Supplementary Information for *Drought and tree size determine total stem CO_2 efflux in a tropical forest*

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Methods S1

Diurnal measurements of CO_{2_stem}

During October 2013, 20 trees of the dominant genera (Trees shown in Table 1 in Rowland et al 2015) across both plots were fitted with automated open path stem respiration system. A large or small transparent acrylic chamber (large: volume (with foam and tubing) = 676 cm^3, surface area =126 cm^2; small: volume (with foam and tubing) = 420 cm^3, surface area = 90 cm^2) was attached to each tree, using a system of straps, as described in the methods section. The chamber was connected to a large storage box which acted as a 145 L buffer volume to minimise fluctuations in CO_2 concentration in the delivery air. Air was pumped from the buffer volume to the chamber and from the chamber using two 1.8 L min^{-1} micro diaphragm air pumps, these pumps were connected to manual flow regulators to regulate the flow to between 1-1.3 L min^{-1}. A CIRAS1 IRGA (PP Systems, Hitchen, UK), was then used in an open path system to sample the coming from the buffer and going into the chamber (reference), and the air coming out of the chamber (sample, Hutchinson & Livingston 1993). The IRGA was connected to a CR1000 data logger (Campbell Scientific, Logan, USA) which recorded data from the reference and the sample tubes every 15 seconds, alongside air temperature and atmospheric pressure. Respiration was calculated as the difference in CO_2 between the reference and the sample lines (moles) multiplied by the moles of gas through the chamber per second, calculated using temperature, pressure and the universal gas constant. The respiration flux was then divided by chamber surface area and converted to μmol m^{-2} s^{-1}. The CR1000 also monitored wood temperature from a type T thermocouple inserted into the sapwood of each tree. Two respiration systems were created and left on each tree for a 24 hour period. After installation each system was tested for leaks following the same method listed above. All data was averaged into hourly intervals for each plot. Hours with data for <16 trees were removed, these hours tended to be between 0900 hrs and 1300 hrs when the chambers were changed

over. Due to problems with high humidity during wet season, we were unable to successfully use this equipment in the wet season, hence our estimates are based off dry season only measurements. However during the dry season we found limited diurnal variation in CO_{2_stem}. On the control plot we found a slight decline (mean -3.5±10.7%) in the measurements between 9 am and 7 pm (Fig. S1a). However on the TFE plot we found very limited diurnal variation in CO_{2_stem} (Fig. S1b), suggesting there was very limited influence of time of day on our measurements during the dry season. Due to very high humidity and water in equipment, data quality was not high enough to use the wet season data, so we assume the same diurnal stability during wet and dry season.

Measurements of sapwood depth

In October 2013 tree cores between 15-20 cm in length were extracted at 1.3 m from 21 trees on the TFE and control plot (trees shown in Table 1 in Rowland et al 2015), using an increment borer. In 18 of these tree cores there was a visible change in colour between the sapwood and the heartwood. The sapwood depth in these trees were measured and the (linear) relationships between sapwood depth and diameter, and sapwood area and basal area were plotted (see Fig. S2).

Scaling CO_{2_stem}

Method 1: Scaling by surface area

The average wet and dry season CO_{2_stem} values were multiplied by the total stem surface area per plot, calculated using the following equation S1 from Chambers et al., 2004.

$$SA = 10\text{^}(-0.105 - 0.686 * log10(dbh) + 2.208 * log10(dbh)^2 - 0.627 * log10(dbh)^3) \quad \textit{Equations S1}$$

Where SA is surface area in m^2 and dbh is diameter at breast height (1.3 m). These scaling equations are based on highly simplified tree forms, and may not accurately represent the diversity of branching structures which exists in tropical forests.

Method 2: Scaling by sapwood volume

Using a relationship between sapwood depth and diameter (Fig. S1, see above for methods) sapwood area was calculated using basal area, calculated from dbh measured on our sample trees in December 2015. Sapwood area was used to convert CO_{2_stem} to μmol m^{-3} s^{-1}. Using the same basal area-sapwood area relationship applied to all trees we calculated that sapwood area comprised on average 34% of basal area at breast height (1.3 m). Firstly, we assumed that this was fixed across the whole tree volume, which was calculated using the tropical moist forest equations from Chave et al. (2005). The small diameter parts of the tree, particularly branches, are however, likely to comprise greater amounts of sapwood and therefore 34% is likely to be a substantial underestimate. Given that there are no estimates of the proportion of total tree volume that is sapwood within tropical trees, we tested how sensitive our flux values were to an increase of sapwood volume to 50% and 80% of total volume.

Method 3: Scaling by surface area and volume

Using a stem tapering function for tropical trees taken from Chave et al. (2005) we estimated the height of the bole at which 10 cm occurred and calculated the volume of this cylinder between this point and the ground using the dbh of each tree measured in December 2015. The sapwood volume was then calculated by applying the same tapering function to our calculated sapwood area for each tree. The respiration by volume for the wood with >10 cm diameter was calculated and summed and the area of this wood subtracted from the total surface area calculated for each plot (see Method 1). Respiration for the remaining surface area was then calculated following Method 1 and added to the respiration by volume to give plot totals.

CO_{2_stem} *time-series.*

From October 2013 to February 2016 CO_{2_stem} measurements on 21 intensively studied trees, of the six most common genera on the control plot and the TFE (trees shown in Table 1 in Rowland et al 2015) were taken using the same method described in the Methods section of this manuscript (closed loop gas analysis measurement method). Measurements were made on the 17/10/2013, 26/10/2013, 08/03/2014, 12/06/2014, 17/06/2014, 10/01/2016, and 10/02/2016. The average values of CO_{2_stem} from these previous measurements appear higher than we estimate here (Fig. 1b), and this may be because of a limited sample size (only 21 trees per plot). However we use these data to support our finding that differences in CO_{2_stem} between the control and the TFE plots are consistently elevated with respect to the control plot during the wet season, and more equal during the dry season (Fig. 1b).

References

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Supplementary Figures

Figure S1: The percentage variation in the CO_2 efflux during a 24 hour period for 20 trees from the control (a.) and TFE (b.) plot during the dry season of 2013 (October). Errors bars indicate the standard error.

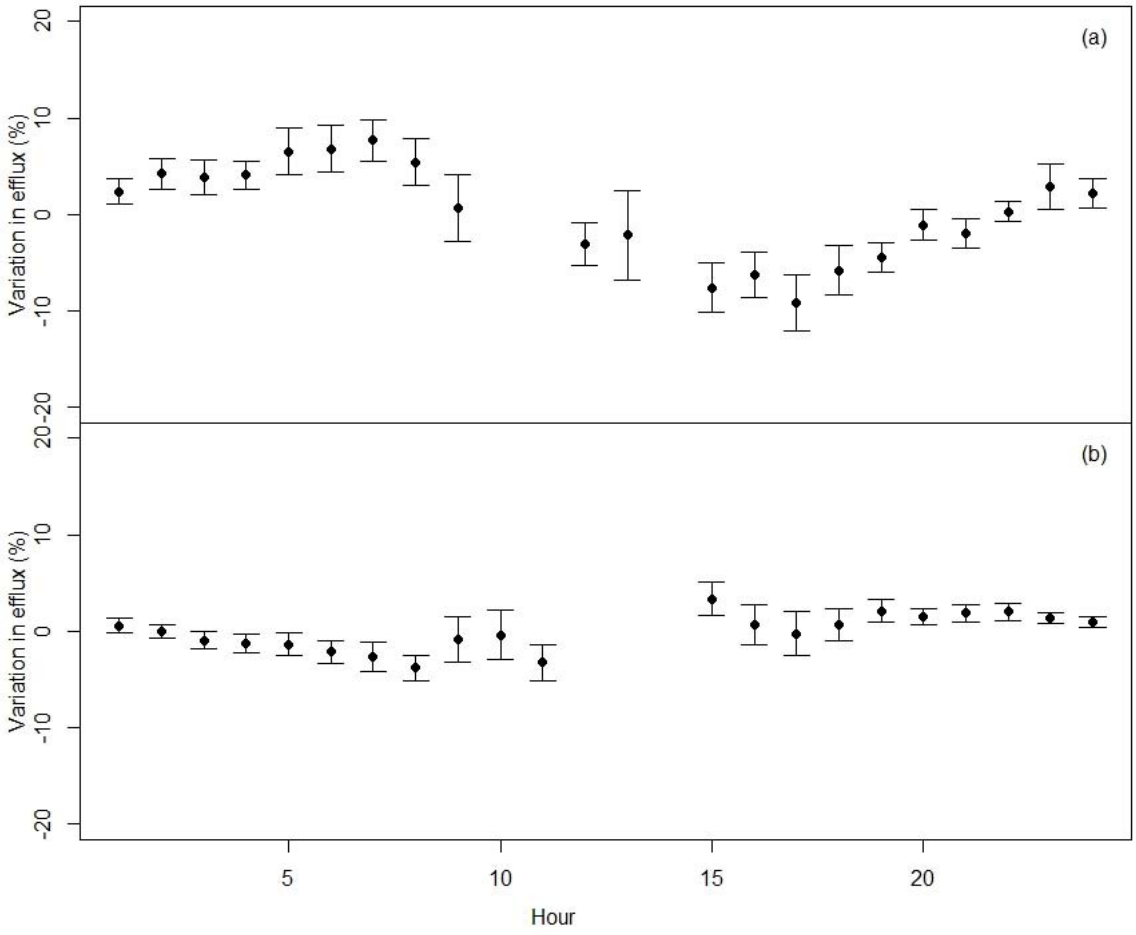

Fig. S2. Relationship between sapwood depth and diameter at breast height (dbh; a.) and the relationship between sapwood area (SA) and basal area (BA; b.), used for scaling by sapwood volume.

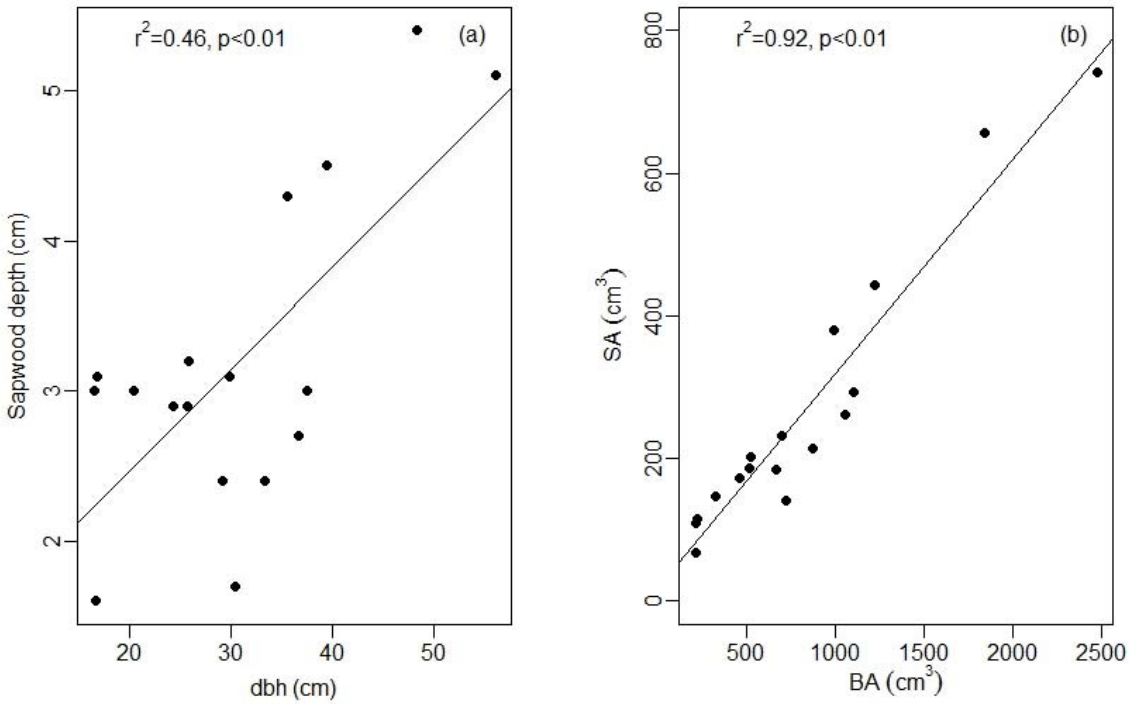

Table S1: List of each tree species sampled, the diameter at breat height of each tree (DBH, cm) and the date a successful stem CO_2 efflux measurement (without leaks, see Materials and Methods) were taken from the trees.

Tr	Pl	Genus	Species	DB	Oc	Oc	Ma	Ju	Ju	Ja	Fe	Oc	Ap
1	C	Vouacapoua	americana	20.								x	x
2	C	Stryphnode		68.								x	x
3	C	Vouacapoua	americana	38.								x	x
4	C	Inga	alba	39.								x	x
5	C	Aspidosper	desmanthu	14.								x	x
6	C	Pouteria	anomala	16.								x	x
7	C	Protium	tenuifoliu	37.								x	x
8	C	Qualea	paraensis	107								x	x
9	C	Swartzia	racemosa	32.								x	
10	C	Vantanea	parvifolia	47.								x	x
11	C	Licania	octandra	11.								x	
12	C	Pouteria	decortican	24.								x	x
13	C	Aspidosper		14.								x	x
14	C	Eschweilera	grandiflor	16.								x	x
15	C	Aspidosper	nitidum	33.									x
16	C	Eschweilera	coriacea	19.								x	x
17	C	Vouacapoua	americana	25.								x	x
18	C	Pouteria	gongriijpii	53.								x	x
19	C	Licania	octandra	18.								x	x
20	C	Eschweilera	grandiflor	18.								x	x
21	C	Vouacapoua	americana	12.								x	x
22	C	Pouteria	decortican	11.								x	x
23	C	Pouteria	decortican	17.								x	x
24	C	Pouteria	anomala	17.								x	x
25	C	Minquartia	guianensis	14.								x	x
26	C	Swartzia	racemosa	21.								x	x
27	C	Syzygiopsis	oppositifol	50.									x
28	C	Vouacapoua	americana	56.								x	x
29	C	Pouteria	guianensis	51.								x	x
30	C	Micropholis	venulosa	21.								x	x
31	C	Pouteria	cladantha	55.								x	x
32	C	Vouacapoua	amaricana	34.								x	x
33	C	Goupia	glabra	68.								x	x
34	C	Vouacapoua	americana	28.								x	x
35	C	Minquartia	guianensis	15.								x	x
36	C	Pouteria	decortican	20.								x	x
37	C	Protium	tenuifoliu	11.								x	x
38	C	Virola	micheli	47.									x
39	C	Eschweilera	coriacea	38.								x	x
40	C	Micropholis	venulosa	26.								x	x
41	C	Pouteria	anomala	13.								x	x
42	C	Swartzia	racemosa	47.								x	x
43	C	Chrysophyll	manoense	56.								x	x
44	C	Newtonia	suaveolen	76.								x	x
45	C	Inga	gracilifoli	15.								x	x
46	C	Licania	octandra	23.								x	x
47	C	Swartzia	racemosa	67.								x	x

48	C	Vouacapoua	americana	21.								x	x
49	C	Vouacapoua	americana	24.								x	x
50	C	Pouteria	decortican	12.								x	x
51	C	Licania	membrana	23.								x	x
52	C	Swartzia	racemosa	26.								x	x
53	C	Pouteria	trilocularis	60.								x	x
54	C	Brosimum	potabile	65.								x	
55	C	Inga	alba	44.								x	x
56	C	Micropholis	venulosa	35.								x	x
57	C	Aspidosper	araracanga	23.								x	x
58	C	Pouteria	anomala	59.								x	x
59	C	Goupia	glabra	92.								x	
60	C	Syzygiopsis	oppositifol	13.								x	x
61	C	Sclerolobiu	paraensis	51.								x	x
62	C	Swartzia	racemosa	29.								x	x
63	C	Syzygiopsis	oppositifol	51.								x	x
64	C	Protium	tenuifoliu	27.								x	x
65	C	Pouteria	venulosa	15.								x	x
66	C	Eschweilera	grandiflor	23.								x	x
67	C	Micropholis	venulosa	62.								x	x
68	C	Syzygiopsis	oppositifol	19.								x	x
69	C	Minquartia	guianensis	12.									
70	C	Pouteria	anomala	37.								x	x
71	C	Minquartia	guianensis	12.								x	x
72	C	Prieurella		48.								x	
73	C	Pouteria	decortican	13.									x
74	C	Protium	paniculatu	13.								x	x
75	C	Minquartia	guianensis	40.								x	x
76	C	Swartzia	racemosa	58.								x	x
77	C	Syzygiopsis	oppositifol	29.								x	x
78	C	Syzygiopsis	oppositifol	34.									x
79	C	Virola	micheli	27.								x	x
80	C	Parkia	ulei	89.								x	x
81	C	Micropholis	venulosa	18.								x	x
82	C	Licania	octandra	10.								x	
83	C	Licania		79.								x	x
84	C	Protium	tenuifoliu	19.								x	x
85	C	Swartzia		73.								x	x
86	C	Swartzia	racemosa	39.								x	x
87	C	Vatairea	erythocarp	63.								x	x
88	C	Inga	indet	18.								x	x
89	C	Minquartia	guianensis	30.								x	x
90	C	Syzygiopsis	oppositifol	64.									x
91	C	Inga	indet	19.								x	x
92	C	Inga	gracilifoli	18.								x	x
93	C	Inga	capitata	29.								x	x
94	C	Eschweilera	grandiflor	41.								x	x
95	C	Inga	rubiginosa	26.								x	x
96	C	Minquartia	guianensis	16.									

97	C	Syzygiopsis	oppositifol	31.								x	x
98	C	Licania	membrana	27.								x	x
99	C	Micropholis	venulosa	29.								x	x
10	C	Licania	membrana	20.								x	x
10	C	Eschweilera	grandiflor	32.								x	x
10	C	Minquartia	guianensis	41.								x	x
10	C	Protium	pilossium	14.								x	x
10	C	Prieurella	prieurii	53.								x	x
10	C	Licania	octandra	21.								x	x
10	TF	Vouacapoua	americana	35.		97	97					x	x
10	TF	Manilkara	bidentata	53.		10	99					x	
10	TF	Guatteria	poeppigia	15.								x	x
10	TF	Vouacapoua	americana	16.								x	x
11	TF	Parkia	N/A	47.								x	x
11	TF	Guatteria	poeppigia	27.								x	x
11	TF	Protium	tenuifoliu	14.								x	x
11	TF	Minquartia	guianensis	12.								x	
11	TF	Guatteria	poeppigia	22.								x	x
11	TF	Dipteryx	Dipteryx	52.								x	x
11	TF	Minquartia	guianensis	28.								x	x
11	TF	Virola	michelii	34.								x	x
11	TF	Protium	tenuifoliu	33.								x	x
11	TF	Syzygiopsis	oppositifol	59.								x	x
12	TF	Mouriri	duckeana	72.								x	x
12	TF	Protium	tenuifoliu	26.								x	x
12	TF	Pouteria	jariensis	42.								x	x
12	TF	Aspidosper	araracanga	32.								x	x
12	TF	Micropholis	venulosa	15.								x	x
12	TF	Vouacapoua	americana	57.								x	x
12	TF	Virola	michelii	28.								x	x
12	TF	Inga	alba	48.								x	x
12	TF	Licania	octandra	14.								x	x
12	TF	Vouacapoua	americana	45.								x	x
13	TF	Minquartia	guianensis	31.								x	x
13	TF	Pouteria	anomala	25.								x	x
13	TF	Pouteria	decortican	12.								x	x
13	TF	Swartzia	racemosa	10.								x	x
13	TF	Swartzia	brachyrac	14.								x	x
13	TF	Diplotropis	purpurea	44.								x	x
13	TF	Protium	pilosimum	18.								x	x
13	TF	Aspidosper	desmanthu	19.								x	x
13	TF	Aspidosper	araracanga	17.								x	x
13	TF	Pouteria	indet	41.								x	x
14	TF	Tetragastris	panamensi	14.								x	x
14	TF	Protium	tenuifoliu	15.								x	x
14	TF	Protium	tenuifoliu	18.								x	x
14	TF	Eschweilera	decolorans	30.								x	
14	TF	Swartzia	racemosa	42.								x	
14	TF	Aspidosper	nitidum	25.								x	x

14	TF	Pouteria	venosa	17.								x	x
14	TF	Protium	tenuifoliu	36.								x	x
14	TF	Inga	gracilifoli	17.								x	x
14	TF	not	not	108								x	
15	TF	Inga	alba	47.								x	x
15	TF	Licania	octandra	21.								x	x
15	TF	Tetragastris	panamensi	23.								x	
15	TF	Inga	alba	56.								x	x
15	TF	Xylopia	nitida	45.								x	x
15	TF	Guatteria	poeppigia	17.								x	x
15	TF	Protium	tenuifoliu	29.								x	x
15	TF	Inga	gracilifoli	25.								x	x
15	TF	Licania	egleri	47.								x	x
15	TF	Trattinickia	N/A	159								x	x
16	TF	Quararibea	guianensis	67.								x	x
16	TF	Erisma	uncinatum	67.								x	x
16	TF	Manilkara	bidentata	53.								x	x
16	TF	Hymenaea	courbaril	47.								x	x
16	TF	Pouteria	decortican	11.								x	x
16	TF	Tetragastris	panamensi	22.								x	x
16	TF	Pouteria	anomala	20.								x	x
16	TF	Pouteria	decortican	11.								x	x
16	TF	Tetragastris	panamensi	14.								x	x
16	TF	Licania	membrana	17.								x	x
17	TF	Tetragastris	panamensi	12.								x	x
17	TF	Licania	octandra	11.								x	x
17	TF	Minquartia	guianensis	37.								x	x
17	TF	Tetragastris	panamensi	16.								x	x
17	TF	Eschweilera	grandiflor	18.								x	x
17	TF	Swartzia	racemosa	22.								x	x
17	TF	Inga	indet	13.								x	x
17	TF	Pouteria	venosa	41.								x	x
17	TF	Eschweilera	grandiflor	13.								x	x
17	TF	Aspidosper	araracanga	15.								x	x
18	TF	Pouteria	anomala	19.								x	x
18	TF	Swartzia	racemosa	49.								x	x
18	TF	Tetragastris	panamensi	13.								x	x
18	TF	Micropholis	venulosa	13.								x	x
18	TF	Aspidosper	araracanga	28.								x	x
18	TF	Licania	membrana	27.								x	x
18	TF	Licania	heteromor	53.								x	
18	TF	Eschweilera	coriacea	20.								x	
18	TF	Minquartia	guianensis	41.								x	x
18	TF	Swartzia	brachyrac	17.								x	x
19	TF	Inga	gracilifoli	22.								x	x
19	TF	Minquartia	guianensis	19.								x	x
19	TF	Virola	michelii	21.								x	x
19	TF	Licania	octandra	12.								x	x
19	TF	Pouteria	anomala	27.								x	x

19	TF	Licania	membrana	47.								x	x
19	TF	Vouacapoua	americana	33.								x	x
19	TF	Inga	gracilifoli	34.								x	x
19	TF	Eschweilera	grandiflor	13.								x	x
19	TF	Vouacapoua	americana	15.								x	x
20	TF	Pouteria	decortican	10.								x	x
20	TF	Pouteria	jariensis	51.								x	x
20	TF	Licania	octandra	17.								x	x
20	TF	Minquartia	guianensis	25.								x	x
20	TF	Syzygiopsis	oppositifol	63.									x
20	TF	Micropholis	egensis	23.								x	x
20	TF	Couma	macrocarp	44.								x	
20	TF	Swartzia	racemosa	63.								x	x
20	TF	Eschweilera	coriacea	18.								x	x
20	TF	Pouteria	venosa	10.								x	x
21	TF	Protium	paniculatu	38.								x	
21	TF	Vouacapoua	americana	53.								x	x
21	TF	Virola	crebrinerv	20.								x	x
21	TF	Ocotea	rubra	47.								x	x
21	TF	Not	Not										x
21	TF	Minquartia	guianensis	16.								x	
21	C	Manilkara	bidentata	32.	x	x	x	x	x	x	x		
21	C	Pouteria	anomala	15.	x	x	x	x	x	x			
21	C	Pouteria	anomala	16.	x	x	x	x	x	x	x		
21	C	Protium	ifolium	29.	x	x	x	x	x	x			
22	C	Manilkara	bidentata	32.	x	x	x	x	x	x	x		
22	C	Swartzia	racemosa	30.	x	x	x	x	x	x	x		
22	C	Eschweilera	grandiflor	34.	x	x	x	x	x	x	x		
22	C	Protium	ifolium	24.	x	x	x	x	x	x			
22	C	Eschweilera	ra coriacea	37.	x	x	x	x	x	x	x		
22	C	Eschweilera	a coriacea	24.	x	x	x	x	x		x		
22	C	Licania	ranacea	20.	x	x	x	x	x	x	x		
22	C	Swartzia	racemosa	45.	x	x		x	x		x		
22	C	Licania	ranacea	23.	x	x	x	x	x	x	x		
22	C	Eschweilera	grandiflor	35.	x	x	x	x	x	x	x		
23	C	Manilkara	bidentata	48.	x	x		x	x	x	x		
23	C	Pouteria	anomala	35.	x	x	x	x	x	x	x		
23	C	Protium	ifolium	33.	x	x	x	x	x	x	x		
23	C	Swartzia	racemosa	37.	x	x	x	x	x	x	x		
23	TF		anomala	25.	x	x	x		x	x	x		
23	TF	Manilkara	bidentata	56.	x	x	x	x	x	x	x		
23	TF	Protium	ifolium	29.	x	x	x	x	x	x	x		
23	TF	Swartzia	racemosa	40.	x	x	x	x	x	x	x		
23	TF	Eschweilera	ra coriacea	36.	x	x	x	x	x	x	x		
23	TF	Eschweilera	grandiflor	24.	x	x	x	x	x	x	x		
24	TF	Protium	ifolium	27.	x	x	x	x	x	x	x		
24	TF	Pouteria	anomala	20.	x	x	x	x	x	x	x		
24	TF	Licania	ranacea	15.	x	x	x	x	x	x	x		
24	TF	Manilkara	bidentata	36.	x	x	x	x	x	x	x		

24	TF	Eschweilera	grandiflor	16.	x	x		x	x	x	x		
24	TF	Swartzia	racemosa	21.	x	x	x	x	x	x	x		
24	TF	Licania	ranacea	25.	x	x	x	x	x	x	x		
24	TF	Eschweilera	ra coriacea	32.	x	x	x	x	x	x	x		
24	TF	Swartzia	racemosa	36.	x	x	x	x	x		x		
24	TF	Manilkara	bidentata	29.	x	x	x	x	x	x	x		
25	TF	Eschweilera	ra coriacea	26.	x	x	x	x	x	x	x		
25	TF	Pouteria	anomala	27.	x	x	x	x	x	x	x		
25	TF	Licania	ranacea	47.	x	x	x	x	x	x	x		
25	TF	Eschweilera	grandiflor	16.	x	x	x	x	x	x	x		

Table S2: Distribution of all trees on the Control and TFE used for the scaling exercise in Table 2, into the size categories of diameter at breast height (cm) used in Figure 2

	<15	15-20	20-25	25-30	30-40	40-50	50-60	>60
Control	158	93	71	45	55	21	14	24
TFE	137	97	52	43	45	25	13	8