Supplementary: New 3D measurements of large redwood trees for biomass and structure

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Mathias Disney, John Armston, Andrew Burt, Laura Duncason and Phil Wilkes
m.disney@ucl.ac.uk

Allometric model details

Table S1 shows the details of all published and TLS-derived (this study) models used. For the previously published models all coefficients a-d are taken direct from the publications. For the TLS-derived DTB, H model, model coefficients are obtained by fitting the Sillett et al. (2019)[8] model to the TLS-derived estimates of volume using TLS estimates of DTB and H. The same is true for the H only model with the given form.

Table S1: Allometric model forms and parameter values. See Methods for definitions of DTB and fDBH.

Model	**Form**	**a**	**b**	**c**	**d**
Parks (1952)[10]	$log_{10}(Vol) = alog_{10}(DBH^2H) - b$	0.9246	0.4147		
Fujimori (1977)[2]	$log_{10}(Vol) = alog_{10}(DBH^2H) - b$	0.9784	0.4843		
Sillett et al. (2015)[19]	$AGB = aDTB^b + cfDBH^d$	3.9656×10^{-4}	2.3122	1.9583×10^{-3}	1.8657
Sillett et al. (2015)[19]	$Vol = aDTB^b + cfDBH^d$	2.2529×10^{-4}	2.3747	1.2574×10^{-3}	1.9171
Sillett et al. (2019)[8]	$AGB = aDTB^b + cH^d$	7.585×10^{-2}	2.401	3.468×10^{-3}	3.301
Sillett et al. (2019)[8]	$Vol = aDTB^b + cH^d$	2.752×10^{-4}	2.372	1.173×10^{-5}	3.306
TLS-derived	$Vol = aDTB^b + cH^d$	7.667×10^{-5}	2.624	0.159	1.040
TLS H only	$Vol = aH^b + c$	1.203×10^{-8}	5.36	4.97	
Kizha & Han (2015)[9]	$log_{10}(AGB) = a + blog_{10}(DBH) + c$	-0.8252	2.2607	0.0054	
Jenkins et al. (2003)[51]	$ln(AGB) = a + bln(DBH)$	-2.0336	2.2592		
Chojnacky et al. (2014)[52]	$ln(AGB) = a + bln(DBH)$	-2.7765	2.4195		

Size of trees in all plots

Figure S1 (left panel) shows the fit of VOL:H allometry derived from the TLH estimates of H, with the model parameters in Table S1. The right panel shows the scatter plot of volume estimated using TLS-derived H-only allometry, with the full Sillett et al. (2015)[19] allometry. This is included as a demonstration of the ability of a H-only allometry based on the TLS data to predict the volume of *Sequoia sempervirens* trees. This relationship would potentially allow Earth Observation-derived estimates of H to be used to estimate volume (and AGB). Unsurprisingly, the model fit is worse than that of the DBH, H models (with large uncertainty in the 60-70m height range), but with greater model parsimony.

Tables S2-S4 show the size of all *Sequoia sempervirens* trees extracted from plots at each of the three sites, in height order.

Table S2: Size of trees in Grove of Old Trees, plot CAL-01.

x (m)	**y (m)**	**H (m)**	**DBH (m)**	**DTB (m)**	**fDBH (m)**
4.89	5.86	19.57	1.14	1.02	1.23
15.75	17.16	44.71	1.10	1.00	1.18
17.74	19.55	50.04	1.26	1.18	1.33
14.32	18.62	57.99	1.34	1.23	1.49
14.25	15.69	58.01	1.20	1.16	1.27

13.22	13.59	58.57	1.15	1.09	1.24
14.66	12.84	58.60	1.29	1.13	1.36
16.47	14.97	58.85	1.01	0.98	0.48
13.55	14.86	59.94	1.27	1.17	1.33
17.17	18.10	63.71	2.08	1.92	2.22
11.30	16.16	64.29	1.39	1.26	1.50
19.09	15.40	64.59	1.22	1.06	1.30
16.57	13.09	66.15	1.73	1.57	1.81
20.00	20.00	66.65	2.82	2.48	3.04
18.51	17.93	67.68	2.04	1.88	2.14
13.63	16.89	67.83	1.22	1.15	1.30
13.81	17.19	68.10	1.75	1.66	1.85
13.80	14.87	68.11	1.60	1.41	1.73
18.18	14.77	68.69	1.83	1.67	1.91
18.40	19.39	69.58	1.87	1.74	1.97
15.49	15.82	70.17	2.68	2.25	2.87
14.53	16.29	70.66	1.50	1.31	1.60
14.49	15.43	70.94	1.35	1.22	1.45
19.56	17.52	72.90	2.16	2.11	2.26
15.77	16.13	73.34	2.35	2.06	2.48
15.98	15.51	87.79	3.39	2.95	3.49

Table S3: Size of trees in Armstrong State Natural Reserve, plot CAL-02.

x (m)	**y (m)**	**H (m)**	**DBH (m)**	**DTB (m)**	**fDBH (m)**
6.60	6.58	15.34	0.24	0.17	0.27
6.37	5.78	19.55	0.25	0.19	0.28
11.10	13.07	36.78	0.78	0.69	0.86
11.99	9.61	36.85	0.88	0.69	0.99
11.40	8.74	37.65	0.83	0.66	0.88
14.28	8.23	38.17	0.88	0.71	0.97
14.81	11.19	38.52	0.89	0.68	0.98
7.03	13.62	41.06	0.91	0.77	0.99
9.71	11.88	47.87	1.27	0.81	1.45
8.37	6.47	51.54	1.27	1.12	1.31
12.96	7.36	53.86	1.06	0.92	1.11
12.30	9.04	53.98	1.07	0.93	1.12
4.95	5.14	55.62	1.20	1.09	1.26
9.08	8.79	55.85	0.77	0.72	0.81
9.09	6.76	55.86	0.93	0.96	0.96
4.25	4.43	56.23	1.48	1.26	1.55
13.67	11.05	59.19	0.73	0.71	0.77
10.14	10.78	59.56	1.55	1.30	1.61
10.40	7.09	60.22	0.79	0.70	0.83
12.37	15.13	60.76	1.46	1.35	1.55
11.79	15.29	61.26	1.18	1.26	1.25
11.93	10.69	62.14	1.36	1.25	1.41
5.32	5.96	63.29	1.36	1.10	0.70
14.93	12.42	63.30	1.49	1.27	1.56
11.29	17.63	63.69	1.72	1.54	1.98
8.35	10.93	63.78	1.58	1.32	1.64
8.63	7.49	63.90	1.60	1.31	1.67
19.33	10.82	64.33	2.10	1.81	2.20
13.15	17.15	64.71	1.62	1.41	1.69
14.04	26.11	64.95	2.10	1.81	2.20
15.36	11.46	66.65	1.06	0.96	1.12
15.55	17.55	66.71	2.26	2.03	2.37
12.41	12.84	68.87	1.73	1.50	1.83

16.24	20.22	68.87	1.73	1.50	1.82
7.35	6.45	69.04	1.75	1.51	1.83
14.37	18.49	70.40	1.87	1.91	2.00
14.29	16.57	71.65	2.02	1.72	2.08
16.06	23.52	72.49	1.78	1.54	1.86

Table S4: Size of trees in Richardson Reserve, plot CAL-07.

x (m)	**y (m)**	**H (m)**	**DBH (m)**	**DTB (m)**	**fDBH (m)**
2.20	2.77	19.45	0.27	0.27	0.30
3.28	3.29	23.79	0.35	0.95	0.39
3.40	4.52	28.16	0.55	0.49	0.60
4.12	3.95	32.06	0.44	0.37	0.47
3.25	3.97	34.50	0.43	0.36	0.47
3.69	3.37	34.51	0.39	0.36	0.44
1.52	3.81	37.99	0.74	0.66	0.79
4.60	4.28	38.43	0.47	0.43	0.50
2.63	3.18	40.30	0.26	0.23	0.29
3.02	6.26	41.49	0.56	0.50	0.60
3.71	4.65	41.73	0.47	0.43	0.54
4.74	4.88	41.89	0.82	0.65	0.80
5.12	5.99	42.53	0.56	0.53	0.62
5.99	5.66	42.53	0.61	0.57	0.67
5.01	5.00	43.16	0.63	0.56	0.68
6.24	6.26	43.73	0.65	0.60	0.71
7.35	2.78	43.81	0.50	0.43	0.53
6.72	6.37	43.88	0.69	0.62	0.74
7.69	3.24	45.37	0.70	0.64	0.74
4.84	3.09	45.46	0.48	0.42	0.51
7.69	4.19	45.54	0.64	0.55	0.71
8.15	4.82	46.11	0.79	0.75	0.85
5.66	2.85	46.13	0.68	0.62	0.73
4.36	4.10	46.85	0.72	0.67	0.76
5.97	7.60	46.85	0.84	0.74	0.90
6.39	6.28	46.86	0.72	0.67	0.77
5.42	5.46	46.91	0.79	0.71	0.84
5.57	4.17	46.98	0.70	0.65	0.75
4.93	8.20	47.11	0.79	0.73	0.86
10.12	10.81	47.19	0.86	0.74	0.92
4.19	4.18	47.41	0.68	0.54	0.74
7.44	7.45	47.77	0.71	0.69	0.78
7.59	6.88	47.82	0.76	0.72	0.83
5.65	4.80	47.87	0.61	0.56	0.66
3.59	3.62	48.13	0.70	0.60	0.78
7.95	7.85	48.28	0.87	0.79	0.93
7.11	7.05	48.43	0.70	0.65	0.74
4.00	5.83	48.51	0.61	0.57	0.68
4.86	4.57	48.70	0.51	0.44	0.55
7.09	4.31	49.07	0.72	0.67	0.78
7.28	4.55	49.13	0.76	0.70	0.83
8.22	8.91	50.02	0.94	0.84	0.99
5.72	4.72	50.26	0.85	0.77	0.91
4.89	9.73	50.75	0.75	0.65	0.79
6.09	5.92	51.05	0.67	0.57	0.74
7.49	7.77	51.08	0.83	0.73	0.91
6.61	8.37	51.92	0.86	0.77	0.90
9.06	6.61	52.61	0.82	0.78	0.87
8.53	9.46	52.74	0.87	0.78	0.94
6.10	6.32	52.89	0.91	0.83	0.95

9.29	9.93	52.97	1.00	0.92	1.06
1.71	10.23	53.69	0.84	0.76	0.89
8.89	7.26	53.89	0.94	0.83	1.01
9.00	9.51	53.90	0.90	0.84	0.96
7.75	9.33	55.74	0.92	0.85	0.99
6.82	6.65	55.85	0.67	0.60	0.72
9.51	9.64	55.96	1.07	0.93	1.11
4.21	9.90	56.31	0.84	0.75	0.90
12.49	11.05	57.54	0.82	0.76	0.86
9.39	10.25	57.54	0.85	0.75	0.89
10.50	10.12	57.61	1.09	0.99	1.15
5.26	7.53	57.88	0.79	0.74	0.84
9.17	6.40	57.96	0.94	0.85	1.00
8.82	9.32	58.30	0.96	0.87	1.00
8.87	5.89	58.35	0.94	0.86	1.02
8.92	8.77	58.72	0.91	0.84	0.93
7.85	7.59	58.86	0.83	0.76	0.88
8.67	9.04	58.91	0.92	0.86	0.97
4.97	6.50	59.12	0.94	0.87	1.00
4.49	4.80	59.13	0.45	0.41	0.48
9.75	10.13	59.46	1.08	0.93	1.13
9.45	9.63	59.59	1.01	0.91	1.06
9.17	8.83	60.12	0.99	0.84	1.04
8.04	9.93	60.56	1.01	0.94	1.09
12.24	10.21	60.65	1.02	0.95	1.06
6.44	6.62	62.10	0.69	0.60	0.77
6.55	6.60	62.27	0.76	0.64	0.84
9.82	12.53	64.05	1.35	1.25	1.37
10.36	10.20	65.37	1.11	0.96	1.15
10.25	10.18	66.48	1.06	0.96	1.09

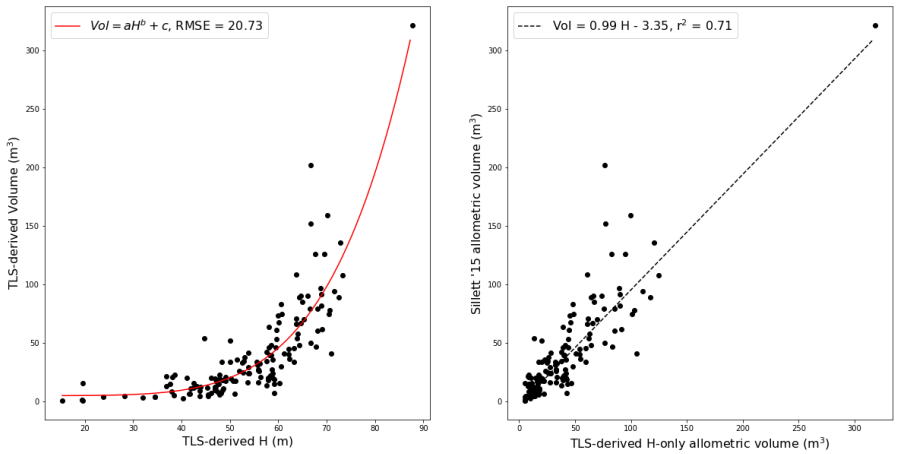

Figure S1: Volume estimated from TLS-derived values of H only, plotted in arithmetic space (left panel); scatter of volume predicted from TLS-derived H only allometry, against volume predicted by Sillett et al. (2015)[19] allometry (right panel).