Supplementary file S3

Tables

Table S3_1   Amount of detected trees [%] at different settings of the span of diameter at breast height and normalized standard deviation of the position error σ√ρ. The average of simulated plots with three stems per hectare, 500, 1000, and 1500, were used.

σ√ρ	Dbh 30 cm	Dbh 15-30 cm	Dbh 10-30 cm	Dbh 10-40 cm	Dbh 10-50 cm	Dbh 10-60 cm
0.05	99.9	99.9	100.0	100.0	99.9	100.0
0.15	96.8	98.0	98.4	98.5	98.4	98.6
0.25	87.6	91.5	92.3	92.6	93.6	94.1
0.35	76.6	82.6	83.9	85.5	86.0	86.7
0.45	66.2	72.3	75.7	76.9	77.7	79.4
0.55	57.1	64.7	67.2	69.4	70.4	72.2
0.65	49.6	56.2	60.4	63.4	64.5	65.5
0.75	44.6	51.1	53.7	56.3	58.0	59.6
0.85	38.7	46.7	49.7	50.7	53.3	53.9
0.95	35.9	41.4	45.4	47.4	48.6	49.6
1.05	33.1	38.5	41.8	43.6	45.3	46.2
1.15	30.5	35.6	38.3	40.3	41.7	42.2
1.25	27.7	32.2	36.0	37.2	39.0	39.5
1.35	25.6	30.7	33.0	35.1	36.7	37.1
1.45	23.7	29.3	31.7	32.7	33.8	34.9
1.55	22.6	27.0	29.7	31.2	32.3	32.4
1.65	21.4	24.8	27.4	29.1	30.7	31.4
1.75	20.8	23.8	25.7	28.5	28.7	29.8
1.85	19.1	23.0	24.8	26.6	27.3	28.1

σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}. Dbh=diameter at breast height.

Table S3_2 Curve fitted function parameters for the detection rate in the simulations with different settings of diameter at breast height ratio and different number of stems per hectare.

Dbh [m]	Dbh ratio	Sph [ha^{-1}]	C1	p1	C2	p2	Rmse
0.30 - 0.30	1.0	all	1.5	2.0	0.34	-0.89	0.101
0.30 - 0.30	1.0	500	1.55	2.0	0.34	-0.86	0.127
0.30 - 0.30	1.0	1000	1.49	2.0	0.33	-0.91	0.086
0.30 - 0.30	1.0	1500	1.47	2.0	0.34	-0.9	0.081
0.15 - 0.30	2.0	all	1.24	2.0	0.39	-0.83	0.102
0.15 - 0.30	2.0	500	1.29	2.0	0.39	-0.8	0.132
0.15 - 0.30	2.0	1000	1.23	2.0	0.39	-0.84	0.088
0.15 - 0.30	2.0	1500	1.2	2.0	0.39	-0.85	0.075
0.10 - 0.30	3.0	all	1.13	2.0	0.42	-0.78	0.098
0.10 - 0.30	3.0	500	1.16	2.0	0.42	-0.75	0.128
0.10 - 0.30	3.0	1000	1.14	2.0	0.41	-0.79	0.081
0.10 - 0.30	3.0	1500	1.09	2.0	0.41	-0.81	0.077
0.10 - 0.40	4.0	all	1.05	2.0	0.44	-0.76	0.099
0.10 - 0.40	4.0	500	1.07	2.0	0.44	-0.74	0.127
0.10 - 0.40	4.0	1000	1.05	2.0	0.43	-0.76	0.089
0.10 - 0.40	4.0	1500	1.02	2.0	0.43	-0.78	0.073
0.10 - 0.50	5.0	all	1.01	2.0	0.45	-0.73	0.098
0.10 - 0.50	5.0	500	1.03	2.0	0.46	-0.7	0.126
0.10 - 0.50	5.0	1000	1.02	2.0	0.44	-0.75	0.086
0.10 - 0.50	5.0	1500	0.99	2.0	0.44	-0.76	0.077
0.10 - 0.60	6.0	all	0.96	2.0	0.46	-0.73	0.098
0.10 - 0.60	6.0	500	0.97	2.0	0.46	-0.71	0.123
0.10 - 0.60	6.0	1000	0.98	2.0	0.45	-0.73	0.09
0.10 - 0.60	6.0	1500	0.94	2.0	0.45	-0.75	0.076

Dbh=diameter at breast height. Sph=stems per hectare. all=an equal amount of 500, 1000 and 1500 Sph. Dbh ratio=the maximum possible Dbh in the span divided by the minimum possible Dbh in the span. Rmse=root mean square error of model fit residuals.

A binomial test was performed to see if the diameter weighted linking algorithm differs from an unweighted euclidean linking algorithm. The difference between the linking accuracy ratios for the weighted and the unweighted algorithms was saved for every simulated forest plot. If the algorithms are equal there should be an equal probability of negative as well as positive differences. A two sided binomial test was performed for the different settings in the simulation. The binomial tests in (Tables S3_3-S3_6) show that the diameter weighted algorithm is an improvement as long as the stands have diverse diameter distributions. This apply for all tested stem densities, 500, 1000, 1500 stems ha^{-1} and the combination of all three. It is only the stands with a single stem diameter 0.30 m that is not possible to separate from a pure euclidean linking algorithm. A small number of tests also had to few observations to make it possible to evaluate if they differ from a pure euclidean linking algorithm. For instance in (Table 5) for the diameter span 0.10-0.3 m only one observation with a difference was found which is too small to be used as a test and for the diameter span 0.10-0.50 m only five differing observations was found which gave a 6.2 % chance of the distributions being equal. For the others the probability levels are extremely small for the chance of the distributions being equal, thus showing that the diameter weighted linking algorithm is an improvement when operating on diverse diameter stands with stem position errors in the single tree detectors.

Table S3_3 Pairwise comparison of the difference between the co-registration tree detection ratio of weighted and unweighted algorithms. The number of stems per hectare are an equal amount of 500, 1000, and 1500. The columns where the trees had equal diameter at breast height did not have any plots with a difference in detection rate, making the weighted and unweighted algorithms work equally well.

Dbh [cm]	30	30	30	10-30	10-30	10-30	10-50	10-50	10-50
$\sigma\sqrt{\rho}$	avg	p	n	avg	p	n	avg	p	n
0.05	0.0	1.0	0	0.001	7.8e-03	8	0.001	6.1e-05	15
0.15	0.0	1.0	0	0.015	3.3e-62	213	0.018	8.8e-75	247
0.25	0.0	1.0	0	0.049	5.7e-160	530	0.058	2.5e-175	581
0.35	0.0	1.0	0	0.079	2.9e-195	665	0.096	1.6e-201	668
0.45	0.0	1.0	0	0.096	4.1e-202	670	0.118	1.5e-210	698
0.55	0.0	1.0	0	0.106	2.3e-218	724	0.134	6.4e-224	752
0.65	0.0	1.0	0	0.106	2.6e-203	674	0.139	9.1e-218	722
0.75	0.0	1.0	0	0.105	2.6e-211	710	0.138	1.6e-215	724
0.85	0.0	1.0	0	0.100	8.6e-201	675	0.135	4.1e-219	736
0.95	0.0	1.0	0	0.091	7.2e-189	626	0.125	9.3e-215	712

Dbh=the diameter at breast height. avg=the average difference. σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}. n=the number of compared plots. p=the binomial probability of the values belonging to the same distribution.

Table S3_4 Pairwise comparison of the difference between the co-registration tree detection ratio of weighted and unweighted algorithms. The number of stems per hectare 500. The columns where the trees had equal diameter at breast height did not have any plots with a difference in detection rate, making the weighted and unweighted algorithms work equally well.

Dbh [cm]	30	30	30	10-30	10-30	10-30	10-50	10-50	10-50
$\sigma\sqrt{\rho}$	avg	p	n	avg	p	n	avg	p	n
0.05	0.0	1.0	0	0.001	3.1e-02	6	0.001	6.2e-02	5
0.15	0.0	1.0	0	0.015	4.4e-16	52	0.018	4.3e-19	62
0.25	0.0	1.0	0	0.049	3.5e-46	152	0.058	7.0e-46	151
0.35	0.0	1.0	0	0.079	2.6e-54	179	0.096	2.5e-60	199
0.45	0.0	1.0	0	0.096	2.1e-53	176	0.118	2.4e-63	209
0.55	0.0	1.0	0	0.106	1.6e-61	203	0.134	2.6e-64	220
0.65	0.0	1.0	0	0.106	1.6e-58	193	0.139	1.2e-63	210
0.75	0.0	1.0	0	0.105	8.2e-63	215	0.138	1.3e-64	221
0.85	0.0	1.0	0	0.100	1.9e-62	206	0.135	2.8e-73	242
0.95	0.0	1.0	0	0.091	6.5e-55	181	0.125	3.8e-65	215

Dbh=the diameter at breast height. avg=the average difference. σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}. n=the number of compared plots. p=the binomial probability of the values belonging to the same distribution.

Table S3_5 Pairwise comparison of the difference between the co-registration tree detection ratio of weighted and unweighted algorithms. The number of stems per hectare 1000. The columns where the trees had equal diameter at breast height did not have any plots with a difference in detection rate, making the weighted and unweighted algorithms work equally well.

Dbh [cm] 30	30	30	10-30	10-30	10-30	10-50	10-50	10-50
$\sigma\sqrt{\rho}$	avg	p	n	avg	p	n	avg	p	n
0.05	0.0	1.0	0	0.001	1.0e+00	1	0.001	6.2e-02	5
0.15	0.0	1.0	0	0.015	1.0e-21	77	0.018	2.0e-28	93
0.25	0.0	1.0	0	0.049	5.3e-51	168	0.058	5.0e-60	198
0.35	0.0	1.0	0	0.079	2.6e-67	237	0.096	9.1e-72	237
0.45	0.0	1.0	0	0.096	2.1e-81	269	0.118	2.3e-72	239
0.55	0.0	1.0	0	0.106	5.4e-79	261	0.134	1.1e-78	260
0.65	0.0	1.0	0	0.106	1.8e-71	236	0.139	1.3e-79	263
0.75	0.0	1.0	0	0.105	5.8e-70	231	0.138	2.2e-78	259
0.85	0.0	1.0	0	0.100	6.6e-65	222	0.135	8.5e-69	235
0.95	0.0	1.0	0	0.091	1.5e-64	213	0.125	2.2e-75	249

Dbh=the diameter at breast height. avg=the average difference. σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}. n=the number of compared plots. p=the binomial probability of the values belonging to the same distribution.

Table S3_6   Pairwise comparison of the difference between the co-registration tree detection ratio of weighted and unweighted algorithms. The number of stems per hectare is 1500. The columns where the trees had equal diameter at breast height did not have any plots with a difference in detection rate, making the weighted and unweighted algorithms work equally well.

Dbh [cm]	30	30	30	10-30	10-30	10-30	10-50	10-50	10-50
$\sigma\sqrt{\rho}$	avg	p	n	avg	p	n	avg	p	n
0.05	0.0	1.0	0	0.001	1.0e+00	1	0.001	6.2e-02	5
0.15	0.0	1.0	0	0.015	1.0e-25	84	0.018	4.0e-28	92
0.25	0.0	1.0	0	0.049	1.2e-63	210	0.058	2.9e-70	232
0.35	0.0	1.0	0	0.079	2.2e-75	249	0.096	2.9e-70	232
0.45	0.0	1.0	0	0.096	3.7e-68	225	0.118	1.1e-75	250
0.55	0.0	1.0	0	0.106	1.1e-78	260	0.134	2.6e-82	272
0.65	0.0	1.0	0	0.106	3.5e-74	245	0.139	2.2e-75	249
0.75	0.0	1.0	0	0.105	6.7e-80	264	0.138	7.1e-74	244
0.85	0.0	1.0	0	0.100	8.8e-75	247	0.135	2.2e-78	259
0.95	0.0	1.0	0	0.091	2.9e-70	232	0.125	4.4e-75	248

Dbh=the diameter at breast height. avg=the average difference. σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}. n=the number of compared plots. p=the binomial probability of the values belonging to the same distribution.

Table S3_7   Statistics of the co-registration quality metric Q for different number of stems ha^{-1} for randomly combined plots. These values are used to set a minimum Q threshold for the level of possible correctly linked field plots. Values lower than this are probably caused by incorrect co-registrations.

Stems/ha	avg Q	StdDev Q	Avg + 3 stdDev	Probability Q < 0.55 [%]
500	0.416	0.0520	0.572	99.51
1000	0.442	0.0372	0.553	99.82
1500	0.459	0.0288	0.545	99.92

avg=the average. StdDev=population standard deviation.

Table S3_8   Statistics of the co-registration quality metric Q for different number of stems ha^{-1} and normalized position error standard deviation $\sigma\sqrt{\rho}$, for correctly co-registered plots. Small stem position errors makes it easier to separate a correct co-registration from an incorrect one.

Stems ha^{-1}	$\sigma\sqrt{\rho}$	Dbh [m]	Probability (Q > 0.55) [%]
500	0.1	0.3-0.3	100.0
500	0.1	0.1-0.6	100.0
1000	0.1	0.3-0.3	100.0
1000	0.1	0.1-0.6	100.0
1500	0.1	0.3-0.3	100.0
1500	0.1	0.1-0.6	100.0
500	0.2	0.3-0.3	83.53
500	0.2	0.1-0.6	91.4
1000	0.2	0.3-0.3	99.06
1000	0.2	0.1-0.6	99.96
1500	0.2	0.3-0.3	99.88
1500	0.2	0.1-0.6	100.0
500	0.3	0.3-0.3	31.36
500	0.3	0.1-0.6	31.72
1000	0.3	0.3-0.3	66.78
1000	0.3	0.1-0.6	79.04
1500	0.3	0.3-0.3	86.09
1500	0.3	0.1-0.6	97.24
500	0.4	0.3-0.3	3.93
500	0.4	0.1-0.6	10.93
1000	0.4	0.3-0.3	16.82
1000	0.4	0.1-0.6	27.25
1500	0.4	0.3-0.3	30.74
1500	0.4	0.1-0.6	53.74

Dbh=the diameter at breast height. σ=stem position radial displacement standard deviation. ρ=the number of stems m^{-2}.