New Phytologist

New Phytologist Supporting Information

Article title: Leaf reflectance spectroscopy captures variation in carboxylation capacity across species, canopy environment, and leaf age in lowland moist tropical forests

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Article acceptance date: 21 June 2019

The following Supporting Information is available for this article:

Fig. S1 Example demonstration of partial least squares regression (PLSR) analysis for spectra-$V_{c,max25}$ relationship.

Fig. S2 Example demonstration of partial least squares regression (PLSR) analysis for spectra-age relationship.

Fig. S3 The final spectra-$V_{c,max25}$ model was trained using two thirds of our entire dataset, and then applied to the remaining, independent validation datasets.

Table S1 Site, species, canopy positions, traits and leaf age for trees sampled with leaf spectral and physiological measurements in two Panamanian tropical forests and one Brazilian tropical forest.

Table S2 Leaf gas exchange, spectra, LMA, and age data sources.

Fig. S1 Example demonstration of partial least squares regression (PLSR) analysis for spectra-$V_{c,max25}$ relationship, including (a) the histogram distribution of field observed $V_{c,max25}$, (b) the histogram distribution of the square root of field-observed $V_{c,max25}$, (c) the relationship between root mean square error (RMSE) of the 30% independent validation through 100-time random 7-fold permutations of calibration data and the number of latent variables (error bars are one standard deviation bootstrapped from 100 random fittings of the calibration data), where the optimal latent variable was achieved at 11 (in blue box), and (d) the PLSR spectral coefficients of the spectra-$V_{c,max25}$ relationship under optimal latent variables with central black line for the mean value and gray shaded region for the 95% confidence interval. The model coefficients shown in panel d multiplied by leaf-level spectral reflectance will enable the prediction of square root of $V_{c,max25}$. The panel (c) and (d) demonstrated here are based on the community level spectra-$V_{c,max25}$ model including the dataset from both Panama and Brazil, as shown in Fig. 3.

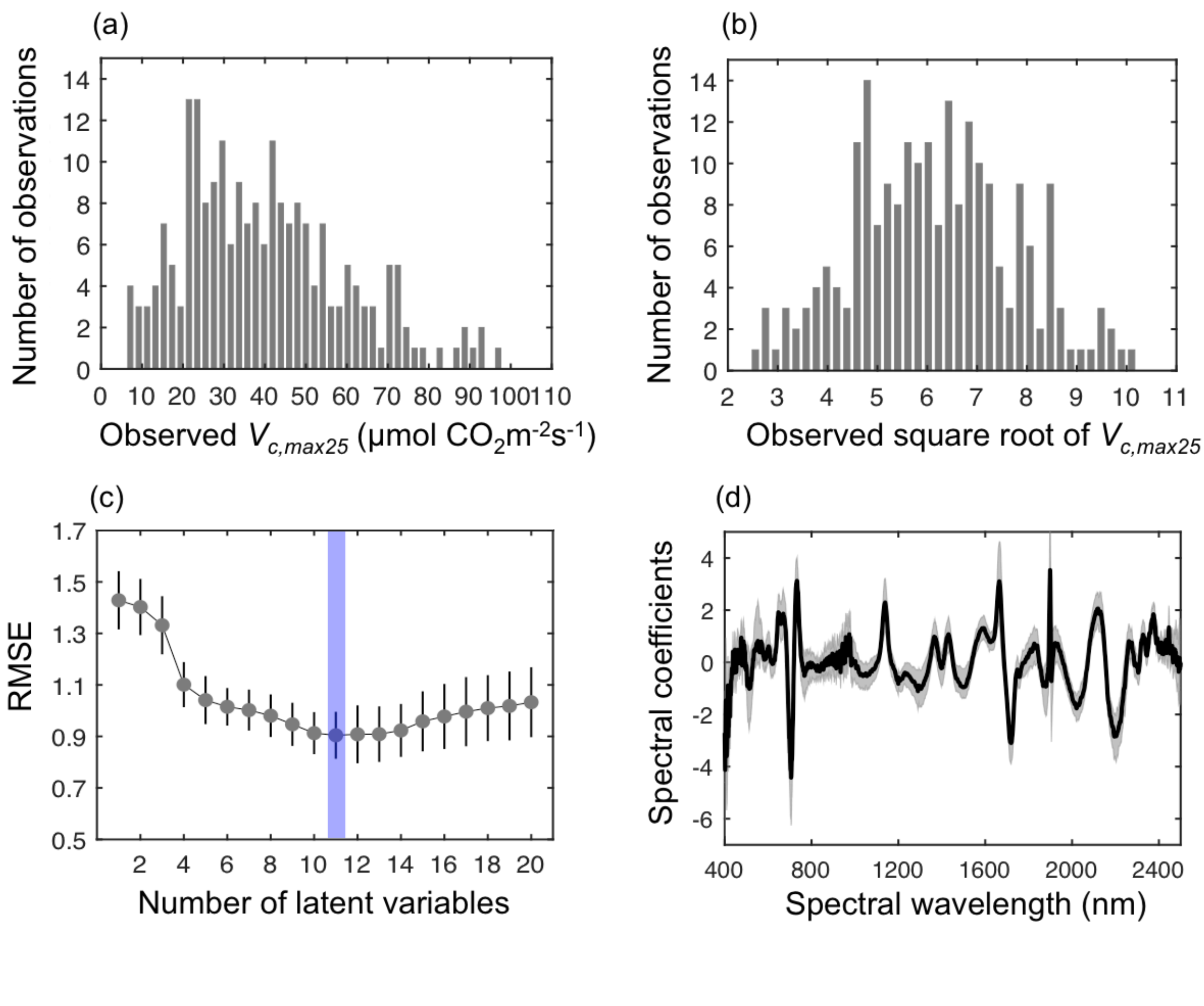

Fig. S2 Example demonstration of partial least squares regression (PLSR) analysis for spectra-age relationship, including (a) the histogram distribution of field observed age (in days), (b) the histogram distribution of the square root of field-observed age, (c) the relationship between root mean square error (RMSE) of the 30% independent validation through 100-time random 7-fold permutations of calibration data and the number of latent variables, where the optimal latent variable was achieved at 5 (in blue box), and (d) the PLSR spectral coefficients of the spectra-age relationship under optimal latent variables with central black line for the mean value and gray shaded region for the 95% confidence interval. The model coefficients shown in panel d multiplied by leaf-level spectral reflectance will enable the prediction of square root of leaf age. The panel (c) and (d) demonstrated here are based on the community level spectra-age model including all Brazilian spectra-age data used in Wu *et al* (2017).

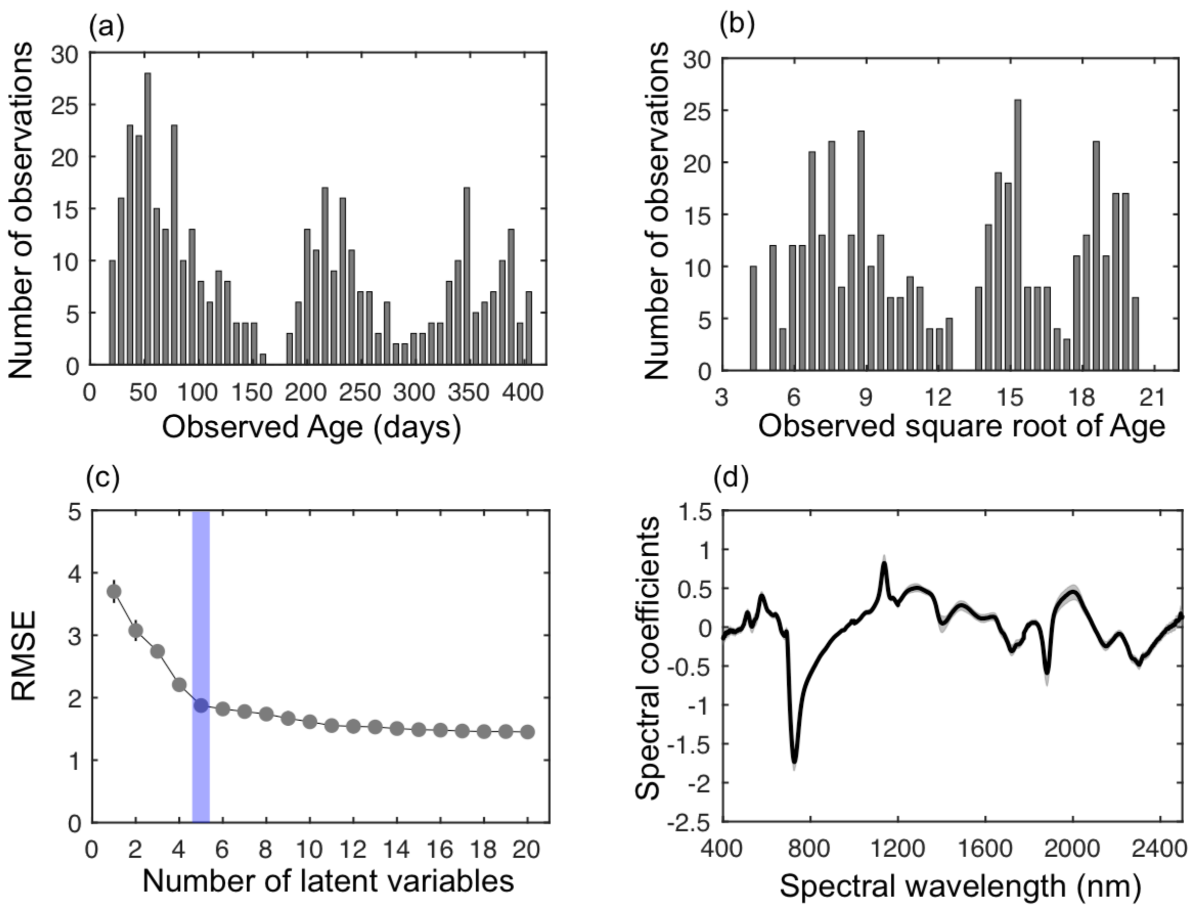

Fig. S3 The final spectra-$V_{c,max25}$ model was trained using two thirds of our entire dataset, and then applied to the remaining, independent validation dataset of (a) Panamanian immature leaves, (b) Brazilian mature and immature leaves, and (c) Panamanian mature leaves. Error bars denote the 95% confidence intervals for each predicted value based on the ensemble PLSR models, the gray line shows the ordinary least square regression fit, and the black line shows the 1:1 line.

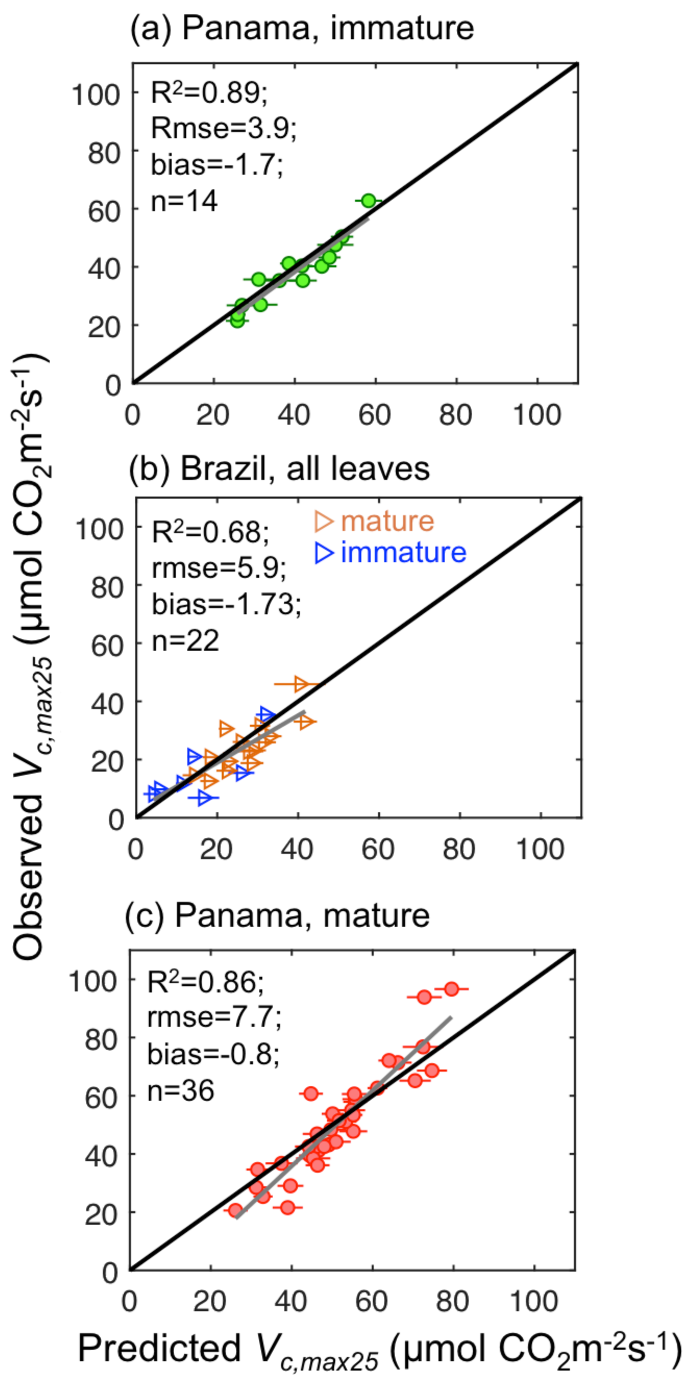

Table S1 Site, species, canopy positions, traits and leaf age for trees sampled with leaf spectral and physiological measurements in two Panamanian tropical forests and one Brazilian tropical forest.

Site	Time (year)	Species	Family	Canopy height (m)	$V_{c,max25}$-mature (μmol $m^{-2}s^{-1}$)	LMA-mature (g m^{-2})	# of gas exchange	# of gas exchange and spectra
SLZ	2016, 2017	*Guatteria dumetorum***	Annonaceae	35	37±11	88±10	24	24
SLZ	2016, 2017	*Miconia borealis***	Melastomataceae	25	59±12	105±12	30	30
SLZ	2016, 2017	*Terminalia Amazonia***	Combretaceae	27	48±11	113±15	21	21
SLZ	2016, 2017	*Vochysia ferruginea***	Vochysiaceae	29	52±14	131±18	25	25
SLZ	2016	*Tocoyena pittieri***	Rubiaceae	27	40±9	95±8	11	10
SLZ	2016	*Tachigali versicolor***	Fabaceae	30	36±4	100±6	8	7
SLZ	2016	*Carapa guianensis***	Meliaceae	34	29±8	124±1	4	4
SLZ	2016	*Apeiba membranacea**	Tiliaceae	29	53±18	119±13	7	6
PNM	2016	*Albizia adinocephala***	Fabaceae	29	67±10	72±10	10	7
PNM	2016	*Anacardium excelsum***	Anacardiacea	39	48±7	96±9	5	4
PNM	2016	*Pittoniotis trichantha**	Rubiaceae	19	30±8	81±25	8	4
PNM	2016	*Calycophyllum candidissimum**	Rubiaceae	20	44±19	82±6	8	3
PNM	2016	*Castilla elastica**	Moraceae	24	41±10	98±5	4	1
PNM	2016	*Cordia alliodora**	Boraginaceae	23	75±6	70±3	4	4
PNM	2016	*Ficus insipida**	Moraceae	31	79±16	119±11	9	6
PNM	2016	*Luehea seemannii**	Tiliaceae	26	87±7	132±21	8	5
K67	2012	*Erisma uncinatum**+*	Vochysiaceae	39	21±9	143±32	34	32
K67	2012, 2013	*Chamaecrista xinguensis**+*	Fabaceae	25	25±11	83±35	18	15
K67	2012	*Mezilaurus itauba**+*	Lauraceae	37	22±8	128±39	11	11
K67	2012, 2013	*Manilkara elata**+*	Sapotaceae	38	37±11	213±28	11	8
K67	2012, 2013	*Tachigali cf. chrysophylla***	Fabaceae	44	44±20	161±26	7	3

Note: Three tropical forest sites include the San Lorezon crane site (SLZ) and the Parque Natural Metropolitano crane site (PNM) in The Republic of Panama, and the K67 eddy covariance tower site (K67) in the Tapajos National Forest near Santarem, Brazil; tree species-specific leaf carboxylation capacity (Vc,max25) and leaf mass per area (LMA) of mature leaves are shown here with mean ± one standard deviation; only sunlit canopy leaves were surveyed for Panamanian tree species, and canopy leaves from both sunlit and shade environments were surveyed for Brazilian tree species; leaf age record for each tree species is indexed by "*" (indicating those species with spectral and gas exchange measurements for the mature leaves only) or "**" (indicating those species with spectral and gas exchange measurements for both mature and immature leaves); the tree-species with in-situ monitoring of leaf age and spectra is marked in "+".

Table S2 Leaf gas exchange, spectra, LMA, and age data sources.

Site	Dataset	References
Panama	Leaf sample detail, Feb 2016 and April 2016, SLZ and PNM	(Ely *et al.*, 2019a)
	CO_2 response (ACi) gas exchange, calculated V_{cmax} & J_{max} parameters, Feb 2016 and April 2016, SLZ and PNM	(Rogers *et al.*, 2019a)
	Leaf spectra, Feb 2016 and April 2016, SLZ and PNM	(Serbin *et al.*, 2019)
	Leaf mass area, Feb 2016 and May 2016, SLZ and PNM	(Ely *et al.*, 2019b)
	Leaf sample details, leaf traits by age, Feb2017, SLZ	(Ely *et al.*, 2019c)
	CO_2 response (ACi) gas exchange by leaf age, V_{cmax} and J_{max} parameters, Feb 2017, SLZ	(Rogers *et al.*, 2019b)
	Leaf mass per area, by age, Feb 2017, SLZ	(Rogers *et al.*, 2019c)
	Leaf spectra by leaf age, Feb 2017, SLZ	(Serbin *et al.*, 2018)
Brazil	CO_2 response (ACi) gas exchange by leaf age, V_{cmax} and J_{max} parameters, leaf mass per area	(Albert *et al.*, 2018)
	Leaf spectra, and spectra-age dataset	(Wu *et al.*, 2017)

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