Change in hydraulic properties and leaf traits in a tall rainforest tree species subjected to long-term throughfall exclusion in the perhumid tropics

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APPENDIX (SUPPLEMENTARY MATERIAL)

Tab. A1. List of abbreviations used in the text.

Symbol	Definition	Unit
A_{Lumen}	Total vessel lumen area	%
D	Vapor pressure deficit	kPa
d	Mean vessel diameter	µm
d_h	Hydraulically weighted mean vessel diameter	µm
HV	Huber value	
k_L	Leaf area-specific conductivity	kg m^{-1} MPa^{-1} s^{-1}
k_S	Sapwood area-specific conductivity	kg m^{-1} MPa^{-1} s^{-1}
k_S^{theo}	Theoretical sapwood area-specific conductivity	kg m^{-1} MPa^{-1} s^{-1}
L	Mean leaf area	cm^2
R	Global radiation	MJ m^{-2} d^{-1}
ρ	Wood density	kg m^{-3}
REW	Relative extractable water	
RH	Relative air humidity	%
SD	Stomatal density	n mm^{-2}
SLA	Specific leaf area	cm^2 g^{-1}
SWC	Saturated water content of stem xylem	%
T	Temperature	°C
VD	Vessel density	n mm^{-2}
Ψ_{soil}	Soil water potential	MPa
θ	Volumetric soil water content	m^3 m^{-3}

Tab. A2: Results from linear mixed-effects model runs comparing 26 sun canopy variables between the control (SuC) and drought (SuD) treatments considering the nested design of the sampling on different branches of a tree and on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

	Treatment SuC vs SuD						
Variable	**Control**	**Drought**	**p**	**δAIC**	**L.-ratio**	**Var. Plot**	**Var. Tree**
k_S	17.00 ± 1.46	12.37 ± 1.45	**0.035**	2.43	4.43	3.12E-07	1.12E+01
k_L (10^{-3})	7.15 ± 2.97	8.94 ± 2.96	0.644	-1.79	0.21	4.02E-13	4.94E-05
HV (10^{-4})	4.50 ± 1.64	6.37 ± 1.64	0.390	-1.26	0.74	2.64E-15	1.41E-07
SLA	71.43 ± 3.11	67.79 ± 3.11	0.379	-1.22	0.78	6.78E-06	6.30E+01
L	16.49 ± 1.75	22.17 ± 1.95	**0.025**	3.01	5.01	4.27E+00	7.33E+00
SD	495.24 ± 21.46	510.67 ± 21.46	0.585	-1.70	0.30	2.55E-04	2.48E+03
ρ_{branch}	547.56 ± 13.36	585.64 ± 15.23	0.072	1.23	3.23	3.42E-12	1.27E-03
$\delta^{13}C$	-28.51 ± 0.18	-28.26 ± 0.18	0.285	-0.86	1.14	8.98E-10	1.68E-01
$\delta^{15}N$	1.59 ± 0.90	2.03 ± 0.90	0.705	-1.86	0.14	1.76E-07	5.09E+00
$\delta^{18}O$	19.14 ± 0.21	19.80 ± 0.21	0.027	2.90	4.90	6.51E-10	2.27E-01
Mass-specific							
C	503.23 ± 5.40	494.37 ± 5.33	0.217	-0.48	1.52	3.65E-06	1.23E+02
N	18.05 ± 0.51	17.56 ± 0.50	0.455	-1.44	0.56	3.12E-01	2.07E-01
P	0.76 ± 0.04	0.78 ± 0.04	0.894	-1.98	0.02	1.79E-03	5.02E-03
Ca	5.00 ± 0.38	3.64 ± 0.38	**0.017**	3.71	5.71	3.93E-09	9.41E-01
Fe	0.05 ± 0.01	0.03 ± 0.01	0.226	-0.53	1.47	2.30E-04	8.97E-05
K	4.87 ± 0.24	4.72 ± 0.24	0.648	-1.79	0.21	1.74E-09	4.03E-01
Mg	1.79 ± 0.10	1.43 ± 0.10	**0.016**	3.76	5.76	3.21E-11	7.12E-02
Mn	0.63 ± 0.09	0.64 ± 0.09	0.931	-1.99	0.01	2.93E-11	4.95E-02
Area-specific							
C	71.19 ± 2.94	74.16 ± 2.94	0.443	-1.41	0.59	7.55E-07	5.43E+01
N	2.50 ± 0.14	2.63 ± 0.16	0.643	-1.79	0.21	2.98E-02	5.91E-02
P	0.10 ± 0.01	0.12 ± 0.01	0.245	-0.65	1.35	1.72E-04	1.70E-05
Ca	0.71 ± 0.06	0.54 ± 0.06	0.057	1.63	3.63	7.11E-12	2.45E-02
Fe	0.007 ± 0.002	0.005 ± 0.002	0.333	-1.06	0.94	4.99E-06	2.71E-06
K	0.69 ± 0.03	0.70 ± 0.03	0.662	-1.81	0.19	7.06E-12	4.35E-03
Mg	0.25 ± 0.01	0.21 ± 0.01	0.074	1.20	3.20	5.20E-12	1.42E-03
Mn	0.09 ± 0.01	0.09 ± 0.01	0.677	-1.83	0.17	5.60E-12	9.71E-04

Tab. A3: Results from linear mixed-effects model runs comparing 26 shade crown variables between the control (ShC) and drought (ShD) treatments considering the nested design of the sampling on different branches of a tree and on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

	Treatment ShC vs ShD						
Variable	**Control**	**Drought**	**p**	**δAIC**	**L.-ratio**	**Var. Plot**	**Var. Tree**
k_S	18.62 ± 2.12	14.15 ± 2.16	0.130	0.30	2.30	1.18E+00	2.44E+01
k_L (10^{-3})	7.15 ± 2.97	8.94 ± 2.96	0.162	-0.05	1.95	1.24E-13	3.19E-06
HV (10^{-4})	4.50 ± 1.64	6.37 ± 1.64	0.561	-1.66	0.34	7.52E-17	4.33E-09
SLA	85.11 ± 5.58	89.10 ± 5.78	0.524	-1.59	0.41	1.72E+01	5.17E+01
L	28.75 ± 4.85	38.91 ± 6.06	0.111	0.54	2.54	6.05E+01	3.73E+01
SD	442.92 ± 28.28	445.23 ± 34.60	0.923	-1.99	0.01	1.88E+03	1.25E+03
ρ_{branch}	531.73 ± 24.61	535.30 ± 24.60	0.916	-1.99	0.01	3.31E-11	3.96E-03
$\delta^{13}C$	-29.54 ± 0.23	-29.18 ± 0.23	0.249	-0.67	1.33	6.30E-04	3.25E-01
$\delta^{15}N$	0.70 ± 0.35	-0.15 ± 0.35	0.085	0.97	2.97	1.89E-08	8.57E-01
$\delta^{18}O$	18.86 ± 0.23	19.25 ± 0.23	0.208	-0.41	1.59	1.11E-09	2.88E-01
Mass-specific							
C	504.51 ± 7.85	488.78 ± 9.44	0.128	0.31	2.31	1.34E+02	1.52E+02
N	18.15 ± 0.46	16.61 ± 0.46	**0.042**	2.14	4.14	2.44E-07	1.28E+00
P	0.77 ± 0.03	0.79 ± 0.03	0.568	-1.67	0.33	1.72E-11	3.06E-03
Ca	4.86 ± 0.34	3.53 ± 0.34	**0.012**	4.31	6.31	2.46E-09	7.32E-01
Fe	0.05 ± 0.01	0.03 ± 0.01	0.194	-0.31	1.69	2.34E-05	2.05E-04
K	5.00 ± 0.30	4.90 ± 0.30	0.796	-1.93	0.07	2.19E-09	5.50E-01
Mg	2.22 ± 0.17	1.86 ± 0.21	0.122	0.39	2.39	7.53E-02	4.58E-02
Mn	0.52 ± 0.06	0.58 ± 0.06	0.493	-1.53	0.47	1.67E-12	2.47E-02
Area-specific							
C	61.08 ± 3.21	58.53 ± 3.20	0.543	-1.63	0.37	3.08E-06	5.97E+01
N	2.18 ± 0.11	1.98 ± 0.11	0.179	-0.19	1.81	7.08E-09	6.10E-02
P	0.092 ± 0.004	0.094 ± 0.004	0.612	-1.74	0.26	1.35E-12	3.56E-06
Ca	0.58 ± 0.04	0.43 ± 0.04	**0.024**	3.08	5.08	4.38E-12	1.01E-02
Fe	0.005 ± 0.001	0.004 ± 0.001	0.200	-0.36	1.64	1.67E-06	2.43E-06
K	0.59 ± 0.03	0.58 ± 0.03	0.770	-1.91	0.09	5.48E-13	1.10E-03
Mg	0.25 ± 0.02	0.23 ± 0.02	0.344	-1.10	0.90	3.59E-12	1.57E-03
Mn	0.06 ± 0.01	0.07 ± 0.01	0.358	-1.15	0.85	1.08E-12	2.64E-04

Tab. A4: Results from linear mixed-effects model runs comparing 26 variables between the upper (SuC) and lower canopy (ShC) for the control considering the nested design of the sampling on different branches of a tree and on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

		Canopy Position SuC vs ShC					
Variable	**Control**	**Drought**	**p**	**δAIC**	**L.-ratio**	**Var. Plot**	**Var. Tree**
k_S	16.20 ± 2.28	17.95 ± 2.28	0.139	0.19	2.19	1.24E+01	6.74E+00
k_L (10^{-3})	7.15 ± 2.97	8.94 ± 2.96	**0.009**	4.74	6.74	7.64E-07	3.95E-13
HV (10^{-4})	4.50 ± 1.64	6.37 ± 1.64	**0.002**	7.83	9.83	2.42E-08	1.96E-16
SLA	73.58 ± 5.47	86.85 ± 5.47	**<0.001**	47.73	49.73	1.11E+02	4.59E+00
L	17.09 ± 3.73	28.16 ± 3.73	**<0.001**	44.91	46.91	3.42E+01	2.36E+01
SD	474.17 ± 29.77	443.70 ± 29.77	**0.026**	2.95	4.95	2.78E+03	4.21E+02
ρ_{branch}	547.82 ± 18.35	535.80 ± 18.38	0.353	-1.14	0.86	1.03E-11	1.77E-03
$\delta^{13}C$	-28.42 ± 0.18	-29.45 ± 0.18	**<0.001**	42.08	44.08	8.00E-02	1.85E-02
$\delta^{15}N$	1.60 ± 0.60	0.74 ± 0.60	**0.006**	5.47	7.47	4.09E-08	2.17E+00
$\delta^{18}O$	19.14 ± 0.14	18.86 ± 0.14	0.108	0.59	2.59	3.07E-10	2.86E-02
Mass-specific							
C	500.49 ± 8.00	506.42 ± 7.97	0.277	-0.82	1.18	1.23E+02	9.06E+01
N	18.04 ± 0.51	18.14 ± 0.51	0.800	-1.94	0.06	4.00E-02	1.19E+00
P	0.77 ± 0.01	0.77 ± 0.01	0.833	-1.96	0.04	5.38E-12	1.82E-14
Ca	4.99 ± 0.36	4.86 ± 0.36	0.438	-1.40	0.60	6.08E-09	7.99E-01
Fe	0.04 ± 0.01	0.05 ± 0.01	0.345	-1.11	0.89	8.37E-05	1.92E-04
K	4.87 ± 0.23	5.00 ± 0.23	0.315	-0.99	1.01	9.40E-09	3.09E-01
Mg	1.88 ± 0.15	2.20 ± 0.15	**<0.001**	31.29	33.29	7.45E-02	1.41E-02
Mn	0.63 ± 0.06	0.52 ± 0.06	**<0.001**	16.28	18.28	9.28E-11	2.09E-02
Area-specific							
C	69.27 ± 3.85	59.00 ± 3.84	**<0.001**	33.26	35.26	5.36E+01	7.65E-01
N	2.46 ± 0.16	2.08 ± 0.16	**<0.001**	21.53	23.53	8.51E-02	4.23E-03
P	0.11 ± 0.01	0.09 ± 0.01	**<0.001**	24.20	26.20	1.16E-04	4.47E-06
Ca	0.71 ± 0.05	0.58 ± 0.05	**<0.001**	17.77	19.77	9.93E-05	1.74E-02
Fe	0.006 ± 0.002	0.006 ± 0.002	0.979	-2.00	0.001	6.41E-06	2.73E-06
K	0.69 ± 0.03	0.59 ± 0.03	**<0.001**	21.22	23.22	1.33E-11	3.70E-03
Mg	0.25 ± 0.01	0.25 ± 0.01	0.839	-1.96	0.04	3.04E-12	2.67E-04
Mn	0.09 ± 0.01	0.06 ± 0.01	**<0.001**	33.79	35.79	3.38E-12	2.47E-04

Tab. A5: Results from linear mixed-effects model runs comparing 26 variables between the upper (SuD) and lower canopy (ShD) for the drought treatment considering the nested design of the sampling on different branches of a tree and on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

		Canopy Position SuD vs ShD					
Variable	**Control**	**Drought**	**p**	**δAIC**	**L.-ratio**	**Var. Plot**	**Var. Tree**
k_S	12.49 ± 1.46	14.02 ± 1.48	0.207	-0.41	1.59	1.32E-07	9.85E+00
k_L (10^{-3})	7.15 ± 2.97	8.94 ± 2.96	**0.005**	5.96	7.96	3.75E-13	2.14E-05
HV (10^{-4})	4.50 ± 1.64	6.37 ± 1.64	**0.001**	10.00	12.00	1.41E-15	4.20E-08
SLA	67.71 ± 4.59	89.12 ± 4.70	**<0.001**	11.22	13.22	3.01E-06	3.94E+01
L	21.94 ± 1.54	38.87 ± 1.57	**<0.001**	52.60	54.60	6.55E-01	3.63E+00
SD	510.67 ± 19.70	446.67 ± 19.70	**<0.001**	13.31	15.31	6.05E-05	1.95E+03
ρ_{branch}	588.49 ± 18.22	534.99 ± 18.35	**<0.001**	22.05	24.05	9.57E-12	2.00E-03
$\delta^{13}C$	-28.18 ± 0.23	-29.24 ± 0.23	**<0.001**	47.00	49.00	1.61E-09	3.24E-01
$\delta^{15}N$	2.22 ± 0.75	-0.10 ± 0.75	**<0.001**	22.75	24.75	4.23E-01	1.81E+00
$\delta^{18}O$	19.77 ± 0.26	19.30 ± 0.26	**0.004**	6.11	8.11	1.82E-09	3.84E-01
Mass-specific							
C	494.37 ± 4.15	488.90 ± 4.15	**<0.001**	28.89	30.89	3.37E-06	1.18E+02
N	17.53 ± 0.44	16.63 ± 0.44	**<0.001**	12.29	14.29	5.59E-08	1.16E+00
P	0.77 ± 0.05	0.79 ± 0.05	0.608	-1.74	0.26	2.43E-03	7.56E-03
Ca	3.65 ± 0.34	3.51 ± 0.34	0.298	-0.91	1.08	6.15E-09	7.30E-01
Fe	0.03 ± 0.01	0.03 ± 0.01	0.857	-1.97	0.03	9.97E-13	1.01E-04
K	4.73 ± 0.27	4.88 ± 0.27	0.251	-0.68	1.32	4.59E-09	4.39E-01
Mg	1.43 ± 0.09	1.87 ± 0.09	**<0.001**	45.79	47.79	1.07E-10	4.53E-02
Mn	0.64 ± 0.08	0.56 ± 0.08	**0.041**	2.19	4.19	9.19E-11	4.26E-02
Area-specific							
C	74.92 ± 2.94	57.82 ± 2.94	**<0.001**	40.62	42.62	9.70E-07	4.38E+01
N	2.65 ± 0.08	1.95 ± 0.08	**<0.001**	47.34	49.34	2.51E-10	2.79E-02
P	0.12 ± 0.01	0.09 ± 0.01	**<0.001**	15.09	17.09	8.06E-05	4.49E-05
Ca	0.54 ± 0.05	0.42 ± 0.05	**<0.001**	14.93	16.93	1.09E-12	1.20E-02
Fe	0.005 ± 0.001	0.004 ± 0.001	0.254	-0.70	1.30	3.81E-14	1.80E-06
K	0.71 ± 0.02	0.58 ± 0.02	**<0.001**	14.02	16.02	1.44E-12	1.20E-22
Mg	0.22 ± 0.02	0.23 ± 0.02	0.184	-0.23	1.77	9.94E-12	2.25E-03
Mn	0.10 ± 0.01	0.07 ± 0.01	**<0.001**	13.14	15.14	4.03E-12	7.41E-04

Tab. A6: Results from linear mixed-effects model runs comparing biometric, morphological, anatomical and hydraulic characteristics of the trunks (Tab. 2) considering the nested design of the sampling on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

Variable	Control	Drought	P	δAIC	L.-ratio	Var. Plot	Var. Tree
DBH	56.17 ± 5.26	58.14 ± 5.46	0.720	-1.87	0.13	14.81	
H_{high}	39.75 ± 3.24	40.19 ± 3.99	0.522	-1.59	0.41	25.41	
H_{low}	18.43 ± 1.50	18.43 ± 1.50	1.000	-2.00	0.00	0.00	
ρ_{stem}	513.74 ± 9.80	538.82 ± 9.80	***0.066***	1.38	3.38	0.00	
SWC	113.69 ± 3.69	102.80 ± 3.69	**0.037**	2.33	4.33	0.00	
A_{Lumen}	17.18 ± 2.10	15.28 ± 2.65	0.544	-1.63	0.37	12.00	
VD	3.26 ± 0.31	3.19 ± 0.38	0.965	-2.00	0.00	0.25	
d	251.17 ± 8.63	240.30 ± 9.90	0.378	-1.22	0.78	133.34	185.23
d_h	295.39 ± 9.27	283.21 ± 10.34	0.380	-1.23	0.77	131.73	
k_S	465.92 ± 75.26	372.80 ± 94.60	0.391	-1.27	0.73	15145.78	

Tab. A7: Results from linear mixed-effects model runs comparing branch wood anatomical traits from upper sun-lit crown (Tab. 5) considering the nested design of the sampling on different branches of a tree and on different trees within a plot. Given are the estimated means ± 1 SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

Variable	Control	Drought	P	δAIC	L.-ratio	Var. Plot	Var. Tree
A_{Lumen}	0.09 ± 0.01	0.10 ± 0.01	0.604	-1.73	0.27	0.00	0.00
VD	20.97 ± 2.23	25.70 ± 2.28	0.131	0.29	2.29	0.92	17.71
d	70.49 ± 3.92	65.63 ± 3.92	0.338	-1.08	0.92	0.00	63.96
d_h	92.96 ± 4.96	85.83 ± 4.96	0.270	-0.78	1.22	0.00	101.33
k_S	21.54 ± 3.80	21.07 ± 3.80	0.921	-1.99	0.01	0.00	58.26
LSC (10^{-4})	34.49 ± 26.54	60.60 ± 26.54	0.443	-1.41	0.59	0.00	0.00

Tab. A8: Results from linear mixed-effects model runs comparing stem increment data considering the nested design of the sampling on different trees within a plot. Given are the estimated means ± SE for the two treatments, the p-value of the treatment difference, the difference in the Akaike Information Criterion of the models (δAIC), the likelihood ratio (L.-ratio), and the variance between plots (Var.Plot) and between the trees in a plot (Var.Tree).

Period	**Control**	**Drought**	**p**	**δAIC**	**L.-ratio**	**s^2 Plot**
1st year	1.12 ± 0.16	0.85 ± 0.12	0.156	0.02	2.02	0.00
2nd year	0.95 ± 0.13	0.68 ± 0.09	***0.079***	1.09	3.09	0.00
Whole period	2.07 ± 0.25	1.53 ± 0.19	***0.077***	1.12	3.12	0.00