SUPPLEMENTARY MATERIAL

Primary forest loss and degradation reduces biodiversity and ecosystem functioning: A global meta-analysis using dung beetles as an indicator taxon

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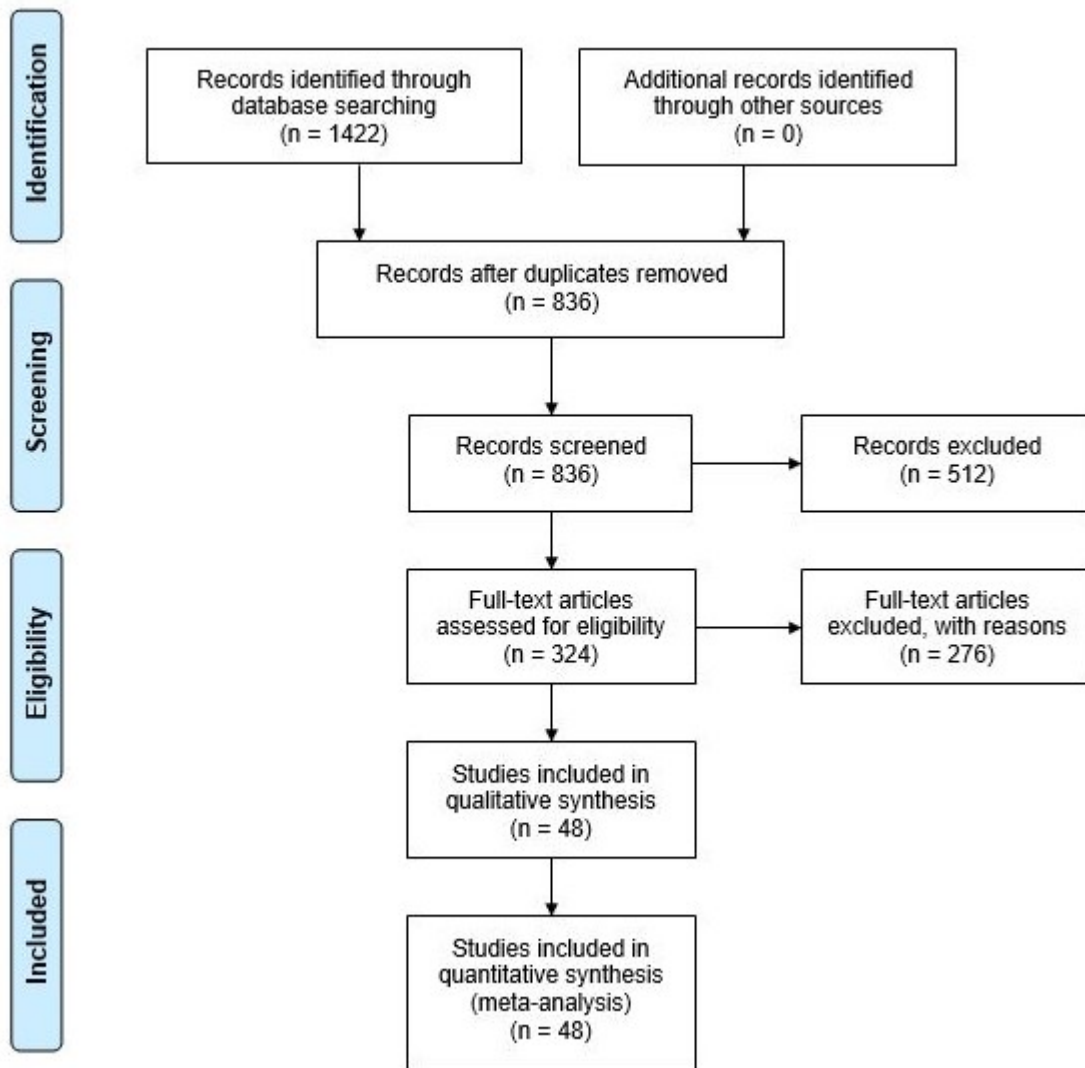*Correspondence: Jorge Ari Noriega. Email: jnorieg@hotmail.com

Identification

Records identified through database searching
(n = 1422)

Additional records identified through other sources
(n = 0)

Screening

Records after duplicates removed
(n = 836)

Records screened
(n = 836)

Records excluded
(n = 512)

Eligibility

Full-text articles assessed for eligibility
(n = 324)

Full-text articles excluded, with reasons
(n = 276)

Included

Studies included in qualitative synthesis
(n = 48)

Studies included in quantitative synthesis (meta-analysis)
(n = 48)

Figure S1. Flow diagram according to the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-analysis) carried out in this study
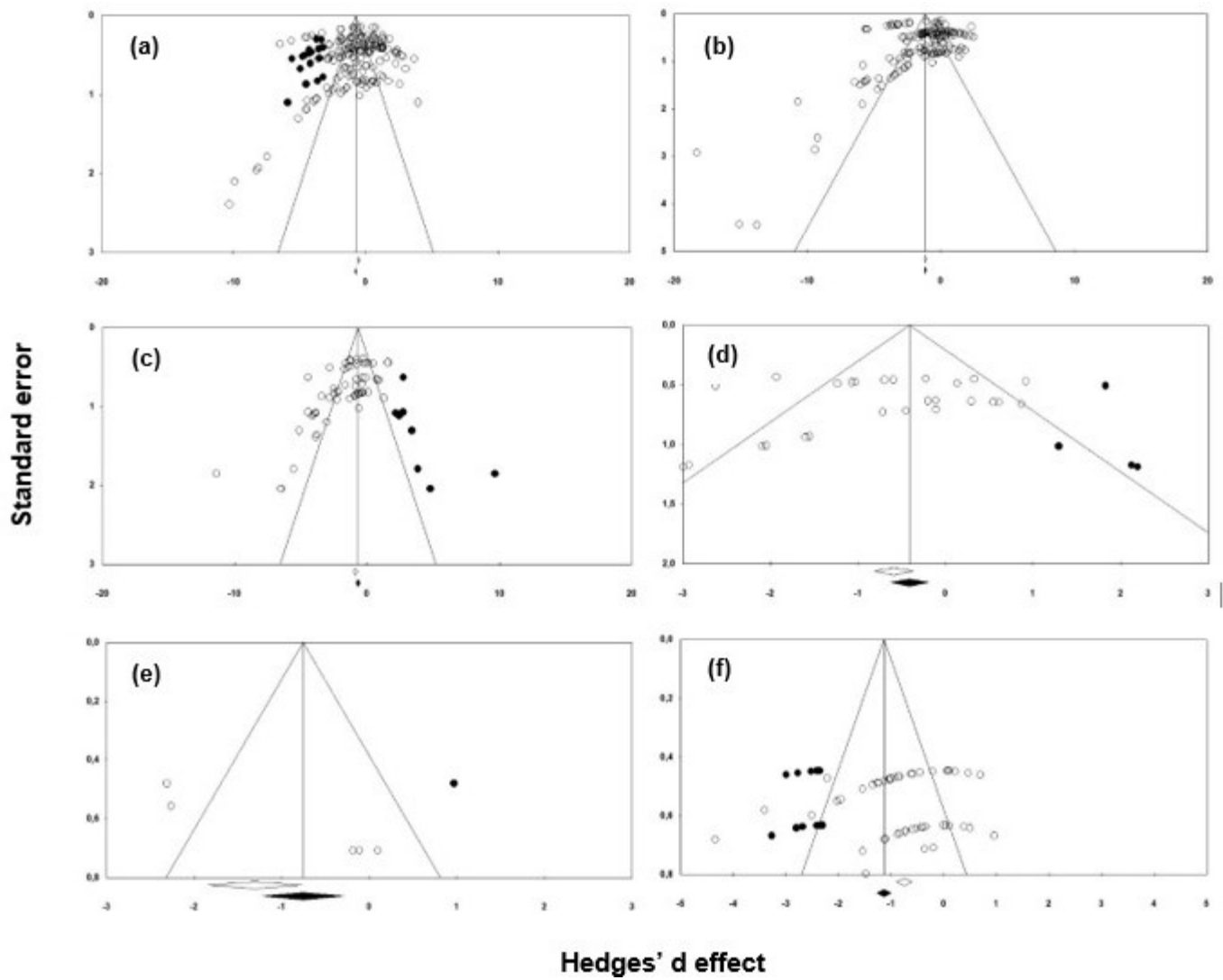
Figure S2. Funnel plot for different metrics of dung beetles in the meta-analysis conducted. (a) richness, (b) total abundance, (c) biomass, (d) dung removal, (e) soil excavated, and (f) seed dispersal. White circles represent observed case studies and black circles represent imputed case studies after trim and fill procedures. White diamond indicates the observed effect size (mean point estimate), and black diamond indicate the adjusted effect size

Table S1. Summary of the case studies for richness and total abundance used in the meta-analysis, detailing utilized metric, coverage type (degraded native forest, secondary forest, forestry plantation and forestry restoration), latitude, zoogeographic region, and biodiversity hotspot location. Some references provided more than one case study, referred to different sampling locations or different sampling time, which were considered as independent cases. Hedges' d and variance values (Var) are reported

Ref.	Metric	Coverage type	Latitude	Zoogeographic region	Hotspot	d value	Var
1	Richness	Secondary forest	Tropical	Nearctic	Mesoamerica	1,310	0,607
1	Richness	Secondary forest	Tropical	Nearctic	Mesoamerica	1,719	0,685
1	Abundance	Secondary forest	Tropical	Nearctic	Mesoamerica	0,709	0,531
1	Abundance	Secondary forest	Tropical	Nearctic	Mesoamerica	0,996	0,562
2	Richness	Secondary forest	Tropical	Neotropical	Mesoamerica	1,183	0,131
2	Richness	Secondary forest	Tropical	Neotropical	Mesoamerica	1,223	0,132
2	Richness	Secondary forest	Tropical	Neotropical	Mesoamerica	2,365	0,189
2	Richness	Secondary forest	Tropical	Neotropical	Mesoamerica	3,670	0,298
3	Richness	Degraded primary forest	Tropical	Neotropical	Atlantic forest	0,056	0,400
3	Richness	Forestry restoration	Tropical	Neotropical	Atlantic forest	-4,536	1,429
3	Richness	Forestry restoration	Tropical	Neotropical	Atlantic forest	-7,467	3,188
3	Richness	Forestry restoration	Tropical	Neotropical	Atlantic forest	-10,309	5,713
3	Abundance	Degraded primary forest	Tropical	Neotropical	Atlantic forest	-0,389	0,408
3	Abundance	Forestry restoration	Tropical	Neotropical	Atlantic forest	-5,740	2,047
3	Abundance	Forestry restoration	Tropical	Neotropical	Atlantic forest	-3,533	1,024
3	Abundance	Forestry restoration	Tropical	Neotropical	Atlantic forest	-6,053	2,232
4	Richness	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-0,225	0,671
4	Richness	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-1,885	0,963
4	Richness	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-0,011	0,667
4	Richness	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-1,662	0,897
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-1,225	0,792
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-1,090	0,766
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-15,097	19,659
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-4,420	2,295
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-3,510	1,693
4	Abundance	Secondary forest	Tropical	Afrotropical	Guinean forest of West Africa	-3,108	1,472
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,759	0,259
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-2,781	0,293
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-2,448	0,322
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,891	0,216
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,979	0,277
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-2,805	0,296
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,149	0,220
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,014	0,169
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-0,818	0,206
5	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-1,468	0,190
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-1,368	0,232
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-1,239	0,178

5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-1,710	0,255
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,673	0,158
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-2,530	0,331
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-1,424	0,188
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,177	0,192
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,361	0,152
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	0,123	0,192
5	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,224	0,151
6	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-0,670	0,704
6	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,655	1,254
7	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-2,584	0,237
7	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,700	0,247
8	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-2,727	0,266
8	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-1,318	0,168
9	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-1,155	0,167
9	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-2,900	0,293
9	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-1,344	0,175
9	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,034	0,217
10	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-0,302	0,202
10	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	0,406	0,204
11	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-0,478	0,080
11	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-0,162	0,076
11	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-0,366	0,073
11	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,203	0,030
11	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,254	0,031
11	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,389	0,031
12	Abundance	Degraded primary forest	Non-tropical	Neotropical	Atlantic forest	-0,365	0,407
13	Richness	Degraded primary forest	Tropical	Afrotropical	Guinean forest of West Africa	0,519	0,172
13	Abundance	Degraded primary forest	Tropical	Afrotropical	Guinean forest of West Africa	0,962	0,186
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,836	0,090
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,651	0,067
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,000	0,072
14	Richness	Forestry plantation	Tropical	Oriental	Sundaland	-2,745	0,130
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,795	0,067
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	1,804	0,087
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,119	0,062
14	Richness	Forestry plantation	Tropical	Oriental	Sundaland	-1,774	0,091
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,013	0,083
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	1,420	0,092
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,165	0,074
14	Richness	Forestry plantation	Tropical	Oriental	Sundaland	-1,927	0,113
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,166	0,078
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	1,304	0,081
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,313	0,067

14	Richness	Forestry plantation	Tropical	Oriental	Sundaland	-2,083	0,108
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,858	0,095
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,560	0,069
14	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,048	0,076
14	Richness	Forestry plantation	Tropical	Oriental	Sundaland	-2,736	0,136
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,173	0,134
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,367	0,227
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,851	0,269
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,840	0,145
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,538	0,138
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,742	0,142
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,639	0,178
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,127	0,154
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,539	0,173
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,218	0,158
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,237	0,217
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,181	0,134
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-2,071	0,205
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,405	0,136
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,457	0,137
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,115	0,134
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,794	0,144
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,204	0,214
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,686	0,254
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,467	0,137
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,296	0,161
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,317	0,135
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,329	0,163
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,725	0,142
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,714	0,142
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,282	0,161

15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,272	0,219
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,217	0,134
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,025	0,151
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,078	0,133
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,745	0,143
15	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,331	0,135
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,465	0,169
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,246	0,159
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,556	0,138
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,105	0,154
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,208	0,158
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,142	0,155
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,134	0,134
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,022	0,133
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-2,322	0,223
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,578	0,175
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,763	0,143
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,029	0,151
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,438	0,168
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,192	0,157
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,048	0,152
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,954	0,149
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,878	0,146
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,127	0,134
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,456	0,234
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,743	0,143
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,306	0,135
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,622	0,140
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,826	0,189
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,489	0,170

15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-1,033	0,151
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,126	0,134
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,138	0,210
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,448	0,137
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,036	0,133
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,321	0,135
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,712	0,182
15	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,416	0,167
16	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	3,983	1,210
16	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,091	0,334
16	Richness	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	3,028	0,452
16	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,486	0,086
16	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	-0,143	0,058
16	Abundance	Secondary forest	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	2,306	0,072
17	Richness	Secondary forest	Tropical	Neotropical	Tropical Andes	0,948	0,122
17	Abundance	Secondary forest	Tropical	Neotropical	Tropical Andes	-0,917	0,121
18	Richness	Forestry restoration	Tropical	Australasia	Forest of East Australia	-2,273	0,823
18	Richness	Forestry restoration	Tropical	Australasia	Forest of East Australia	-1,247	0,597
18	Richness	Forestry restoration	Tropical	Australasia	Forest of East Australia	-1,070	0,572
18	Abundance	Forestry restoration	Tropical	Australasia	Forest of East Australia	-2,489	0,887
18	Abundance	Forestry restoration	Tropical	Australasia	Forest of East Australia	-1,549	0,650
18	Abundance	Forestry restoration	Tropical	Australasia	Forest of East Australia	-0,855	0,546
19	Richness	Secondary forest	Tropical	Nearctic	Mesoamerica	2,285	0,367
19	Richness	Forestry restoration	Tropical	Nearctic	Mesoamerica	1,574	0,291
19	Abundance	Secondary forest	Tropical	Nearctic	Mesoamerica	-10,721	3,415
19	Abundance	Forestry restoration	Tropical	Nearctic	Mesoamerica	-5,835	1,168
20	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,647	0,446
20	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-1,518	0,429
21	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,870	0,274
21	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,959	0,279
21	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,128	0,050
21	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	0,342	0,051
22	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,955	0,172
22	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-3,612	0,306
22	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,349	0,157
22	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-2,895	0,241

23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,304	0,021
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-4,564	0,075
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,897	0,023
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-6,482	0,130
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,553	0,022
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-4,421	0,072
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,958	0,023
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-5,618	0,103
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	0,553	0,022
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,316	0,049
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,692	0,022
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-4,057	0,064
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	0,770	0,022
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-1,926	0,030
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,543	0,022
23	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-1,858	0,030
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,151	0,047
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,657	0,056
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,765	0,058
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,644	0,055
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,994	0,062
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-5,554	0,101
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-5,651	0,104
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-5,507	0,100
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-1,079	0,024
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,274	0,049
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,451	0,052
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-3,201	0,048
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	0,000	0,021
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-2,366	0,035

23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-2,627	0,039
23	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-2,283	0,034
24	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-0,186	0,502
24	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-1,216	0,592
25	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,857	0,285
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-0,631	0,420
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,920	0,584
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,104	0,461
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	0,000	0,400
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	0,000	0,400
26	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-2,177	0,637
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	1,575	0,524
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,567	0,523
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	0,156	0,401
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	1,508	0,514
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,538	0,518
26	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	-1,516	0,515
27	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-2,944	0,833
27	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-4,441	1,386
27	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-5,094	1,698
27	Richness	Forestry plantation	Tropical	Neotropical	No hotspot	-3,910	1,164
27	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,440	0,698
27	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-1,060	0,456
27	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,189	0,640
27	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-3,057	0,867
28	Richness	Forestry plantation	Non-tropical	Neotropical	No hotspot	1,271	0,060
29	Richness	Forestry plantation	Non-tropical	Neotropical	No hotspot	-1,919	0,073
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	-1,415	0,834
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	-0,585	0,695
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	0,590	0,696
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	0,530	0,690
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	-0,266	0,673
30	Richness	Degraded primary forest	Tropical	Neotropical	Tropical Andes	0,487	0,686
31	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,350	0,290

31	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,504	0,295
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-3,704	1,103
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-4,436	1,153
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-3,745	1,118
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-8,120	3,713
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-9,904	4,420
32	Richness	Secondary forest	Tropical	Oriental	Sundaland	-8,269	3,835
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-2,323	0,686
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-2,728	0,643
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-2,380	0,700
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-5,488	1,923
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-6,439	2,061
32	Abundance	Secondary forest	Tropical	Oriental	Sundaland	-5,625	1,999
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,407	1,149
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,468	1,174
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-2,759	1,301
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-3,337	1,595
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-3,761	1,845
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-4,724	2,526
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,255	0,672
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,211	0,670
33	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,566	0,693
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	0,079	0,667
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	1,364	0,822
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	0,445	0,683
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,427	0,682
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	0,387	0,679
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,163	0,669
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,687	0,706
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	0,035	0,667
33	Abundance	Forestry plantation	Tropical	Neotropical	No hotspot	-0,445	0,683
34	Richness	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-1,339	0,245
34	Abundance	Secondary forest	Tropical	Neotropical	Tumbes-Chocó-Magdalena	-18,290	8,563
35	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-0,057	0,222
35	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	0,244	0,224
35	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	0,070	0,222
35	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	0,317	0,225
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,976	0,165
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,506	0,083
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,983	0,165
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,515	0,083
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,162	0,171
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,729	0,085
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	1,299	0,176
36	Richness	Forestry plantation	Non-tropical	Afrotropical	Maputaland-Pondoland-Albany	0,788	0,086
37	Richness	Secondary forest	Tropical	Neotropical	No hotspot	-0,735	0,356

37	Abundance	Secondary forest	Tropical	Neotropical	No hotspot	-0,450	0,342
38	Richness	Degraded primary forest	Tropical	Neotropical	No hotspot	-0,446	1,025
38	Abundance	Degraded primary forest	Tropical	Neotropical	No hotspot	-0,632	1,050
39	Richness	Degraded primary forest	Tropical	Oriental	Wallacea	-2,465	0,880
40	Richness	Degraded primary forest	Tropical	Oriental	Wallacea	-0,913	0,552
40	Abundance	Degraded primary forest	Tropical	Oriental	Wallacea	-1,288	0,604
41	Richness	Degraded primary forest	Tropical	Oriental	Wallacea	-1,466	0,846
41	Richness	Degraded primary forest	Tropical	Oriental	Wallacea	0,857	0,728
42	Richness	Secondary forest	Tropical	Oriental	Wallacea	-2,753	0,974
42	Abundance	Secondary forest	Tropical	Oriental	Wallacea	-4,663	1,859
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,161	0,201
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,363	0,203
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,400	0,204
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,906	0,221
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,357	0,203
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,281	0,202
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	0,186	0,201
43	Richness	Degraded primary forest	Tropical	Oriental	Sundaland	-0,374	0,203
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,320	0,203
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,222	0,201
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	0,696	0,212
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,241	0,201
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,638	0,210
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,579	0,208
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	0,441	0,205
43	Abundance	Degraded primary forest	Tropical	Oriental	Sundaland	-0,604	0,209
44	Abundance	Forestry plantation	Tropical	Oriental	Sundaland	-3,835	0,875

Table S2. Summary of the case studies for biomass, dung removal, soil excavated and seed dispersal used in the meta-analysis

Ref.	Metric	Coverage type	d value	Var
3	Biomass	Degraded primary forest	-0,081	0,400
3	Biomass	Forestry restoration	-4,028	1,211
3	Biomass	Forestry restoration	-4,128	1,252
3	Biomass	Forestry restoration	-5,101	1,701
45	Biomass	Secondary forest	-3,027	1,430
45	Biomass	Secondary forest	-5,528	3,213
45	Biomass	Secondary forest	-3,864	1,911
45	Biomass	Secondary forest	-6,489	4,176
45	Biomass	Secondary forest	-3,754	1,841
45	Biomass	Secondary forest	-6,495	4,182
45	Dung removal	Secondary forest	-1,598	0,880
45	Dung removal	Secondary forest	-1,551	0,867
45	Dung removal	Secondary forest	-2,093	1,032
45	Dung removal	Secondary forest	-2,045	1,015
45	Dung removal	Secondary forest	-2,993	1,413
45	Dung removal	Secondary forest	-2,925	1,380
5	Biomass	Forestry plantation	-1,226	0,178
5	Biomass	Forestry plantation	1,586	0,197
5	Biomass	Forestry plantation	-0,260	0,151
5	Biomass	Forestry plantation	-0,767	0,161
5	Biomass	Forestry plantation	1,595	0,197
7	Biomass	Secondary forest	-2,802	0,256
7	Dung removal	Secondary forest	-1,932	0,189
8	Biomass	Secondary forest	-1,298	0,167
8	Dung removal	Secondary forest	-2,625	0,257
8	Soil excavated	Secondary forest	-2,310	0,230
8	Seed dispersal	Secondary forest	-2,214	0,223
8	Seed dispersal	Secondary forest	-4,342	0,463
8	Seed dispersal	Secondary forest	-3,400	0,337
18	Biomass	Forestry restoration	-2,280	0,825
18	Biomass	Forestry restoration	-0,876	0,548
18	Biomass	Forestry restoration	-0,350	0,508
18	Dung removal	Forestry restoration	-0,717	0,532
18	Dung removal	Forestry restoration	-0,107	0,501
18	Dung removal	Forestry restoration	-0,450	0,513
18	Soil excavated	Forestry restoration	-0,184	0,502
18	Soil excavated	Forestry restoration	0,097	0,501

18	Soil excavated	Forestry restoration	-0,110	0,501
18	Seed dispersal	Forestry restoration	-1,477	0,636
18	Seed dispersal	Forestry restoration	-0,197	0,502
18	Seed dispersal	Forestry restoration	-0,364	0,508
22	Biomass	Degraded primary forest	-1,551	0,201
22	Biomass	Degraded primary forest	-4,445	0,399
46	Seed dispersal	Forestry plantation	-0,429	0,409
46	Seed dispersal	Secondary forest	-0,401	0,408
46	Seed dispersal	Forestry plantation	-0,580	0,417
46	Seed dispersal	Secondary forest	-0,723	0,426
46	Seed dispersal	Forestry plantation	-0,838	0,435
46	Seed dispersal	Secondary forest	-0,881	0,439
46	Seed dispersal	Forestry plantation	0,382	0,407
46	Seed dispersal	Secondary forest	-0,731	0,427
46	Seed dispersal	Forestry plantation	-0,346	0,406
46	Seed dispersal	Secondary forest	-1,106	0,461
46	Seed dispersal	Forestry plantation	0,965	0,447
46	Seed dispersal	Secondary forest	-0,522	0,414
25	Biomass	Degraded primary forest	-1,685	0,276
25	Dung removal	Degraded primary forest	0,135	0,235
25	Soil excavated	Degraded primary forest	-2,264	0,310
26	Biomass	Degraded primary forest	0,734	0,427
26	Biomass	Degraded primary forest	-1,628	0,533
26	Biomass	Degraded primary forest	0,782	0,431
26	Biomass	Degraded primary forest	0,930	0,443
26	Biomass	Degraded primary forest	-0,334	0,406
26	Biomass	Degraded primary forest	-0,762	0,429
26	Dung removal	Degraded primary forest	0,549	0,415
26	Dung removal	Degraded primary forest	0,866	0,438
26	Dung removal	Degraded primary forest	-0,200	0,402

26	Dung removal	Degraded primary forest	0,296	0,404
26	Dung removal	Degraded primary forest	0,611	0,419
26	Dung removal	Degraded primary forest	-0,112	0,401
26	Seed dispersal	Degraded primary forest	0,111	0,401
26	Seed dispersal	Degraded primary forest	0,498	0,412
26	Seed dispersal	Degraded primary forest	-1,542	0,519
26	Seed dispersal	Degraded primary forest	0,039	0,400
26	Seed dispersal	Degraded primary forest	0,000	0,400
26	Seed dispersal	Degraded primary forest	-1,126	0,463
27	Biomass	Secondary forest	-2,463	0,703
27	Biomass	Forestry plantation	-2,787	0,788
30	Biomass	Degraded primary forest	-0,631	0,700
30	Biomass	Degraded primary forest	-0,298	0,674
30	Biomass	Degraded primary forest	-0,859	0,728
30	Biomass	Degraded primary forest	-0,579	0,695
30	Biomass	Degraded primary forest	-0,679	0,705
30	Biomass	Degraded primary forest	-1,288	0,805
32	Biomass	Secondary forest	-2,185	0,655
32	Biomass	Secondary forest	-2,497	0,593
32	Biomass	Secondary forest	-2,165	0,651
32	Biomass	Secondary forest	-3,874	1,167
32	Biomass	Secondary forest	-4,422	1,148
32	Biomass	Secondary forest	-3,846	1,156
34	Biomass	Secondary forest	-11,361	3,427
38	Biomass	Degraded primary forest	-0,614	1,047
43	Biomass	Degraded primary forest	-1,223	0,237
43	Biomass	Degraded primary forest	-0,761	0,214
43	Biomass	Degraded primary forest	0,067	0,200
43	Biomass	Degraded primary forest	-1,451	0,253
43	Biomass	Degraded primary forest	-0,224	0,201
43	Biomass	Degraded primary forest	0,077	0,200
43	Biomass	Degraded primary forest	0,482	0,206
43	Biomass	Degraded primary forest	-0,131	0,200
43	Dung removal	Degraded primary forest	-1,232	0,238
43	Dung removal	Degraded primary forest	-0,224	0,201

43	Dung removal	Degraded primary forest	-1,024	0,226
43	Dung removal	Degraded primary forest	-1,071	0,229
43	Dung removal	Degraded primary forest	0,327	0,203
43	Dung removal	Degraded primary forest	0,919	0,221
43	Dung removal	Degraded primary forest	-0,695	0,212
43	Dung removal	Degraded primary forest	-0,594	0,209
43	Seed dispersal	Degraded primary forest	-1,348	0,245
43	Seed dispersal	Degraded primary forest	-0,925	0,221
43	Seed dispersal	Degraded primary forest	-0,859	0,218
43	Seed dispersal	Degraded primary forest	-1,254	0,239
43	Seed dispersal	Degraded primary forest	0,469	0,206
43	Seed dispersal	Degraded primary forest	0,693	0,212
43	Seed dispersal	Degraded primary forest	-0,590	0,209
43	Seed dispersal	Degraded primary forest	-0,620	0,210
43	Seed dispersal	Degraded primary forest	-1,959	0,296
43	Seed dispersal	Degraded primary forest	-1,032	0,227
43	Seed dispersal	Degraded primary forest	-1,539	0,259
43	Seed dispersal	Degraded primary forest	-0,841	0,218
43	Seed dispersal	Degraded primary forest	-0,452	0,205
43	Seed dispersal	Degraded primary forest	0,215	0,201
43	Seed dispersal	Degraded primary forest	-1,003	0,225
43	Seed dispersal	Degraded primary forest	0,055	0,200
43	Seed dispersal	Degraded primary forest	-1,238	0,238
43	Seed dispersal	Degraded primary forest	-1,129	0,232
43	Seed dispersal	Degraded primary forest	-2,512	0,358
43	Seed dispersal	Degraded primary forest	-2,024	0,302
43	Seed dispersal	Degraded primary forest	-0,206	0,201
43	Seed dispersal	Degraded primary forest	0,079	0,200
43	Seed dispersal	Degraded primary forest	-1,027	0,226
43	Seed dispersal	Degraded primary forest	0,113	0,200
44	Biomass	Forestry plantation	-3,408	0,756

47	Biomass	Forestry plantation	-0,958	0,743
47	Biomass	Secondary forest	-0,577	0,694
48	Biomass	Secondary forest	-0,372	0,678
48	Biomass	Forestry plantation	0,113	0,668
48	Biomass	Secondary forest	-0,431	0,682
48	Biomass	Secondary forest	1,277	0,802

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Table S3. Summary of results obtained using the Rosenthal test for the different metrics evaluated in dung beetles

	Number of comparisons needed to obtain non-significant results	Rosenthal safe number
Species richness	5822	869
Total abundance	19232	740
Biomass	2725	310
Dung removal	179	140
Soil excavated	17	35
Seed dispersal	1141	250

Table S4. Observed and adjusted overall effect size values after Duval & Tweedie (2000) trim and fill procedure

Species richness				
	Studies trimmed	Effect estimate	Lower limit	Upper limit
Observed values		-0.627	-0.867	-0.387
Adjusted values	19	-0.984	-1.233	-0.734
Total abundance				
Observed values		-1.240	-1.534	-0.946
Adjusted values	0	-1.240	-1.534	-0.946
Biomass				
Observed values		-1.384	-1.789	-0.978
Adjusted values	10	-0.893	-1.327	-0.459
Dung removal				
Observed values		-0.652	-1.059	-0.244
Adjusted values	4	-0.408	-0.848	0.031
Soil excavated				
Observed values		-1.033	-2.143	-0.075
Adjusted values	1	-0.656	-1.882	0.568
Seed dispersal				
Observed values		-0.782	-1.053	-0.512
Adjusted values	12	-1.154	-1.444	-0.863