Ecography

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Supplementary material

Appendix 1

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As an alternative methodology to the convex hull calculations, we also used a Maxent model to estimate species distributions. This algorithm uses 19 current climate layers (average 1950-2000 conditions) from WorldClim 1.4 at 30-arc second resolution and 19 spatial filters following (Griffith and Peres-Neto 2006) and (Blach-Overgaard et al. 2010). These spatial filters are geographic distance-based eigenvectors that capture the geometry of the study area. They have been used in the past to represent non-climatic range controls such as dispersal limitation and biotic interactions(Blach-Overgaard, A. et al. 2010). They constrain the species ranges and limit overpredictions that may appear when only using climate predictors (Blach-Overgaard, A. et al. 2010, Griffith, D. A. and Peres-Neto, P. R. 2006). We then applied a 1 percent training presence threshold (Freeman, E. A. and Moisen, G. G. 2008) to convert each suitability map to a presence-absence map. To further constrain potential overpredictions, we removed any non-contiguous areas that were more than 1,000 km away from the main range area of each species.

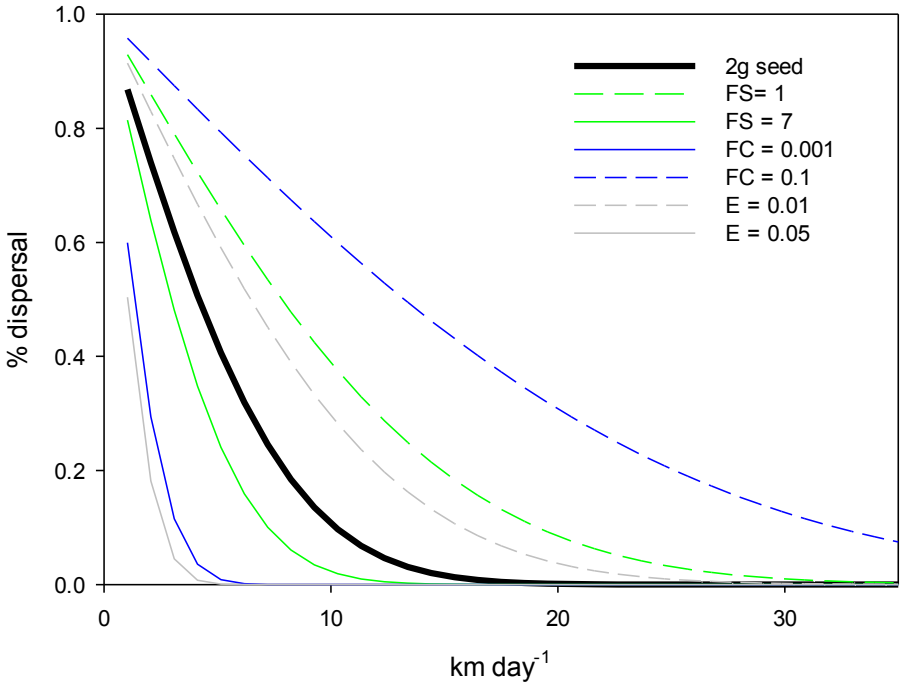

Figure A1 – Sensitivity study of estimated dispersal of seeds over a day of a 2g seed assuming the presence of 11 species listed in the methods including 4 species of now extinct megafauna. The black line is equivalent to the dashed grey line from Fig3a. We vary the following parameters: edibility (E) of the seeds (grey), originally 0.0027*M+1.734 (but slope varied between 0.001 and 0.005); fruit consumption (FC) (blue), originally any given fruit tree species is ~1% of the diet (but varied here between 0.1% and 10%), and the amount of fruit per seed (FS), originally 3.5 times the seed weight but varied here between 1 and 7 (green).

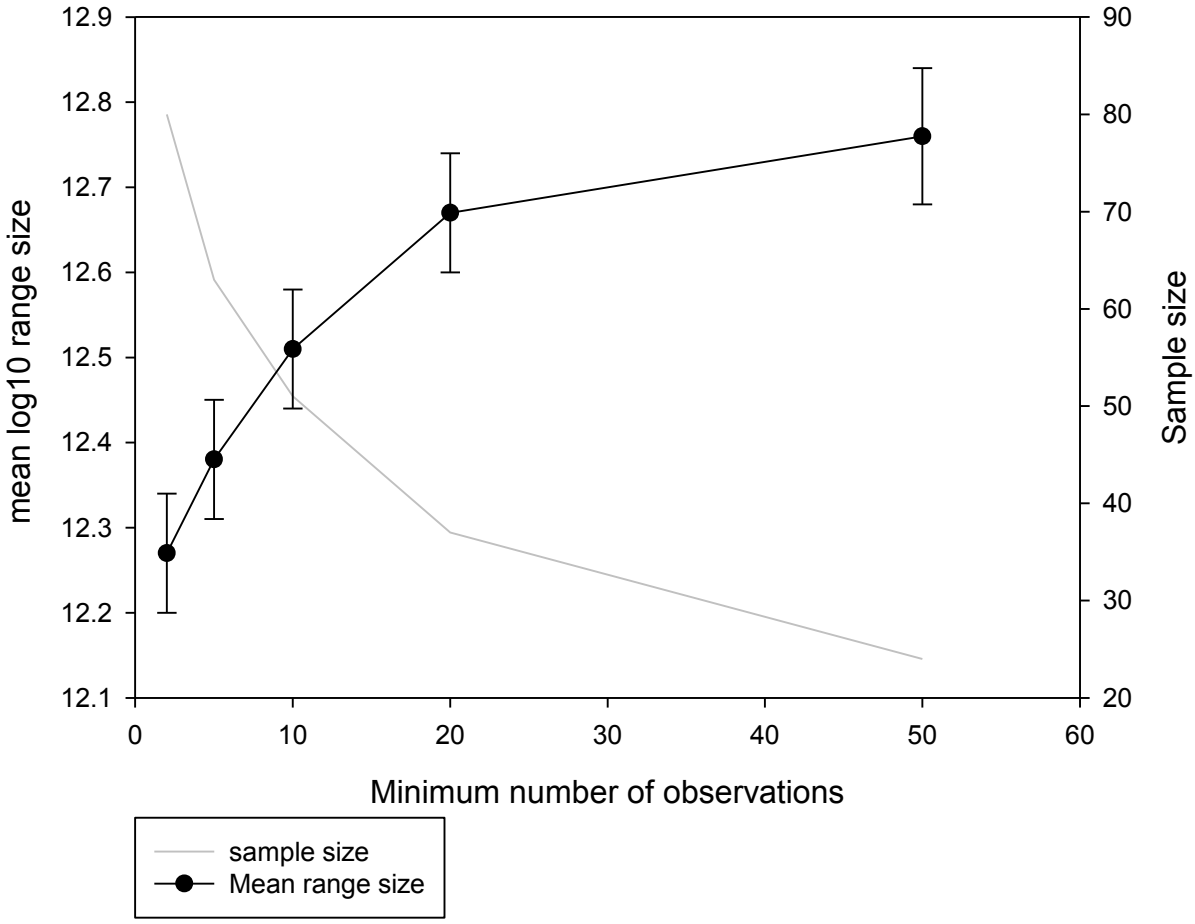

Figure A2 – Minimum number of observations used to create a convex hull versus the mean estimated range size of the species and the number of different species that meet each category.

Table A1 – Description of the variables modified in the sensitivity analysis and a description of what the uncertainty is.

Variable	Description	Uncertainty	reference
BIEN convex hull assumption	This is how we scale individual GPS locations of species to an estimated species distribution. A convex hull is the smallest convex set that contains all the points or mathematically 'wraps a rubber band' around all the points. Alternatively we could use the maxent (Maxent BioclimSpatial 1Pct TP Clipped) methodology.	Each model has a range of uncertainties. Convex hull is the simplest method while maxent is more complicated and includes a larger range of assumptions. We now model the data under several scenarios including both the convex hull, maxent (Maxent BioclimSpatial 1Pct TP Clipped), best (combination of maxent, gentry boxes, convex hull), and mean and average of the three.	(Enquist, B. J. et al. 2009)
Minimum number of unique points used for a convex hull model	This is the minimum number of unique GPS points that are used to create a convex hull to estimate species ranges.	Five data points is a very small number of points to estimate a convex hull, especially at the spatial scale of tree distribution. A small number of points is more likely to result in an underestimation of range size.	(Enquist, B. J. et al. 2009)
Megafauna syndrome species	This is an estimate of which species were thought to have been formerly distributed by the now extinct megafauna. We discuss this more extensively in the opening paragraph of the SI.	There is great uncertainty about which species may have co-evolved with megafauna. The major issues are which South American megafauna lived in the forest and consumed fruit and how long is necessary to "coevolve"? Do to this great uncertainty we use two potential species lists (SI table 3 and 4), one from Guimaraes et al. 2008 and another more conservative list	(Guimaraes, P. R. et al. 2008)
Population density of animals (PD)	An estimate of the mean population density of a species using only its body mass. We use the equation - $PD = 36.4*M^{\wedge -0.58}$	Of all the mass scaling animal parameters, how animal population density scales with body mass probably has the largest uncertainty.	(Wolf, A. et al. 2013)

Animal body mass	The estimated mean body mass of a species	The uncertainty of individual species are generally captured with +/-25. However, we use an error of +/- 10% which is for entire communities because as long as the estimates are unbiased the combined error for all co-occurring species will be smaller since some are under and some are over estimated.	(Faurby, S. and Svenning, J. C. submitted)
Metabolic rate	An estimate of the amount of dry food needed by an animal for its metabolic requirements. We model it using body mass and the following equation - $MR = 0.01*M^{\wedge 0.67}$	This term is well quantified both theoretically and with data and probably has the lowest uncertainty of all the mass scaling parameters.	(Wolf, A. et al. 2013)
Day Range	Day range - $DD = 0.32*M^{\wedge 0.43}$ or the average distance travelled by an animal in a day based on body mass.	This parameter is well constrained and based on a large dataset of mean animal motion in a day period. Its uncertainty is greater than metabolic rate, but lower than population density.	(Wolf, A. et al. 2013)
Food passage time – PT	An estimate of the time it takes for a piece of food to pass through the body between food consumption and defecation. We model it using the following equation based on body mass- $PT = 0.29*M^{\wedge 0.28}$	This is the least well parameterized assumption because there is little available data and is therefore highly uncertain.	equation from Demment and Van Soest et al. 1985 assuming a digestibility of 0.5 (Demment, M. W. and Van Soest, P. J. 1985)
Esophagus size	The ability of an animal to swallow a seed which is related to the size of the seed and the esophagus size	This is an estimate of the likelihood an animal will swallow a fruit seed. Esophagus size scales with body mass, but there	

(E(S,M))	of the animal. We assume this is linearly related to animal size with the equation 0.0027*M+1.	are other factors besides size that can influence this and it is therefore very uncertain. Due to this uncertainty, we vary the slope - 0.0027*M between 0.001 and 0.005.	
Percent fruit consumption (PFC) by the animal	This is an estimate of the percent fruit consumption by the extinct megafauna. We estimate 30% of the diet is fruit of ~70-90 different species in different central African forests, so any given fruit tree species may provide ~1% of the diet (ranged between 0.1 and 10%).	There is no data to estimate this for the extinct megafauna and we are forced to assume that it is a similar percent to African elephants, and therefore uncertainty is high.	(Blake, S. et al. 2009, Poulsen, J. R. et al. 2001)
Fruit provided per seed (FS)	We estimate the amount of fruit per seed based on the megafauna fruit from Guimaraes et al. 2008. We calculate that the average wet weight of fruit is seven times the seed and, assuming 50% water, dry fruit is 3.5 times the seed weight.	For a given fruit, this is well quantified, but uncertainty is increased due to the large uncertainty in which species actually were consumed by the megafauna. Dry fruit is 3.5 (ranged between 1 and 7) times the seed weight.	(Guimaraes, P. R. et al. 2008)
Seed mortality (SM)	We estimate seed mortality is (SM) is equal among seed types (1), and does not influence our model here.	There is a large literature about this, but as this is not a main goal of the paper and we therefore use a null assumption of 1, but which we vary between 0.1 and 10.	

Table A2 – Values used in our sensitivity analysis: the estimated range in uncertainty, how this uncertainty was assessed, and a global calculation of the seed movement for the low and high estimates. Expert opinion was estimated by the authors of the variable value in which the group was 95% certain the true value would fall within. If the number is calculated as a slope, then the 95% confidence interval (1.96*standard error on the slope) is the potential error.

Variable	Value used	Potential error estimate	How the error was assessed	Results	Reference
BIEN convex hull assumption	convex hull	Use best, maxent and convex hull	New dataset and expert opinion	12.38 ± 0.07 convex hull megafauna 12.45 ± 0.06 best megafauna 12.04 ± 0.19 maxent megafauna **Mean- 12.29** 12.72 ±0.05 convex hull abiotic 12.01 ± 0.05 maxent abiotic 12.52 ± 0.05 best abiotic **Mean- 12.42**	(Enquist, B. J. et al. 2009)
Minimum number of unique points used for a convex hull model	5 data points	2, 5,10,20, 50 data points	New thresholds	2 - 12.27 ± 0.07 – N=80 5 - 12.38 ± 0.07 – N=63 10 - 12.51 ± 0.07 – N=51 20 - 12.67 ± 0.07 – N=37 50 - 12.76 ± 0.08 – N=24	(Enquist, B. J. et al. 2009)
Megafauna syndrome species	Table 3	Table 3 and 4	New dataset and expert opinion	12.38 ± 0.07 – Table 3 12.55 ±0.22 – Table 4	(Guimaraes, P. R. et al. 2008)
Population density of	-0.58	±30% for	Expert	13- 65 % dispersal at 5	(Wolf, A. et al.

animals (PD)		megafauna	opinion	km day^{-1}	2013)
Animal body mass	See Faurby et al.	±20%	Expert opinion	33-34 % dispersal at 5 km day^{-1}	(Faurby, S. and Svenning, J. C. submitted)
Metabolic rate	0.67	±0.06	Slope error	32-49 % dispersal at 5 km day^{-1}	(Wolf, A. et al. 2013)
Day Range	0.43	±0.10	Slope error	26-54% dispersal at 5 km day^{-1}	(Wolf, A. et al. 2013)
Food passage time – PT	0.28	±0.15	Slope error and expert opinion	34- 47 % dispersal at 5 km day^{-1}	equation from Demment and Van Soest et al. 1985 assuming a digestibility of 0.5 (Demment, M. W. and Van Soest, P. J. 1985)
Esophagus size (E(S,M))	0.0027*M	±0.001	Slope error and expert opinion	28-51 % dispersal at 5 km day^{-1}	
Percent fruit consumption (PFC) by the animal	Any given fruit tree species may provide ~1% of the diet	Between 0.5 and 5%	Expert opinion	24-71 % dispersal at 5 km day^{-1}	(Blake, S. et al. 2009, Poulsen, J. R. et al. 2001)
Fruit provided per seed (FS)	Dry fruit is 3.5 times the seed weight.	Between 1 and 7	Expert opinion	24-66 % dispersal at 5 km day^{-1}	(Guimaraes, P. R. et al. 2008)
Seed mortality (SM)	Seed mortality is equal among seed types (1)	ranged between 0.5 and 5)	Expert opinion	24 – 71 % dispersal at 5 km day^{-1}	

Table A3 – Full species list used to calculate table 1 and figure 1 for animal dispersed species, megafauna dispersed species, and wind or water dispersed species.

Animal dispersed species	***Wind or water dispersed species***	***Megafauna dispersed species***
Anacardium giganteum	*Aspidosperma spruceanum*	*Carpotroche brasiliensis*
Annona hypoglauca	*Astronium fraxinifolium*	*Anacardium giganteum*
Astronium graveolens	*Elytraria imbricata*	*Annona cacans*
Bocageopsis multiflora	*Mesechites trifidus*	*Annona coriacea*
Dendropanax arboreus	*Ageratum conyzoides*	*Annona montana*
Duguetia quitarensis	*Aristolochia elegans*	*Rollinia mucosa*
Geissospermum sericeum	*Arrabidaea candicans*	*Acrocomia aculeate*
Schefflera morototoni	*Callichlamys latifolia*	*Allagoptera leucocalyx*
Schinus terebinthifolia	*Chromolaena odorata*	*Astrocaryum aculeatissimum*
Spondias mombin	*Conyza bonariensis*	*Astrocaryum aculeatum*
Tabernaemontana sananho	*Mikania micrantha*	*Astrocaryum murumuru*
Tabernaemontana siphilitica	*Sonchus oleraceus*	*Astrocaryum vulgare*
Tapirira guianensis	*Tanacetum vulgare*	*Attalea phalerata*
Unonopsis rufescens	*Cydista aequinoctialis*	*Mauritia carana*
Unonopsis stipitata	*Syagrus oleracea*	*Mauritia flexuosa*
Astrocaryum aculeatum	*Cochlospermum vitifolium*	*Syagrus cocoides*
Astrocaryum murumuru	*Cordia alliodora*	*Syagrus oleracea*
Bactris acanthocarpoides	*Jacaranda copaia*	*Ananas ananassoides*
Desmoncus polyacanthos	*Mansoa verrucifera*	*Caryocar brasiliense*
Attalea speciosa	*Ochroma pyramidale*	*Caryocar microcarpum*
Syagrus romanzoffiana	*Pachira aquatic*	*Caryocar villosum*
Calophyllum brasiliense	*Pithecoctenium crucigerum*	*Platonia insignis*
Caryocar glabrum	*Tabebuia rosea*	*Andira anthelmia*
Caryocar nuciferum	*Tabebuia serratifolia*	*Andira humilis*
Cordia collococca	*Tillandsia recurvata*	*Cassia leiandra*
Cordia nodosa	*Macfadyena unguis-cati*	*Dipteryx alata*
Crateva tapia	*Cyperus rotundus*	*Dipteryx odorata*
Protium decandrum	*Eupatorium odoratum*	*Hymenaea courbaril*
Protium tenuifolium	*Evolvulus alsinoides*	*Hymenaea stigonocarpa*
Quararibea wittii	*Fimbristylis dichotoma*	*Inga alba*
Tetragastris panamensis	*Ipomoea purpurea*	*Inga cinnamomea*
Bursera simaruba	*Laguncularia racemosa*	*Inga edulis*
Capparis flexuosa	*Pouteria grandiflora*	*Inga heterophylla*
Chrysobalanus icaco	*Terminalia oblonga*	*Inga laurina*
Buchenavia fanshawei	*Cyperus odoratus*	*Inga macrophylla*
Clusia grandiflora	*Drosera intermedia*	*Inga marginata*
Clusia panapanari	*Vernonia patens*	*Inga sessilis*
Connarus perrottetii	*Abrus precatorius*	*Inga thibaudiana*
Garcinia madruno	*Caesalpinia pyramidalis*	*Inga velutina*

Hirtella paniculata	*Canavalia rosea*	*Swartzia macrostachya*
Licania incana	*Cassia biflora*	*Swartzia oblate*
Licania majuscula	*Centrosema plumieri*	*Duckesia verrucosa*
Maripa scandens	*Chamaecrista apoucouita*	*Endopleura uchi*
Parinari campestris	*Cnidoscolus urens*	*Poraqueiba paraensis*
Parinari excelsa	*Crotalaria incana*	*Poraqueiba sericea*
Sloanea guianensis	*Dalechampia scandens*	*Couroupita guianensis*
Symphonia globulifera	*Eperua falcate*	*Theobroma cacao*
Tradescantia zanonia	*Hevea brasiliensis*	*Theobroma grandiflorum*
Sloanea obtusifolia	*Peltogyne venosa*	*Theobroma obovatum*
Licania heteromorpha	*Poecilanthe hostmannii*	*Theobroma subincanum*
Alchornea latifolia	*Pterocarpus officinalis*	*Eugenia klotzschiana*
Casearia arborea	*Rhynchosia minima*	*Eugenia stipitata*
Casearia javitensis	*Senna alata*	*Lacunaria jenmanii*
Chaetocarpus schomburgkianus	*Sesbania emerus*	*Genipa Americana*
Cnidoscolus urens	*Sophora tomentosa*	*Pouteria caimito*
Garcinia macrophylla	*Amanoa oblongifolia*	*Pouteria grandiflora*
Laetia procera	*Croton schiedeanus*	*Pouteria macrocarpa*
Mayna odorata	*Lonchocarpus sericeus*	*Pouteria macrophylla*
Ormosia coccinea	*Hura crepitans*	*Pouteria ramiflora*
Sapium glandulosum	*Caesalpinia bonduc*	*Pouteria speciose*
Swartzia benthamiana	*Ceiba pentandra*	*Pouteria torta*
Swartzia brachyrachis	*Diplotropis purpurea*	*Pouteria venosa*
Casearia aculeata	*Elizabetha princeps*	*Solanum lycocarpum*
Casearia sylvestris	*Juncus bufonius*	
Margaritaria nobilis	*Lafoensia punicifolia*	
Abarema jupunba	*Machaerium floribundum*	
Andira inermis	*Macrolobium multijugum*	
Byrsonima aerugo	*Malvastrum americanum*	
Catostemma commune	*Mimosa pigra*	
Clathrotropis macrocarpa	*Myroxylon balsamum*	
Dialium guianense	*Nissolia fruticose*	
Elizabetha princeps	*Pentaclethra macroloba*	
Enterolobium cyclocarpum	*Platymiscium pinnatum*	
Eschweilera parviflora	*Platypodium elegans*	
Eschweilera sagotiana	*Pterocarpus rohrii*	
Gustavia hexapetala	*Zapoteca Formosa*	
Hymenaea courbaril	*Tachigali guianensis*	
Hyptis mutabilis	*Vigna luteola*	
Hyptis suaveolens	*Acacia farnesiana*	
Inga edulis	*Cedrela odorata*	
Inga leiocalycina	*Mimosa quadrivalvis*	
Inga marginata	*Pseudobombax munguba*	

Inga nobilis	*Sida acuta*
Mimosa pudica	*Swietenia macrophylla*
Parkia pendula	*Axonopus compressus*
Strychnos guianensis	*Chloris virgate*
Strychnos tarapotensis	*Cynodon dactylon*
Stryphnodendron microstachyum	*Leptochloa fusca*
Swartzia polyphylla	*Oplismenus burmannii*
Swartzia schomburgkii	*Panicum trichoides*
Swartzia simplex	*Scoparia dulcis*
Bertholletia excelsa	*Diodia teres*
Couroupita guianensis	*Polygonum aviculare*
Lacistema aggregatum	*Polygonum lapathifolium*
Lecointea amazonica	*Portulaca oleracea*
Lecythis zabucajo	*Roupala montana*
Acacia farnesiana	*Rumex acetosella*
Batocarpus amazonicus	*Polygonum persicaria*
Brosimum lactescens	*Rhizophora mangle*
Cabralea canjerana	*Cardiospermum halicacabum*
Calyptranthes lanceolata	*Hybanthus prunifolius*
Calyptranthes multiflora	*Typha latifolia*
Carapa guianensis	*Petrea volubilis*
Carapa procera	
Cissampelos pareira	
Clarisia biflora	
Clarisia ilicifolia	
Clarisia racemosa	
Enterolobium schomburgkii	
Eugenia patrisii	
Ficus insipida	
Guarea glabra	
Guarea grandifolia	
Guarea guidonia	
Guarea kunthiana	
Guarea macrophylla	
Heisteria cauliflora	
Inga acrocephala	
Iryanthera juruensis	
Miconia aulocalyx	
Myrcia splendens	
Neea floribunda	
Otoba parvifolia	
Perebea tessmannii	
Pseudolmedia laevis	

Sida rhombifolia
Sida spinosa
Sorocea steinbachii
Tococa aristata
Trichilia martiana
Trichilia pleeana
Trichilia quadrijuga
Virola calophylla
Virola sebifera
Virola surinamensis
Chlorophora tinctoria
Eugenia punicifolia
Brosimum alicastrum
Attalea maripa
Bactris simplicifrons
Heteropogon contortus
Hyospathe elegans
Mauritia flexuosa
Oplismenus hirtellus
Paspalum dilatatum
Passiflora foetida
Phytolacca rivinoides
Piper aequale
Piper amalago
Piper arboreum
Piper marginatum
Socratea exorrhiza
Trichostigma octandrum
Iriartea deltoidea
Passiflora vitifolia
Piper hispidum
Piper reticulatum
Chiococca alba
Coussarea paniculata
Faramea occidentalis
Genipa americana
Moutabea guianensis
Palicourea guianensis
Palicourea longiflora
Psychotria horizontalis
Symmeria paniculata
Tragus berteronianus
Hamelia patens
Randia armata

Apeiba membranacea
Casearia decandra
Casearia fasciculata
Cecropia membranacea
Cecropia peltata
Cecropia sciadophylla
Chrysophyllum argenteum
Chrysophyllum pomiferum
Citharexylum poeppigii
Cupania cinerea
Cupania hirsuta
Cupania scrobiculata
Cyphomandra hartwegii
Dodonaea viscosa
Guazuma ulmifolia
Hasseltia floribunda
Lantana achyranthifolia
Leonia glycycarpa
Manilkara bidentata
Manilkara zapota
Micropholis venulosa
Mollia lepidota
Paypayrola longifolia
Pleuranthodendron lindenii
Pouteria cuspidata
Pouteria ephedrantha
Pouteria guianensis
Pouteria macrophylla
Pouteria speciosa
Smilax syphilitica
Solanum americanum
Solanum sessile
Trema micrantha
Celtis iguanaea
Pouteria cladantha
Simarouba amara
Urera caracasana
Lantana camara
Sapindus saponaria
Turpinia occidentalis

Table A4 – In table 3, we show megafauna dispersed species as classified from (Guimaraes, P. R. et al. 2008). Here, we show a much more conservative potential list of megafauna dispersed species. For our more conservative list, we assume a more strict definition of megafauna dispersed fruit based on characteristics of fruit dispersed by megafauna in Africa. In Africa, the fruits that attract elephants are large, usually 1-seeded and released together from the crown when ripe so that a large quantity of fruit falls to the forest floor producing a strong odor of overripe fruits that attracts the elephants. In contrast, primate dispersed fruits are typically held on the tree after they ripen, allowing time for the primates to discover and exploit the crop. This is not an exhaustive list and there are likely other species that meet these more strict criteria that we have not included.

Megafauna dispersed species
Mauritia flexuosa
Hymenaea courbaril
Theobroma bicolor
Theobroma cacao
Theobroma grandiflorum
Theobroma obovatum

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