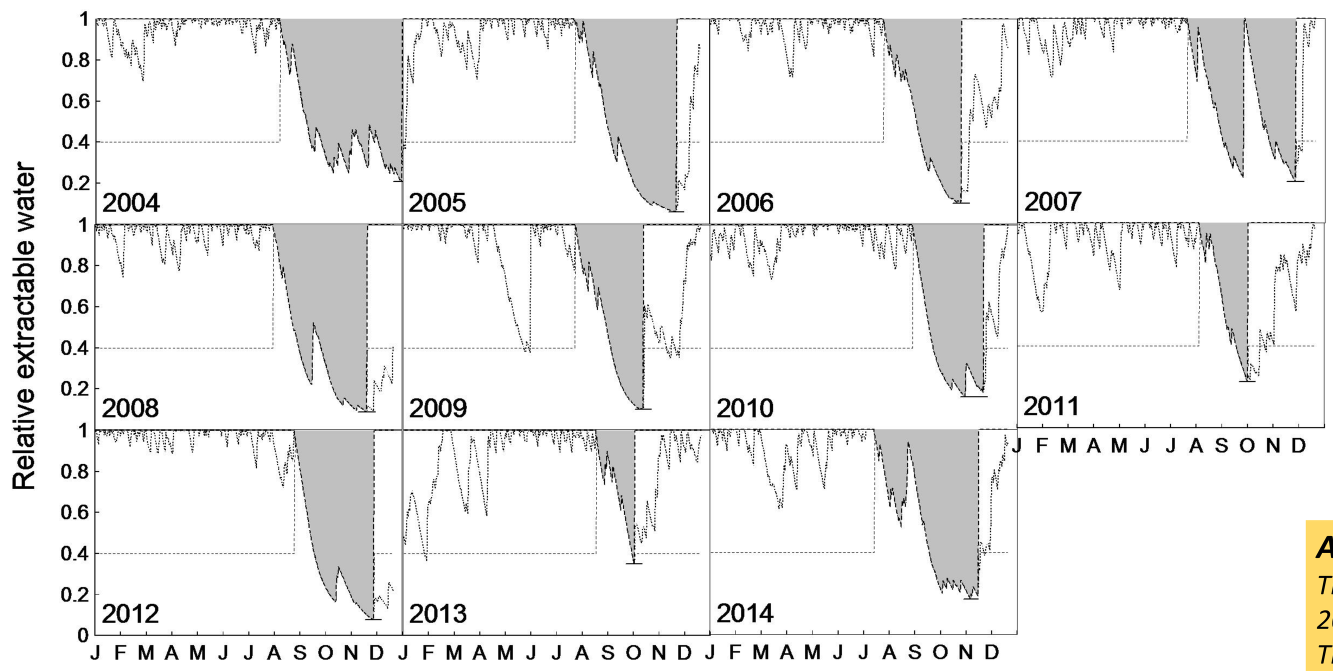


Fig. 7 Relationship between radiation-normalized ET with SWSI

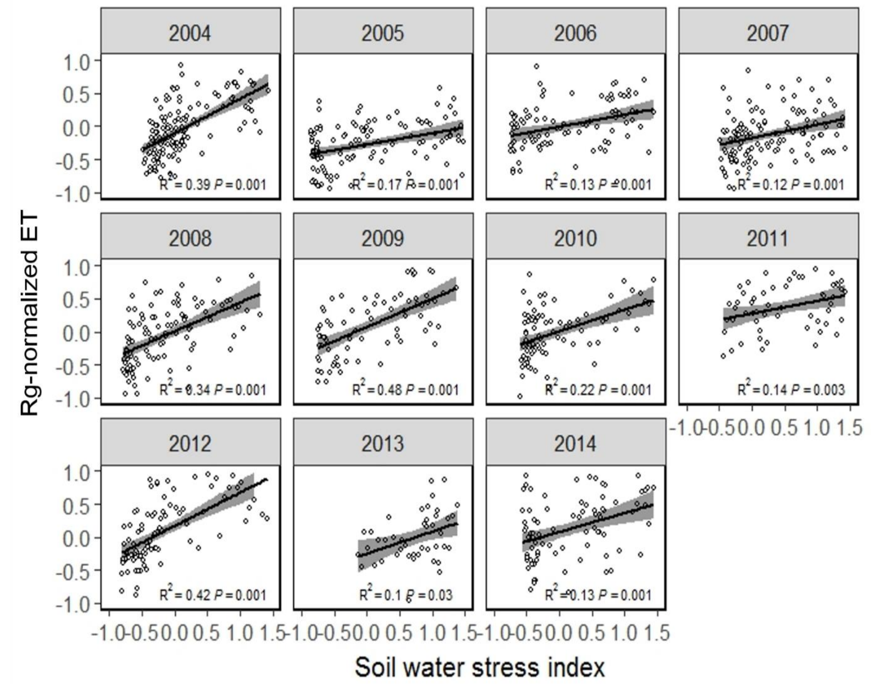


Table 2. Soil water stress index

Year	Soil water deficit duration (no. of days)	Soil water stress index (SWSI)	Maximum intensity of water stress
2004	143	13.2	0.21
2005	119	-5.06	0.06
2006	91	11.29	0.10
2007	127	40.04	0.20
2008	110	-12.11	0.09
2009	80	11.13	0.10
2010	83	-5.94	0.16
2011	57	29.97	0.23
2012	93	-17.37	0.08
2013	45	32.89	0.35
2014	122	26.65	0.17

D. Summary/Conclusion

- Over 11– year period, ET exhibited significant interannual variability ($P < 0.001$; Fig. 2)
- Annually, global radiation (Rg) is the best climate predictor for ET followed by relative extractable water (REW) then soil temperature (Ts) (Table 1).
- During drought period, almost 50% of the combined effect of Rg and REW drove the variability in ET although Rg has more control over REW. There was no effect of Ts (Table 1).
- Driest years in French Guiana occurred in 2004, 2005, 2008 and 2012 (NOAA, 2015). Interestingly, years having negative drought index (SWSI) values during drought period correspond to most of these dry years: 2005, 2008, 2010, and 2012 (Fig. 5). These were also the same years with relatively longer drought duration and with severe water stress intensity (Fig. 6).
- Regression analysis showed that when the soil water stress level is strong, normalized ET were reduced (Fig. 7).
- After comparing the slopes among years, we assume that at tree level, depending on drought intensity, some species would suffer from drought and some do not. Thus, at ecosystem level, the response of ET to drought might depend upon the severity of drought (as some trees may or may not be affected by drought, depending on drought length and/or severity).

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