

Supplementary Information

Improved simulation of fire-vegetation interactions in the Land surface Processes and eXchanges Dynamic Global Vegetation Model (LPX-Mv1)

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Benchmarking scores in the main text are a summary of skill scores obtained using the Kelley et al. (2013) benchmarking system. Tables S1 and S2 give the full set of scores for comparisons against all datasets, split into individual parameterisation and the combination of all parameterisation with and without resprouting (LPX-Mv1-nr and LPX-Mv1-rs respectively). Fig. S1 shows simulated burnt area for each individual parameterisation, and Fig. S2 shows where resprouting (RS) has a competitive advantage of non-resprouting (NR) PFTs in climate space. Eq. S1-S4 describes the derivation of the ratio of NDVI from tree and grass used in Eq. 36 in the main text. We also provide a complete list of references for the data used to parameterize adaptive bark thickness.

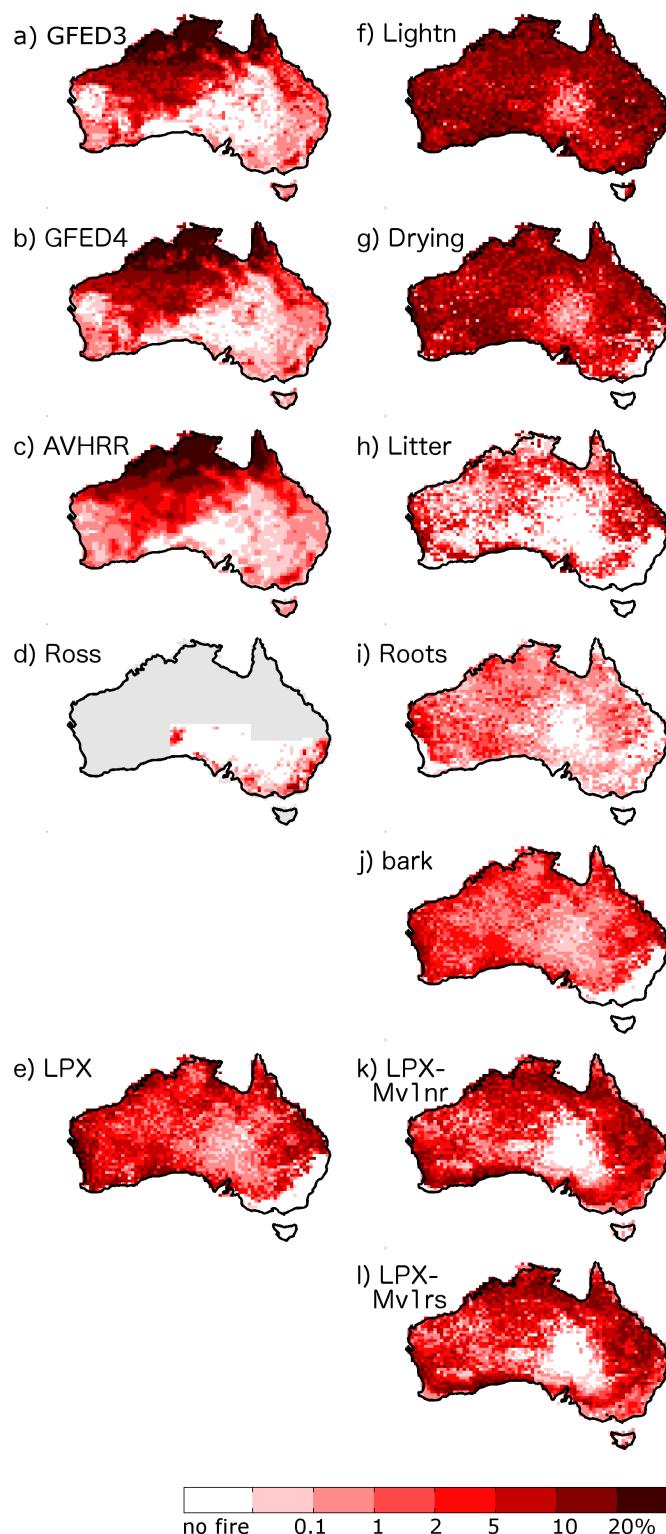


Figure S1. Annual average burnt area between 1997-2005 based on observations from (a) GFED3 (Giglio et al., 2010); b) GFED4 (Giglio et al., 2013); c) AVHRR (Maier and Russell-Smith, 2012);

d) based on ground data (Bradstock, submitted); and as simulated by e) LPX; and by each new parameterisation: f) lightning described in section 3.1 in the main text; g) fuel drying rates described in section 3.2; h) fuel decomposition rate in section 3.3; i) rooting depth in section 3.4; j) adaptive bark thickness in section 3.5; k) LPX-Mv1nr; g) LPX-M v1rs.

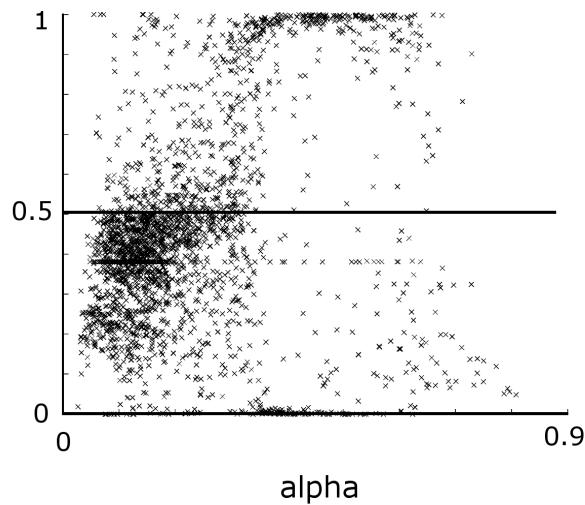


Figure S2. Comparison of the simulated abundance of resprouting (RS) tree PFTs and their non-resprouting (NR) equivalent PFTs along the climatic gradient in moisture, as measured by alpha (x-axis). Y-axis shows ratio of $RS/(RS+NR)$. Values >0.5 are when RS has a competitive advantage over NR and values <0.5 is when NR has a competitive advantage of RS.

Table S1. Extended version of Table 6 in main text. Scores obtained using the mean of the data (Data mean), and the mean and standard deviation of the scores obtained from bootstrapping experiments (Bootstrap mean, Bootstrap SD). Step 1 is a straight comparison; 2 is a comparison with the influence of the mean removed; 3 is with mean and variance removed. Step 2 and 3 have been included for inter-annual variability (IAV) and Seasonal concentration, and full scores have been included for each burnt area dataset.

Variable	Step	Measure	time period	mean	bootstrap mean	bootstrap SD
fAPAR	1	Annual average	1997-2005	1.00	1.33	0.015
	2			1.00	1.33	0.015
	3			1.00	1.32	0.014
	2	Inter-annual variability		1.00	1.23	0.32
	3			1.00	1.35	0.36
	1	Seasonal concentration		1.00	1.46	0.014
	2			1.00	1.46	0.014
	3			1.00	1.45	0.014
	N/A	Phase		0.30	0.38	0.0033
	N/A	life forms	1992-1993	0.71	0.89	0.0018
	N/A	tree cover		0.43	0.54	0.0015
	N/A	herb cover		0.49	0.66	0.0017
	N/A	bare ground		0.46	0.56	0.0017
	N/A	broadleaf		0.83	0.96	0.0041
	N/A	evergreen		0.70	0.87	0.0032
fine litter NPP 1		Annual average	1997-2005	1.00	1.44	0.21
	2			1.00	1.44	0.22
	3			1.00	1.43	0.095
	1	Annual average	2005	1.00	1.32	0.016
Height	2			1.00	1.32	0.016
	3			1.00	1.31	0.016

Variable	Step	Measure	time period	Mean	bootstrap mean	bootstrap SD
Fire: GDED3	1	Annual average	1997-2006	1.00	1.25	0.015
	2			1.00	1.26	0.015
	3			1.00	1.28	0.016
	2	Inter-annual variability		1.00	1.31	0.36
	3			1.00	1.25	0.33
	1	Seasonal Conc		1.00	1.36	0.020
	2			1.00	1.36	0.020
	3			1.00	1.36	0.018
	N/A	Phase		0.39	0.44	0.0046
	1	Annual average		1.00	1.19	0.024
SE	2			1.00	1.19	0.024
	3			1.00	1.21	0.024
	2	Inter-annual variability		1.00	1.26	0.33
	3			1.00	1.41	0.54
	1	Seasonal Conc		1.00	1.31	0.053
	2			1.00	1.31	0.052
	3			1.00	1.31	0.045
	N/A	Phase		0.47	0.47	0.011
	1	Annual average	1997-2006	1.00	1.14	0.0028
	2			1.00	1.24	0.0037
Fire: GDED4	3			1.00	1.30	0.0053
	2	Inter-annual variability		1.00	1.50	0.34
	3			1.00	1.28	0.27
	1	Seasonal Conc		1.00	1.32	0.0073
	2			1.00	1.33	0.0071
	3			1.00	1.34	0.0061
	N/A	Phase		0.45	0.47	0.0015

Variable	Step	Measure	time period	mean	bootstrap mean	bootstrap SD
Fire: GDED4 SE	1	Annual average		1.00	1.18	0.024
	2			1.00	1.18	0.024
	3			1.00	1.20	0.025
	2	Inter-annual variability		1.00	1.24	0.34
	3			1.00	1.52	0.67
	1	Seasonal Conc		1.00	1.33	0.043
	2			1.00	1.33	0.043
	3			1.00	1.33	0.038
	N/A	Phase		0.44	0.47	0.010
Fire: AVHRR	1	Annual average	1997-2009	1.00	1.16	0.010
	2			1.00	1.18	0.010
	3			1.00	1.20	0.011
Fire: AVHRR	1	Annual average	1997-2009	1.00	1.20	0.025
	2			1.00	1.20	0.025
	3			1.00	1.21	0.025
Fire: Rosses	1	Annual average	1996.5-2005.5	1.00	1.13	0.026
	2			1.00	1.15	0.027
	3			1.00	1.10	0.025
	2	Inter-annual variability		1.00	1.32	0.37
	3			1.00	1.34	0.36

Table S2. Comparison metric scores for model simulations against observations. Mean and variance rows show mean and variance of simulation for annual average values, by the ratio of the mean/variance with observed mean or variance. Numbers in bold indicates if the model performs better than the original LPX model. Italic indicates model scores better than the mean of the data score listed in Table S1. Asterisks indicate model scores that are significantly better than randomly resampling listed in Table S1. S1 are step 1 comparisons, S2 are step 2; and S3 are step 3. All metrics defined in Kelley et al. (2013). Lightn column give the scores for lightning parametrisations to LPX; Drying for fuel drying time parametrisation; Roots for deep rooting fraction; Litter for litter decomposition; and Bark for the inclusion of adaptive bark. LPX-M-v1-nr incorporates all parametrisations and LPX-M-v1-rs incorporates resprouting into LPX-Mv1-nr. fAPAR is the fraction of absorbed photosynthetically active radiation, NPP is net primary productivity.

Variable	Metric used	Measure	LPX	Lightn	Drying	Roots	Litter	bark thickness	LPX-Mv1-nr	LPX-Mv1-rs
Burnt area: GFED3	Mean	Annual Average	0.082	0.12	0.084	0.086	0.02	0.003	0.049	0.050
	Mean ratio		1.13	1.64	1.15	1.18	0.28	0.039	0.67	0.69
	Variance		0.047	0.049	0.046	0.047	0.025	0.005	0.041	0.041
	Variance ratio		0.56	0.59	0.54	0.55	0.29	0.061	0.48	0.48
	NME S1	Annual Average	1.00*	1.24*	1.00*	1.00*	0.90*	0.88*	0.89*	0.85*
	NME S2		0.97*	1.06*	0.97*	0.97*	1.03*	1.02*	0.94*	0.93*
	NME S3		1.22*	1.32	1.23*	1.23*	1.22*	1.38	1.12*	1.09*
	NME S2	Inter-annual variability	0.94	1.06	0.97	0.97	0.89	1.00	0.66*	0.68*
	NME S3		0.91	0.97	0.93	0.87	1.09	1.02	0.78	0.83
	NME S1	Seasonal Conc.	1.39	1.30*	1.39	1.41	1.44	1.35*	1.31 *	1.32*
	NME S2		1.36	1.27*	1.37	1.37	1.14*	1.09*	1.29 *	1.32*
	NME S3		1.24*	1.46	1.24*	1.23*	1.33*	1.40	1.31*	1.32*
MPD	Phase		0.44	0.38*	0.44	0.44	0.57	0.53	0.49	0.49

Variable	Metric used	Measure	LPX	Lightn	Drying	Roots	Litter	bark thickness	LPX-Mv1-nr	LPX-Mv1-rs
Burnt area: GFED3 SE Aus	Mean	Annual	0.048	0.099	0.053	0.051	0.012	0.002	0.024	0.024
	Mean ratio	Average	6.69	13.1	7.34	7.02	1.63	0.25	3.33	3.38
	Variance		0.023	0.054	0.041	0.041	0.018	0.003	0.026	0.026
	Variance ratio		2.17	5.05	3.84	3.85	1.66	0.31	2.46	2.49
	NME S1	Annual average	4.03	8.41	4.75	4.64	1.64	0.81*	2.43	2.46
	NME S2		3.58	5.07	3.93	3.97	1.85	1.05*	2.66	2.69
	NME S3		2.07	1.34	1.37	1.38	1.23	1.22*	1.29	1.30
	NME S2	Inter-annual variability	12	14.5	14.1	15.8	5.21	1.52	8.05	8.00
	NME S3		1.74	1.54	1.47	1.46	1.36	1.45	1.47	1.50
	NME S1	Seasonal Conc.	1.15	1.3	1.15	1.14	1.08	1.25	0.95	0.96
	NME S2		1.17	1.10	1.16	1.16	0.98	1.06	0.97	0.98
	NME S3		1.41	1.32	1.33	1.35	1.22	1.44	1.26	1.25
	MPD		0.47	0.52	0.47	0.48	0.52	0.57	0.50	0.50
Burnt area: GFED4	Mean	Annual	0.083	0.12	0.084	0.086	0.02	0.003	0.049	0.050
	Mean ratio	Average	1.21	1.77	1.24	1.27	0.29	0.043	0.72	0.74
	Variance		0.047	0.049	0.046	0.047	0.025	0.005	0.041	0.041
	Variance ratio		0.60	0.63	0.58	0.6	0.32	0.068	0.53	0.53
	NME S1	Annual average	1.01*	1.29	1.02*	1.02*	0.93*	0.9*	0.88*	0.88*
	NME S2		0.97*	1.09*	0.98*	0.97*	1.04*	1.02*	0.93*	0.93*
	NME S3		1.2*	1.32	1.21*	1.2*	1.23*	1.39	1.10	1.09*
	NME S2	Inter-annual variability	1.05	1.05	1.08	1.17	1.03	1.03	0.91	0.90
	NME S3		1.26*	1.21*	1.25*	1.29*	1.33	1.60	1.23	1.25*

Variable	Metric used	Measure	LPX	Lightn	Drying	Roots	Litter	bark thickness	LPX-Mv1-nr	LPX-Mv1-rs
Burnt area: GFED4	NME S1	Seasonal Conc.	1.43	1.33	1.43	1.44	1.49	1.44	1.32	1.31*
	NME S2		1.41	1.3*	1.42	1.41	1.16*	1.03*	1.31*	1.3*
	NME S3		1.26*	1.47	1.26*	1.24*	1.33*	1.31*	1.29*	1.29*
	MPD	Phase	0.5	0.46	0.5	0.49	0.57	0.59	0.52	0.52
	Mean	Annual Average	0.048	0.099	0.053	0.051	0.012	0.002	0.024	0.025
	Mean ratio		6.00	12.4	6.68	6.37	1.55	0.27	3.07	3.12
	Variance		0.04	0.056	0.041	0.041	0.019	0.004	0.027	0.027
	Variance ratio		3.43	4.74	3.47	3.48	1.6	0.33	2.28	2.31
	NME S1	Annual average	4.03	7.97	4.35	4.23	1.59	0.83*	2.29	2.33
Burnt area: SE Aus	NME S2		3.58	4.8	3.6	3.61	1.78	1.05*	2.50	2.53
	NME S3		1.39	1.35	1.37	1.38	1.22	1.21	1.30	1.30
	NME S2	Inter-annual variability	8.59	10.1	9.05	10.1	3.83	1.27	5.56	5.71
	NME S3		1.3	1.32	1.29	1.26	1.20-	1.41	1.17	1.24
	NME S1	Seasonal Conc.	1.29	1.38	1.29	1.25*	1.20*	1.50	1.04*	1.04*
	NME S2		1.29	1.20*	1.28	1.24*	1.08*	0.98*	1.06*	1.05*
	NME S3		1.41	1.39	1.38	1.37	1.29	1.28	1.33	1.32
	MPD	Phase	0.53	0.57	0.52	0.52	0.57	0.62	0.56	0.55
	Mean	Annual Average	0.082	0.12	0.084	0.086	0.02	0.003	0.049	0.050
burnt area: AVHRR	Mean ratio		1.32	1.91	1.35	1.38	0.32	0.048	0.81	0.82
	Variance		0.047	0.05	0.046	0.047	0.025	0.005	0.042	0.04
	Variance ratio		0.63	0.67	0.61	0.63	0.33	0.073	0.57	0.57
	NME S1	Annual average	1.05*	1.36	1.06*	1.08*	0.9*	0.87*	0.86*	0.86*
	NME S2		0.99*	1.1*	0.99*	1*	1.03*	1.02*	0.90*	0.89*
	NME S3		1.21	1.31	1.22	1.22	1.2	1.35	1.07	1.06*

Variable	Metric used	Measure	LPX	Lightn	Drying	Roots	Litter	bark thickness	LPX-Mv1-nr	LPX-Mv1-rs
Burnt area: AVHRR SE Aus	Mean	Annual Average	0.047	0.094	0.053	0.05	0.012	0.002	0.024	0.024
	Mean ratio		8.98	18	10.1	9.61	2.23	0.34	4.57	4.64
	Variance		0.04	0.054	0.041	0.041	0.018	0.003	0.026	0.026
	Variance ratio		5.37	7.22	5.49	5.51	2.37	0.44	3.52	3.56
	NME S1	Annual average	6.13	12.1	6.73	6.53	2.06	0.91*	3.29	3.31
	NME S2		5.39	7.13	5.46	5.51	2.51	1.07*	3.66	3.70
	NME S3		1.33	1.28	1.32	1.32	1.22	1.22	1.26	1.26
	Mean	Annual Average	0.048	0.099	0.053	0.051	0.012	0.002	0.029	0.025
	Mean ratio		10.9	22.6	12.2	11.6	2.83	0.49	6.61	5.68
	Variance		0.04	0.056	0.041	0.041	0.019	0.004	0.039	0.027
Burnt area: Bradstock	Variance ratio		5.96	8.23	6.03	6.05	2.77	0.58	3.12	4.01
	NME S1	Annual average	7.19	14	7.67	7.59	2.4	0.92*	4.27	3.67
	NME S2		6.13	7.91	6.06	6.21	2.99	1.08*	4.75	4.20
	NME S3		1.41	1.23	1.35	1.4	1.25	1.18	1.29	1.28
	NME S2	Inter-annual variability	16.6	19.3	17.5	19.4	7.65	2.33	11.5	11.2
	NME S3		1.88	1.83	1.86	1.88	1.84	1.83	1.78	1.84
	Mean	Annual Average	0.19	0.12	0.19	0.18	0.24	0.26	0.22	0.22
	Mean ratio		1.59	1.02	1.56	1.55	2.02	2.18	1.83	1.87
	Variance		0.076	0.034	0.073	0.074	0.099	0.11	0.11	0.092
	Variance ratio		0.95	0.42	0.91	0.92	1.24	1.35	1.34	1.16
fAPAR	NME S1	Annual Average	1.11*	0.98*	1.11*	1.07*	1.61	1.8	1.31	1.35
	NME S2		0.69*	0.97*	0.72*	0.68*	0.7*	0.69*	0.61*	0.61*
	NME S3		0.71*	1.21*	0.76*	0.71*	0.57*	0.51*	0.57*	0.54*
	NME S2	Inter-annual variability	1.01	1.11	1.01	0.97	2.44	2.86	1.83	1.85

Variable	Metric used	Measure	LPX	Lightn	Drying	Roots	Litter	bark thickness	LPX-Mv1-nr	LPX-Mv1-rs
fAPAR	NME S3	Inter-annual variability	0.67	1	0.64*	0.63*	0.65*	0.66	0.66	0.74
	NME S1	Seasonal Conc.	1.34*	1.44	1.35*	1.36*	1.31*	1.31*	1.32*	1.33*
	NME S2		1.02*	1.05*	1.03*	1.02*	1.02*	1.03*	1.02*	1.00*
	NME S3		1.23*	1.27*	1.24*	1.23*	1.21*	1.21*	1.21*	1.21*
	MPD	Phase	0.25*	0.25*	0.25*	0.24*	0.25*	0.25*	0.24*	0.24*
Veg cover	Mean	Trees	0.034	0.011	0.022	0.034	0.059	0.075	0.042	0.049
	Mean ratio		0.4	0.13	0.26	0.4	0.69	0.88	0.49	0.58
	Mean	Herb	0.44	0.34	0.45	0.44	0.55	0.57	0.55	0.55
	Mean ratio		0.65	0.5	0.65	0.65	0.81	0.84	0.80	0.81
	Mean	Bare ground	0.52	0.65	0.53	0.52	0.39	0.35	0.41	0.40
	Mean ratio		2.79	3.45	2.83	2.77	2.08	1.88	2.18	2.12
	Mean	Phenology	0.066	0.014	0.042	0.063	0.12	0.15	0.10	0.12
	Mean ratio		0.13	0.026	0.081	0.12	0.23	0.28	0.20	0.22
	Mean	Leaf type	0.055	0.01	0.035	0.056	0.10	0.14	0.096	0.11
	Mean ratio		0.094	0.018	0.059	0.096	0.18	0.24	0.17	0.18
Variance	Trees		0.066	0.021	0.042	0.066	0.11	0.14	0.11	0.084
	ratio		0.64	0.21	0.41	0.64	1.07	1.33	1.03	0.82
	Herb		0.26	0.21	0.26	0.25	0.28	0.28	0.28	0.25
	ratio		1.78	1.46	1.77	1.73	1.9	1.94	1.9	1.69
	Bare ground		0.26	0.21	0.26	0.25	0.26	0.26	0.26	0.24
	ratio		1.8	1.48	1.79	1.74	1.8	1.77	1.76	1.65
	Phenology		0.062	0.014	0.041	0.06	0.11	0.13	0.099	0.11
	ratio		0.2	0.043	0.13	0.19	0.33	0.41	0.32	0.33
	Leaf type		0.051	0.01	0.033	0.052	0.092	0.12	0.093	0.1
	ratio		0.15	0.029	0.094	0.15	0.26	0.33	0.27	0.29
MM	Life Form		0.77*	0.96	0.79*	0.76*	0.59*	0.56*	0.59*	0.58*
	Trees		0.16*	0.17*	0.17*	0.17*	0.17*	0.19*	0.17*	0.17*
	Herb		0.66	0.77	0.67	0.65*	0.53*	0.52*	0.51*	0.51*

Derivation of parameter for grass in Eq. 36

Fraction Projected Cover (FPC) can be derived from the Normalised Difference Vegetation Index ($NDVI$) using the following relationship, described in full by Lu & Shuttleworth (2002) and Sellers et al. (1996):

$$FPC \approx LAI_{pft,max} \frac{fAPAR}{fAPAR_{max}} \quad (S1)$$

where:

$$fAPAR \approx \frac{(SR - SR_{pft,min})(fAPAR_{max} - fAPAR_{min})}{(SR_{pft,max} - SR_{pft,min})} \quad (S2)$$

$fAPAR_{max}$ and $fAPAR_{min}$ are the pft-independent, maximum and minimum possible fraction of absorbed photosynthetic radiation ($fAPAR$), SR is the ‘Simple Ratio’ and $SR_{pft,min}$ and $SR_{pft,max}$ are pft specific parameters. SR is related to $NDVI$ using the following relationship from Lu & Shuttleworth (2002):

$$SR = (1 + NDVI)/(1 - NDVI) \quad (S3)$$

Here, we are interested in the contribution of grass pfts to NDVI compared to temperate broadleaf evergreen trees (tbe – denoted ‘tree’ in the following equations), the dominant tree pft in the study area. According to Sellers et al. (1996), $SR_{pft,min}$ is the same for tbe and grass. Re-arranging Eq. (S1) and (S2), we get:

$$P_{grass} = \frac{FPC_{grass}}{FPC_{tree}} \approx \frac{LAI_{grass,max}}{LAI_{tree,max}} \frac{(SR_{tree,max} - SR_{min})}{(SR_{grass,max} - SR_{min})} \quad (S4)$$

Using the parameters for biome 1 (tbe) for wood and biome 6-other and 9 (C3/C4 grass and cropland) for grass from Sellers et al. (1996) in Eq. (S3) and (S4), we obtain the value of 0.32 used in Eq. 36 in the main manuscript.

References for data used to parameterize adaptive bark thickness vs diameter at breast height.

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