Supporting Information to the paper:
McCarthy JK, Dwyer JM, Mokany K. A regional-scale assessment of using metabolic scaling theory to predict ecosystem properties. *Proceedings of the Royal Society B: Biological Sciences*. (doi: 10.1098/rspb.2019-2221)

Electronic supplementary material S1. Study area

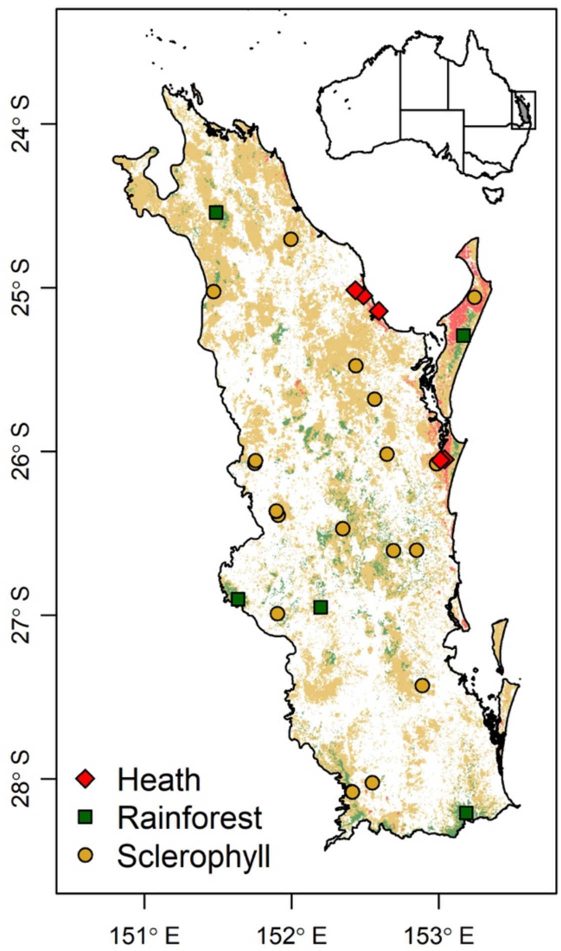

Figure S1-1. Our study area, southeast Queensland, contains approximately 2.1 million ha of woody vegetation and is situated on the east coast of Australia. Size distribution data were collected from 30 sites across the region, covering the three main vegetation types: heath shrublands (red, five sites), subtropical rainforest (green, five sites), and *Eucalyptus* spp. dominated sclerophyll forest (yellow, 20 sites; some points overlap in the figure).

Electronic supplementary material S2. Functional trait data sources

Table S2-1. Functional trait data for the species that were not measured directly by the authors were obtained from a range of sources. Values indicate the number of unique species each source contributed to the overall data set for three traits: maximum height (Height), specific leaf area (SLA), and wood density (WD).

Reference	Height	SLA	WD
Boland, *et al.* [1]	4	0	2
Cause, *et al.* [2]	0	0	7
Chaturvedi and Raghubanshi [3]	0	0	1
Chave, *et al.* [4]*	0	0	2
Choat, *et al.* [5]*	0	0	1
Clarke, *et al.* [6]	0	0	0
Cunningham, *et al.* [7]	0	1	0
Curran, *et al.* [8]	0	1	0
Dwyer and Mason [9]	0	1	0
Falster and Westoby [10]	0	1	0
Falster and Westoby [11]	0	1	0
Falster and Westoby [12]	0	2	0
Floyd [13]	7	0	0
Fonseca, *et al.* [14]*	0	17	0
Gallagher, *et al.* [15]	0	1	0
Gallagher and Leishman [16]	0	13	0
Green and Juniper [17]	0	0	0
Grubb and Metcalfe [18]	0	0	0
Grubb, *et al.* [19]	0	0	0
Hamilton, *et al.* [20]	0	2	0
Harden, *et al.* [21]	8	0	0
Hunt, *et al.* [22]	0	1	0
Knox and Clarke [23]	0	3	2
Kooyman and Westoby [24]	0	0	11
Lake [25]	0	0	1
Lal, *et al.* [26]	0	1	0
Leiper, *et al.* [27]	18	0	0
Lindsay and French [28]	0	1	0
Mokany, *et al.* [29]	119	0	0
Moles and Westoby [30]	0	1	0
Ordonez, *et al.* [31]	0	15	0
Osunkoya, *et al.* [32]	0	1	0
Peñuelas, *et al.* [33]*	0	2	0
Poorter, *et al.* [34]*	0	7	0
Poropat [35]	0	0	1
Poropat [36]	0	0	9
Read and Sanson [37]	0	1	0
Reich, *et al.* [38]*	0	0	1
Royal Botanic Gardens Kew [39]	0	0	0

Reference	**Height**	**SLA**	**WD**
Sams*, et al.* [40]	0	3	0
Shiels and Drake [41]	0	0	0
Shipley [42]*	0	4	0
Stanley and Ross [43]	78	0	0
Tng*, et al.* [44]	0	10	2
Westoby*, et al.* [45]	0	0	0
Wright and Westoby [46]	0	3	0
Wright*, et al.* [47]	0	1	0
Zanne*, et al.* [48]	0	0	117
Zheng and Shangguan [49]	0	1	0

* Accessed through the TRY functional trait database [50].

Electronic supplementary material S2 references

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Electronic supplementary material S3. Site-level size distributions

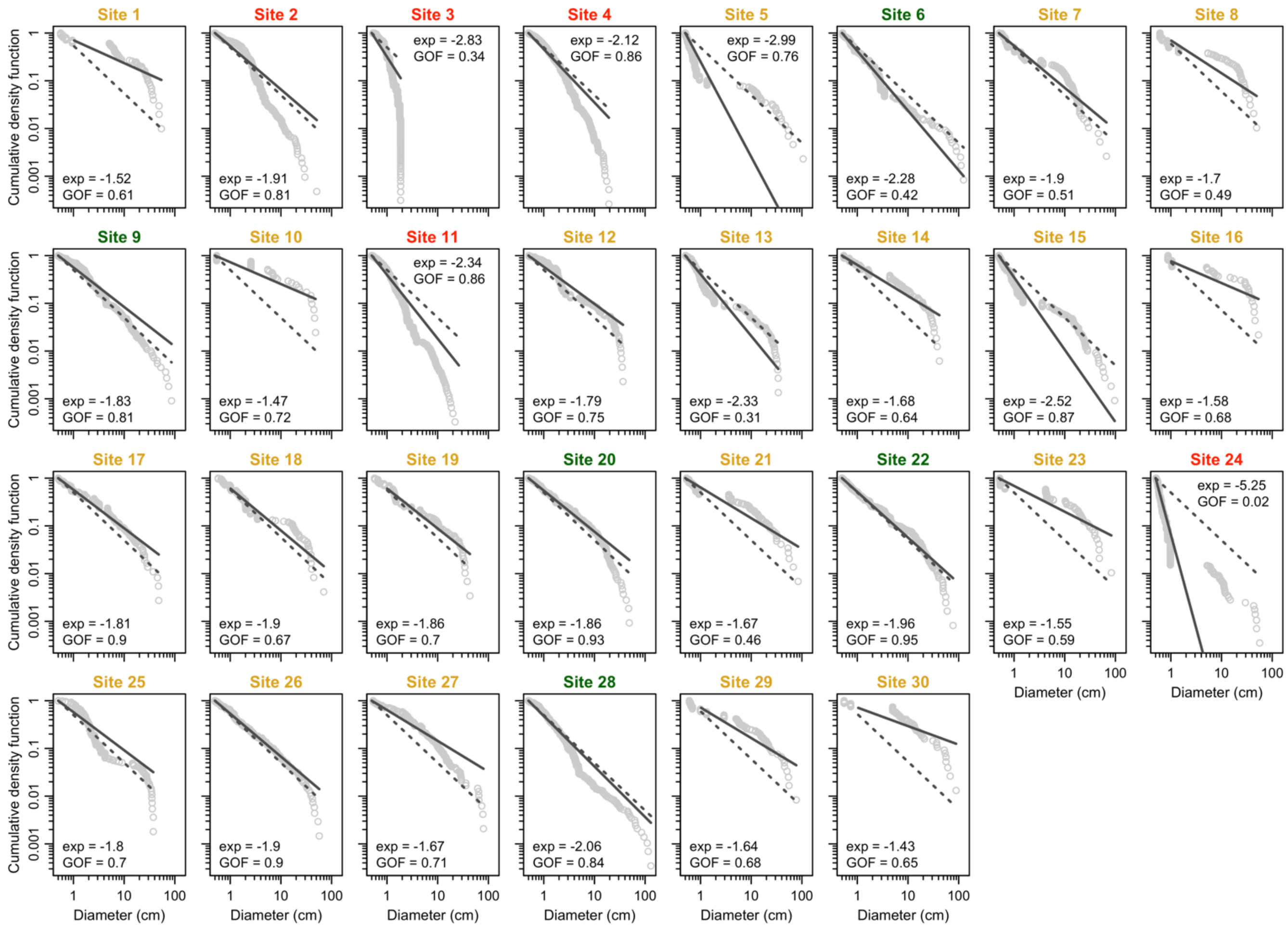

Figure S3-1. Continuous size distributions for all our 30 sites measured across three broad vegetation types in southeast Queensland: sclerophyll (yellow text), heath (red text) and rainforest (green text). Solid lines show the actual exponent of each site determined using maximum likelihood (see Methods in main text) and dotted lines show the –2 exponent assumed by MST to be universal. Values of actual exponent and goodness of fit to a power law (GOF; another MST assumption) are shown for each site.

Table S3-1. Results from analyses of continuous size distributions from all our 30 sites measured across three broad vegetation types in southeast Queensland. Values of the actual exponent and goodness of fit to power law (GOF) are as presented in figure S3-1. Test statistics and *P* values are from comparisons between two models; one where we estimated the scaling exponent from the data, and a simpler model with the exponent fixed at –2; using one-sided Vuong's likelihood ratio tests (see Methods in main text). ΔAIC values between the two models are also provided. Only 6/30 sites had estimated exponents that were statistically equivalent to the –2 MST prediction ($P > 0.05$), but ΔAIC values indicated that four of these sites had better fits when the exponent was estimated (ΔAIC > 2), despite the added complexity of estimating this parameter. Thus, the –2 MST prediction received strong statistical support from just two sites (18 and 22; bold text).

Site	Vegetation type	Exponent	GOF	Test statistic	*P*	ΔAIC
1	Sclerophyll	–1.52	0.61	3.776	< 0.001	54.112
2	Heath	–1.91	0.81	3.246	0.001	18.014
3	Heath	–2.83	0.34	49.544	< 0.001	1942.839
4	Heath	–2.12	0.86	5.051	< 0.001	44.139
5	Sclerophyll	–2.99	0.76	4.153	< 0.001	164.116
6	Rainforest	–2.28	0.42	4.232	< 0.001	65.922
7	Sclerophyll	–1.90	0.51	0.978	0.164	2.610
8	Sclerophyll	–1.70	0.49	1.555	0.060	12.353
9	Rainforest	–1.83	0.81	4.209	< 0.001	40.376
10	Sclerophyll	–1.47	0.72	2.865	0.002	27.664
11	Heath	–2.34	0.86	17.096	< 0.001	468.751
12	Sclerophyll	–1.79	0.75	3.197	0.001	24.310
13	Sclerophyll	–2.33	0.31	3.599	< 0.001	52.587
14	Sclerophyll	–1.68	0.64	2.535	0.006	24.559
15	Sclerophyll	–2.52	0.87	5.279	< 0.001	163.270
16	Sclerophyll	–1.58	0.68	1.831	0.034	14.614
17	Sclerophyll	–1.81	0.90	2.243	0.012	16.175
18	**Sclerophyll**	**–1.90**	**0.67**	**0.847**	**0.199**	**1.078**
19	Sclerophyll	–1.86	0.70	1.314	0.094	4.688
20	Rainforest	–1.86	0.93	2.792	0.003	23.050
21	Sclerophyll	–1.67	0.46	2.286	0.011	25.064
22	**Rainforest**	**–1.96**	**0.95**	**0.770**	**0.221**	**0.423**
23	Sclerophyll	–1.55	0.59	2.914	0.002	39.635
24	Heath	–5.25	0.02	28.491	< 0.001	3876.580
25	Sclerophyll	–1.80	0.70	4.159	< 0.001	28.470
26	Sclerophyll	–1.90	0.90	1.513	0.065	5.815
27	Sclerophyll	–1.67	0.71	5.404	< 0.001	85.162
28	Rainforest	–2.06	0.84	2.042	0.021	7.381
29	Sclerophyll	–1.64	0.68	2.396	0.008	25.789
30	Sclerophyll	–1.43	0.65	4.870	< 0.001	69.595

Electronic supplementary material S4. Analyses repeated including removed outlier plot.

To avoid violating model assumptions, we removed one outlier heath site in the analyses presented in figures 2-4 in the main text, and tables S5-1 & S5-2. Here, we present a repeat of the analyses included in the main text exploring relationships between MST assumptions (scaling exponents [–2] and power law goodness of fit values), environmental and community-weighted mean (CWM) functional trait variables, and our three estimates of MST-calculated relative productivity (B_{tot}) and remote-sensed gross primary productivity (GPP) with the outlier heath site included. In all cases, slope directions are consistent with and without the outlier heath site (figures S4-1 – S4-3, tables S4-1 & S4-2; also see figures 2-4 in the main text, and tables S5-1 & S5-2). When including the outlier, however, there is no support for a statistically significant relationship between scaling exponent and soil sand content (P = 0.010 vs P = 0.202; tables S4-1a & S5-1a) but support remains for the aridity index, fire frequency, and their interaction. Also, support for a statistically significant relationship between goodness of fit to power law and CWM specific leaf area is reduced (P = 0.003 to P = 0.055; tables S5-1d & S4-1d), and there is no longer marginal significance for the relationship with wood density. Given we were limited to a relatively small number of sites in this study (30), and that many of our covariates are marginally significant, it is highly likely that collection of additional data would yield more significant results. There are no major differences between the analyses of B_{tot} and GPP when the outlier site is removed.

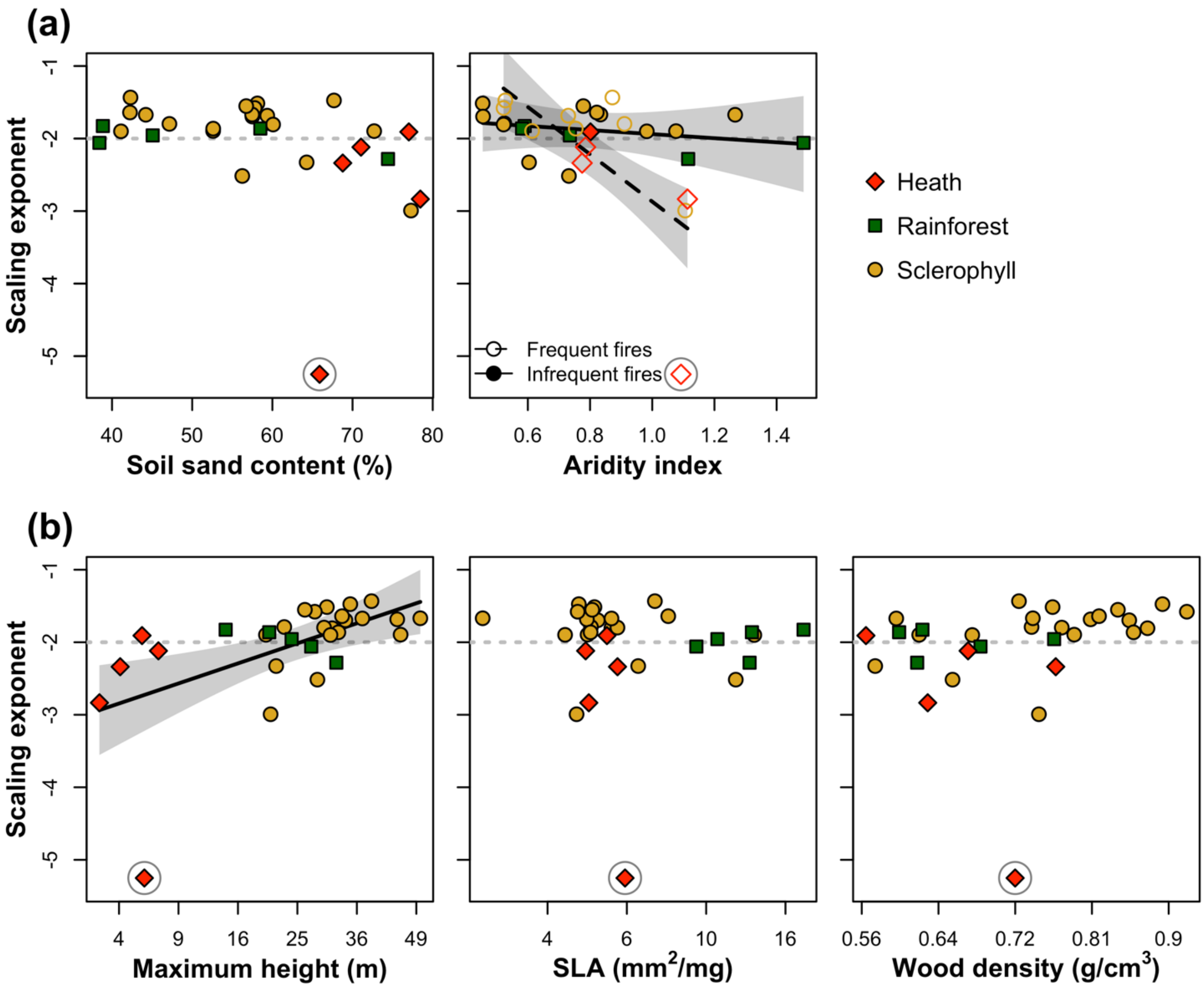

Figure S4-1. Relationships between size distribution exponents and site-level variables for models, including (a) soil sand content, and an interaction between fire frequency and aridity; and (b) community-weighted means for three functional traits: maximum height, specific leaf area (SLA), and wood density. This analysis is a repeat of figure 2 in the main text but includes the removed outlier heath site (identified with a grey circle). The lines are fitted relationships, and grey shading indicates 95% confidence intervals. The shaded lines indicate significance at $P < 0.05$. When each bivariate relationship (and the interaction) was fitted, all other covariates were held at their mean values.

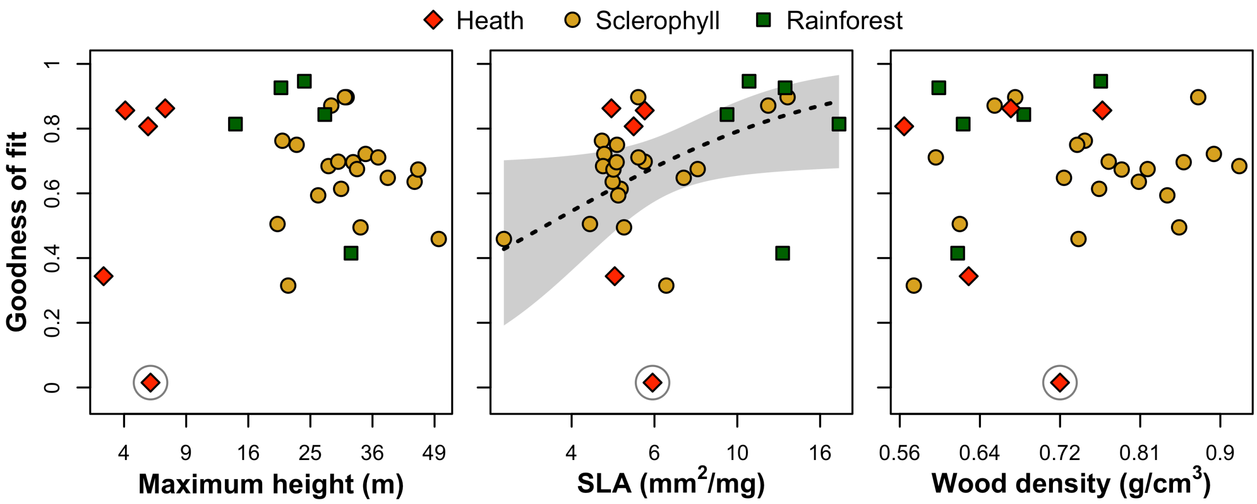

Figure S4-2. Relationships between the degree to which the size distribution of a site follows a power law (goodness of fit), one of the main assumptions of metabolic scaling theory, and three community-level functional traits: maximum height, specific leaf area (SLA), and wood density. This analysis is a repeat of figure 3 in the main text but includes the removed outlier heath site (identified with a grey circle). A model with environmental predictor variables was also fitted for goodness of fit, like figure S4-1a, but these relationships were all non-significant. The lines are fitted relationships, and grey shading indicates 95% confidence intervals. The shaded line indicates significance at $P < 0.05$. Panels without lines have non-significant relationships. When each bivariate relationship was fitted, all other covariates were held at their mean values.

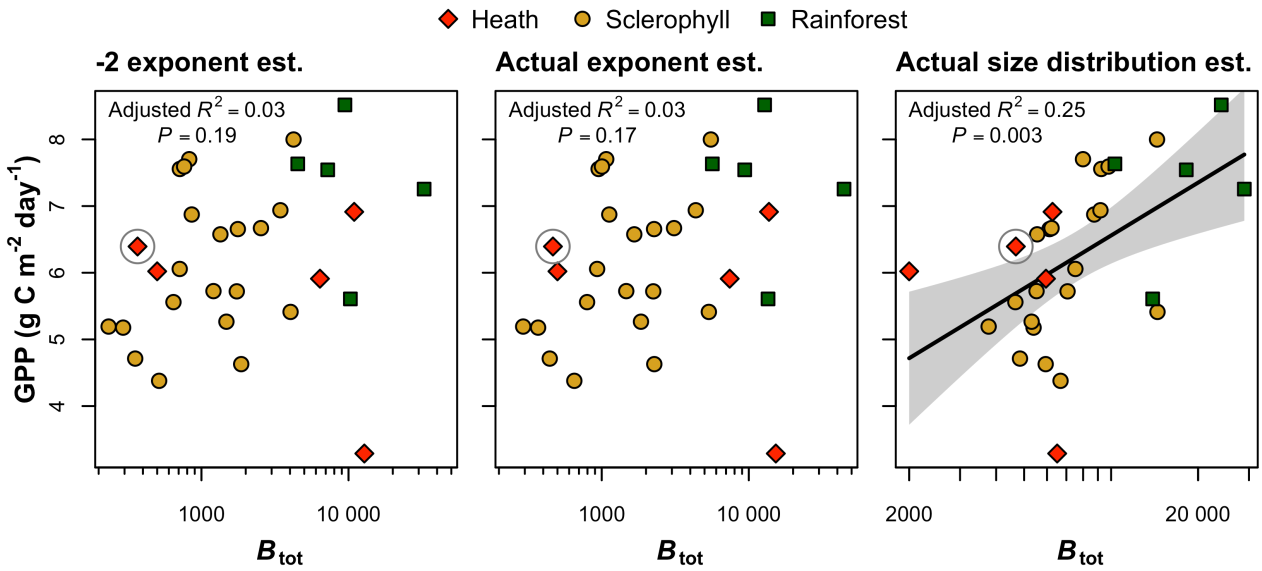

Figure S4-3. Relationship between metabolic scaling theory (MST)-calculated relative productivity (B_{tot}) and remote-sensed gross primary productivity (GPP). Here, we show B_{tot} calculated three different ways: using the MST-assumed power law and –2 size distribution exponent (–2 exponent estimate); using the power law and the actual exponent (actual exponent estimate); and using neither the power law nor an exponent (actual size distribution estimate). This analysis is a repeat of figure 4 in the main text but includes the removed outlier heath site (identified with a grey circle). There was a significant relationship between B_{tot} and GPP in (c), when MST assumptions were relaxed and B_{tot} was calculated using actual stand properties. The lines show fitted relationships, with grey shading indicating 95% confidence intervals. Panels without lines have non-significant relationships.

Table S4-1. Model coefficients from the four linear models used to explain the deviation of size distributions from two central metabolic scaling theory (MST) assumptions: the –2 exponent and the power law. This analysis is a repeat of table S5-1 but including the removed outlier heath site. For each assumption, we fit a model with environmental predictors and a model with community-weighted mean functional trait predictors—both explaining factors ignored by the theory. Adherence to the power law is measured as a goodness of fit (GoF) with a value of 1 indicating a perfect fit (i.e., a straight line when plotted on a log-log axis). Bold *P* values denote statistically significant slopes (α = 0.05).

Coefficient	**Estimate**	**Standard error**	**t-value**	***P***
(a) *Exponent model – environmental predictors* (R^2 = 0.43, P < 0.001)				
Intercept	0.051	0.608	0.084	0.934
Aridity index	–1.772	0.449	–3.946	**< 0.001**
Fire frequency (binary)	1.500	0.541	2.771	**0.010**
Soil sand content (%)	–0.012	0.009	–1.309	0.202
Aridity index × fire frequency	–2.109	0.654	–3.222	**0.004**
(b) *Exponent model – functional trait predictors* (R^2 = 0.22, P = 0.023)				
Intercept	–3.365	2.169	–1.552	0.133
Maximum height (square root)	0.276	0.091	3.055	**0.005**
Specific leaf area ($\log_{10}$)	–0.056	0.709	–0.079	0.938
Wood density (square root)	0.016	2.341	0.007	0.994
(c) *Power law model – environmental predictors* (R^2 = 0.09, P = 0.174)				
Intercept	3.436	1.409	2.439	0.022
Aridity index	< 0.001	< 0.001	–1.693	0.103
Fire frequency (binary)	1.376	1.254	1.097	0.283
Soil sand content (%)	–0.022	0.021	–1.047	0.305
Aridity index × fire frequency	< 0.001	< 0.001	–1.371	0.183
(d) *Power law model – functional trait predictors* (R^2 = 0.05, P = 0.223)				
Intercept	–4.782	4.374	–1.093	0.284
Maximum height (square root)	0.102	0.183	0.559	0.581
Specific leaf area ($\log_{10}$)	2.879	1.430	2.014	0.055
Wood density (square root)	3.204	4.722	0.678	0.504

Table S4-2. Model coefficients from linear models testing for relationships between metabolic scaling theory (MST)-predicted relative productivity (B_{tot}) and a remote-sensed measure of gross primary productivity. This analysis is a repeat of table S5-2 but including the removed outlier heath site. B_{tot} was calculated three different ways: (a) using the MST-assumed power law and –2 size distribution exponent (–2 exponent estimate), (b) using the power law and the actual exponent (actual exponent estimate), and (c) using neither the power law nor an exponent (actual size distribution estimate). Bold *P* values denote statistically significant slopes ($\alpha = 0.05$).

Coefficient	Estimate	Standard error	t-value	*P*
(a) *–2 exponent estimate* ($R^2 = 0.03$, $P = 0.192$)				
Intercept	4.512	1.317	3.426	0.002
B_{tot} ($\log_{10}$)	0.533	0.398	1.338	0.192
(b) *Actual exponent estimate* ($R^2 = 0.03$, $P = 0.166$)				
Intercept	4.371	1.337	3.268	0.003
B_{tot} ($\log_{10}$)	0.558	0.392	1.424	0.166
(c) *Actual size distribution estimate* ($R^2 = 0.25$, $P = 0.003$)				
Intercept	–3.976	3.152	–1.262	0.218
B_{tot} ($\log_{10}$)	2.634	0.810	3.250	**0.003**

Appendix S5. Model summaries.

Table S5-1. Model coefficients from the four linear models used to explain the deviation of size distributions from two central metabolic scaling theory assumptions: the –2 exponent and the power law. For each assumption, we fitted a model with environmental predictors and a model with community-weighted mean functional trait predictors – both explaining factors ignored by the theory. Adherence to the power law is measured as a goodness of fit, with a value of 1 indicating a perfect fit (i.e., a straight line when plotted on a log-log axis). Bold *P* values denote statistically significant slopes ($\alpha = 0.05$).

Coefficient	**Estimate**	**Standard error**	**t-value**	***P***
(a) *Exponent model – environmental predictors* ($R^2 = 0.49$, $P < 0.001$)				
Intercept	–0.405	0.313	–1.297	0.207
Aridity index	–1.007	0.244	–4.120	**<0.001**
Fire frequency (binary)	0.769	0.287	2.678	**0.013**
Soil sand content (%)	–0.013	0.005	–2.801	**0.010**
Aridity index × fire frequency	–1.016	0.355	–2.859	**0.009**
(b) *Exponent model – functional trait predictors* ($R^2 = 0.25$, $P = 0.016$)				
Intercept	–3.748	1.139	–3.289	0.003
Maximum height (square root)	0.125	0.051	2.456	**0.021**
Specific leaf area ($\log_{10}$)	–0.013	0.372	–0.034	0.973
Wood density (square root)	1.413	1.241	1.139	0.266
(c) *Power law model – environmental predictors* ($R^2 = –0.040$, $P = 0.582$)				
Intercept	2.620	1.083	2.420	0.024
Aridity index	<0.001	<0.001	–0.465	0.646
Fire frequency (binary)	0.069	0.995	0.069	0.946
Soil sand content (%)	–0.023	0.016	–1.494	0.148
Aridity index × fire frequency	<0.001	<0.001	–0.101	0.921
(d) *Power law model – functional trait predictors* ($R^2 = 0.24$, $P = 0.019$)				
Intercept	–5.487	2.774	–1.978	0.059
Maximum height (square root)	–0.178	0.124	–1.431	0.165
Specific leaf area ($\log_{10}$)	2.959	0.906	3.266	**0.003**
Wood density (square root)	5.779	3.021	1.913	0.067

Table S5-2. Model coefficients from linear models testing for relationships between metabolic scaling theory (MST)-predicted relative productivity (B_{tot}) and a remote-sensed measure of gross primary productivity. B_{tot} was calculated three different ways: (a) using the MST-assumed power law and –2 size distribution exponent (–2 exponent estimate), (b) using the power law and the actual exponent (actual exponent estimate), and (c) using neither the power law nor an exponent (actual size distribution estimate). Bold *P* values denote statistically significant slopes ($\alpha = 0.05$).

Coefficient	**Estimate**	**Standard error**	**t-value**	***P***
(a) *–2 exponent estimate* ($R^2 = 0.03$, $P = 0.177$)				
Intercept	4.352	1.384	3.144	0.004
B_{tot} ($\log_{10}$)	0.576	0.415	1.386	0.177
(b) *Actual exponent estimate* ($R^2 = 0.04$, $P = 0.153$)				
Intercept	4.205	1.404	2.995	0.006
B_{tot} ($\log_{10}$)	0.602	0.409	1.471	0.153
(c) *Actual size distribution estimate* ($R^2 = 0.26$, $P = 0.003$)				
Intercept	–4.363	3.233	–1.350	0.188
B_{tot} ($\log_{10}$)	2.727	0.830	3.287	**0.003**