Rubber agroforestry in Thailand provides some biodiversity benefits without reducing yields

Supplementary Information

This supplementary information includes (text, figures, then tables, in sequence as referred to in main text):

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Habitat structure measures of rubber agroforests (AF) and monocultures (MO) in biodiversity dataset plots.

Figure S13
Sampling completeness of biodiversity surveys.

Figure S14
Comparison of detections of birds, reptiles and butterflies in agroforests and monocultures.

Figure S15
Correlation between proportion of natural forest in block and density of non-rubber trees in rubber plots

Figure S16
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Soil types of plots in the yield and biodiversity datasets

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Results of Redundancy Analysis (RDA) of species composition response to the best model of plot type, habitat structure variables and land use composition variables, excluding rare species.

Figure S1:

Rubber plantation area globally, and in Southeast Asia, 1980 to 2016.

Data from (FAO 2018).

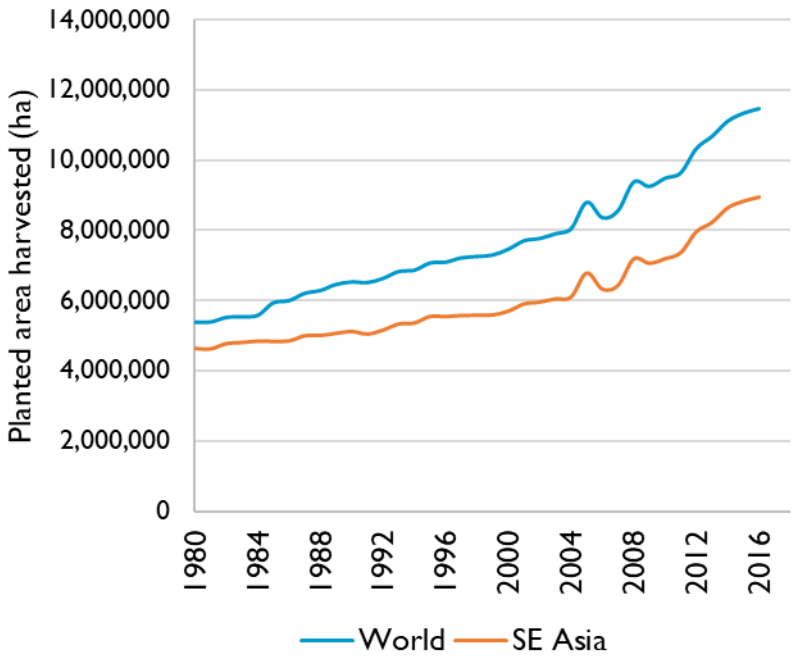


Figure S2:

Map of study region showing location of farms in the yield dataset within Phatthalung province, and sampling blocks in the biodiversity dataset in Phatthalung and Songkhla provinces. Letters A – E indicate "districts" that identify spatially clumped sampling blocks.

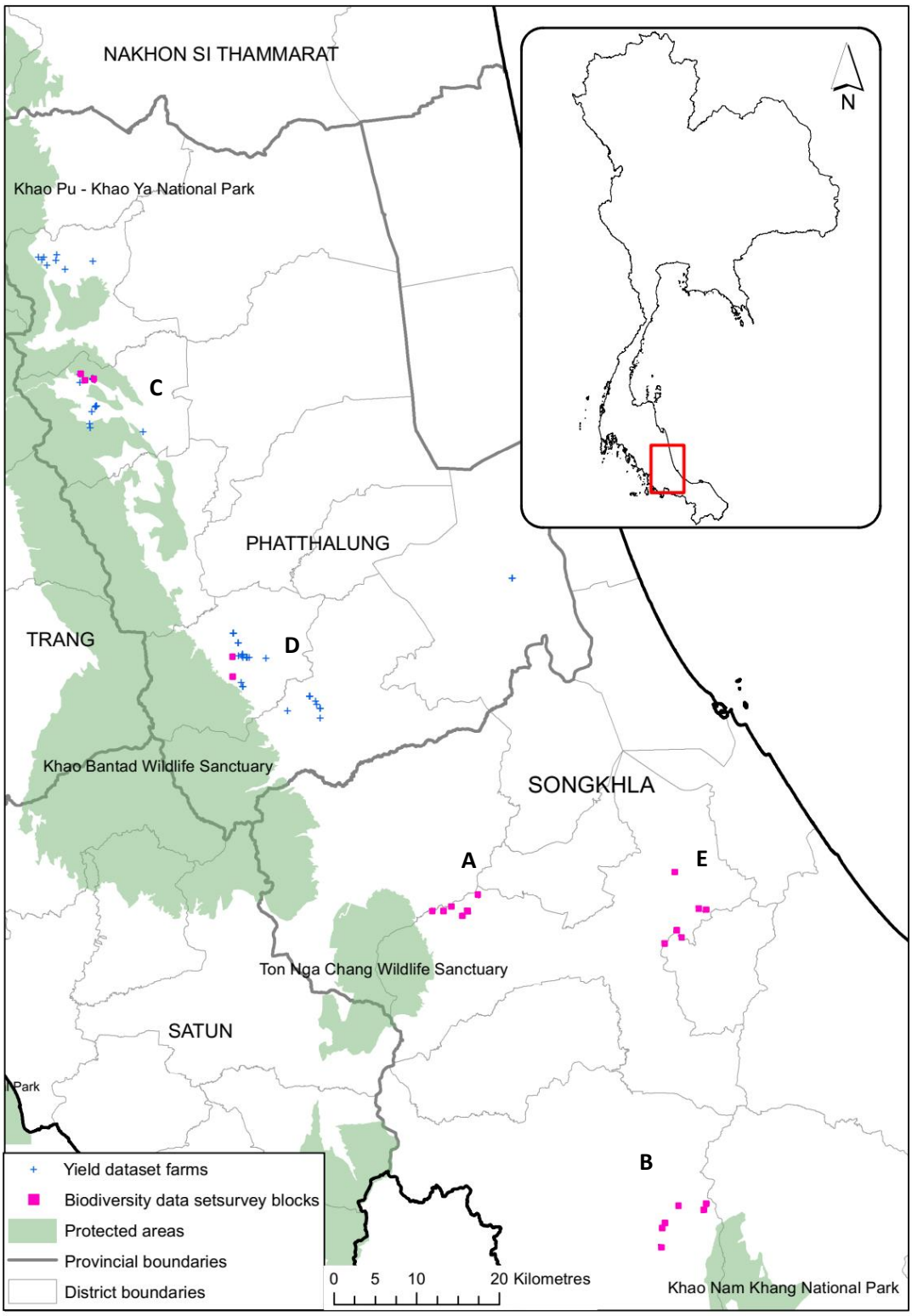


Figure S3:

Monthly rainfall (sum of daily records) and maximum daily temperatures recorded at Hat Yai airport, Songkhla province, Thailand.

Data obtained from the Global Historical Climatology Network database via Climate Data Online (NOAA 2017). Diamonds show 2016 data (the year data for this study was collected; no data available for March), filled points show mean for each month across 2007 – 2016 inclusive, and range lines show minimum and maximum value for each month across 2007 – 2016. Unusually low rainfall and high temperatures were linked to a strong El Niño-Southern Oscillation event (Limsakul & Singhruck 2016).

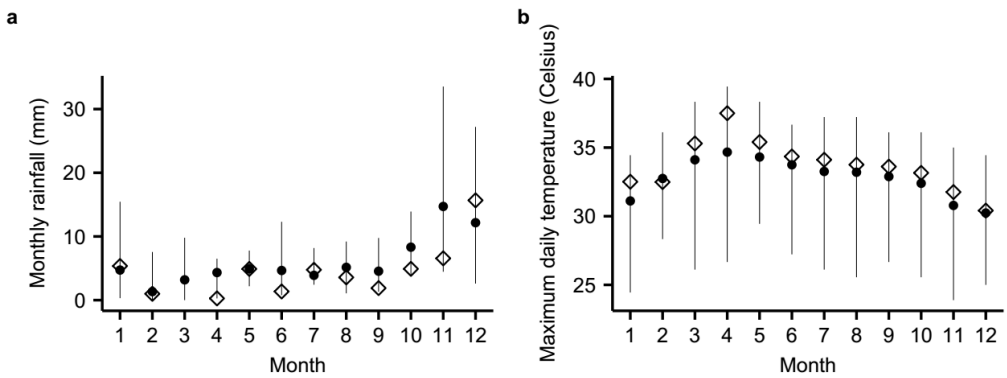


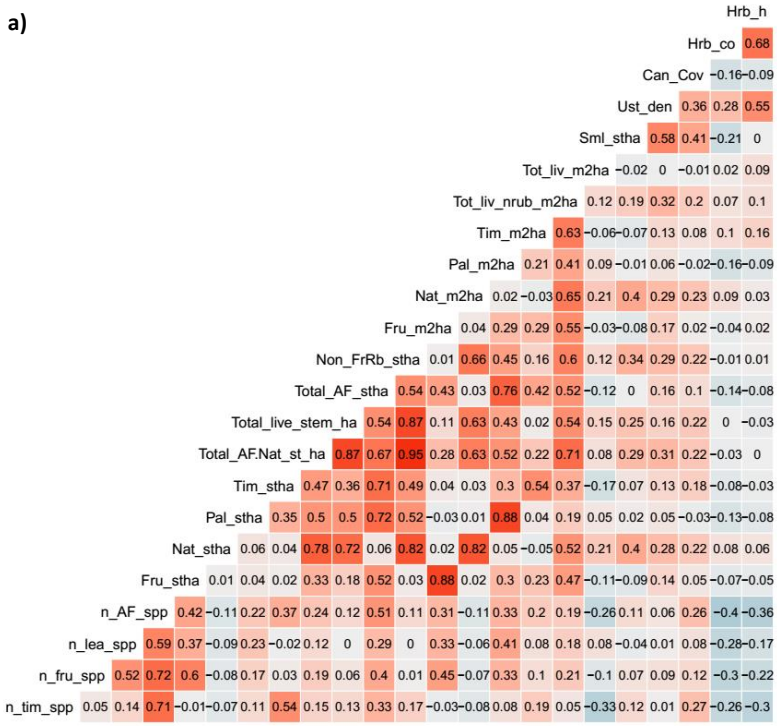
Figure S4:

Correlation matrix of a) all possible rubber plot management/vegetation structure variables across all plots using Pearson correlation, showing and b) selected summarised variables

Field measurements of rubber plot management and vegetation structure were made as follows: stem density and DBH of trees ≥5 cm diameter at breast height (DBH; categorised as rubber, fruit, timber, palm or wild trees) was measured in two 10 m radius subplots 50 m apart, following Barlow *et al* (2007). Small stems ≥1 m high but ≤ 5 cm DBH were counted within two 5 m radius subplots. Data from subplots were pooled to calculate stem and basal area density of each plot. Understorey density index (0 – 25) was measured by counting how many 10 cm sections of a 2.5 m pole were visible from each subplot centre, when placed 15 m away in each of the four cardinal directions, giving eight points per plot (Barlow et al. 2007). Maximum height (10 cm resolution) and percentage cover (estimated visually) of herbaceous vegetation in 1 m x 1 m quadrats, and percentage canopy cover (measured using a spherical densitometer) were recorded at each of the eight points by one observer (E.W-T). A mean of the eight measurements was then calculated per plot.

All habitat variables were checked for collinearity; those with a Pearson correlation ≥ 0.7, above which collinearity severely distorts model estimation (Dormann et al. 2013), were considered for exclusion from further modelling of biodiversity response. Basal area of each tree type was correlated with its respective stem density, so basal area was excluded from further modelling; stem density is more informative for management recommendations, as basal area will simply increase with time once planting density has been established. Stem density of palms, fruit trees, timber trees and native trees were then combined into a single variable: non-rubber tree stem density (ha-1). Fruit tree stem density was also included as a separate variable, as the food resource provided by fruit trees may have unique effects compared to other tree types; this did not correlate strongly with the stem density of all non-rubber trees (Pearson correlation: 0.33). The pooled number of agroforestry species was included, as this was correlated with the number of specific agroforestry species types. Understory density showed moderate correlation with small stem density (Pearson correlation 0.58) and herb height (Pearson correlation 0.55), so was omitted, and small stem density retained. Herb cover and herb height were strongly correlated (Pearson correlation 0.68), so herb cover was omitted from analysis.

a)


Hrb_h
Hrb_co 0.68
Can_Cov −0.16 −0.09
Ust_den 0.36 0.28 0.55
Sml_stha 0.58 0.41 −0.21 0
Tot_liv_m2ha −0.02 0 −0.01 0.02 0.09
Tot_liv_nrub_m2ha 0.12 0.19 0.32 0.2 0.07 0.1
Tim_m2ha 0.63 −0.06 −0.07 0.13 0.08 0.1 0.16
Pal_m2ha 0.21 0.41 0.09 −0.01 0.06 −0.02 −0.16 −0.09
Nat_m2ha 0.02 −0.03 0.65 0.21 0.4 0.29 0.23 0.09 0.03
Fru_m2ha 0.04 0.29 0.29 0.55 −0.03 −0.08 0.17 0.02 −0.04 0.02
Non_FrRb_stha 0.01 0.66 0.45 0.16 0.6 0.12 0.34 0.29 0.22 −0.01 0.01
Total_AF_stha 0.54 0.43 0.03 0.76 0.42 0.52 −0.12 0 0.16 0.1 −0.14 −0.08
Total_live_stem_ha 0.54 0.87 0.11 0.63 0.43 0.02 0.54 0.15 0.25 0.16 0.22 0 −0.03
Total_AF.Nat_st_ha 0.87 0.67 0.95 0.28 0.63 0.52 0.22 0.71 0.08 0.29 0.31 0.22 −0.03 0
Tim_stha 0.47 0.36 0.71 0.49 0.04 0.03 0.3 0.54 0.37 −0.17 0.07 0.13 0.18 −0.08 −0.03
Pal_stha 0.35 0.5 0.5 0.72 0.52 −0.03 0.01 0.88 0.04 0.19 0.05 0.02 0.05 −0.03 −0.13 −0.08
Nat_stha 0.06 0.04 0.78 0.72 0.06 0.82 0.02 0.82 0.05 −0.05 0.52 0.21 0.4 0.28 0.22 0.08 0.06
Fru_stha 0.01 0.04 0.02 0.33 0.18 0.52 0.03 0.88 0.02 0.3 0.23 0.47 −0.11 −0.09 0.14 0.05 −0.07 −0.05
n_AF_spp 0.42 −0.11 0.22 0.37 0.24 0.12 0.51 0.11 0.31 −0.11 0.33 0.2 0.19 −0.26 0.11 0.06 0.26 −0.4 −0.36
n_lea_spp 0.59 0.37 −0.09 0.23 −0.02 0.12 0 0.29 0 0.33 −0.06 0.41 0.08 0.18 0.08 −0.04 0.01 0.08 −0.28 −0.17
n_fru_spp 0.52 0.72 0.6 −0.08 0.17 0.03 0.19 0.06 0.4 0.01 0.45 −0.07 0.33 0.1 0.21 −0.1 0.07 0.09 0.12 −0.3 −0.22
n_tim_spp 0.05 0.14 0.71 −0.01 −0.07 0.11 0.54 0.15 0.13 0.33 0.17 −0.03 −0.08 0.08 0.19 0.05 −0.33 0.12 0.01 0.27 −0.26 −0.3
1.0
0.5
0.0
−0.5
−1.0

b)

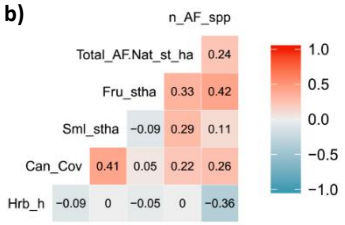

n_AF_spp
Total_AF.Nat_st_ha 0.24
Fru_stha 0.33 0.42
Sml_stha −0.09 0.29 0.11
Can_Cov 0.41 0.05 0.22 0.26
Hrb_h −0.09 0 −0.05 0 −0.36
1.0
0.5
0.0
−0.5
−1.0

Figure S5:

Validation of point-based land-use quantification

To test the validity of the 39-point land-use classification method, area-based measures of landscape composition were extracted by manually mapping management units using high-resolution Google Earth imagery for a subset of ten blocks. This manual mapping was informed by all available GPS points for each block (mean 139 ± 43 SD per block). The proportion of each block within each land use, as measured using the two methods, was compared per block using a Pearson correlation.

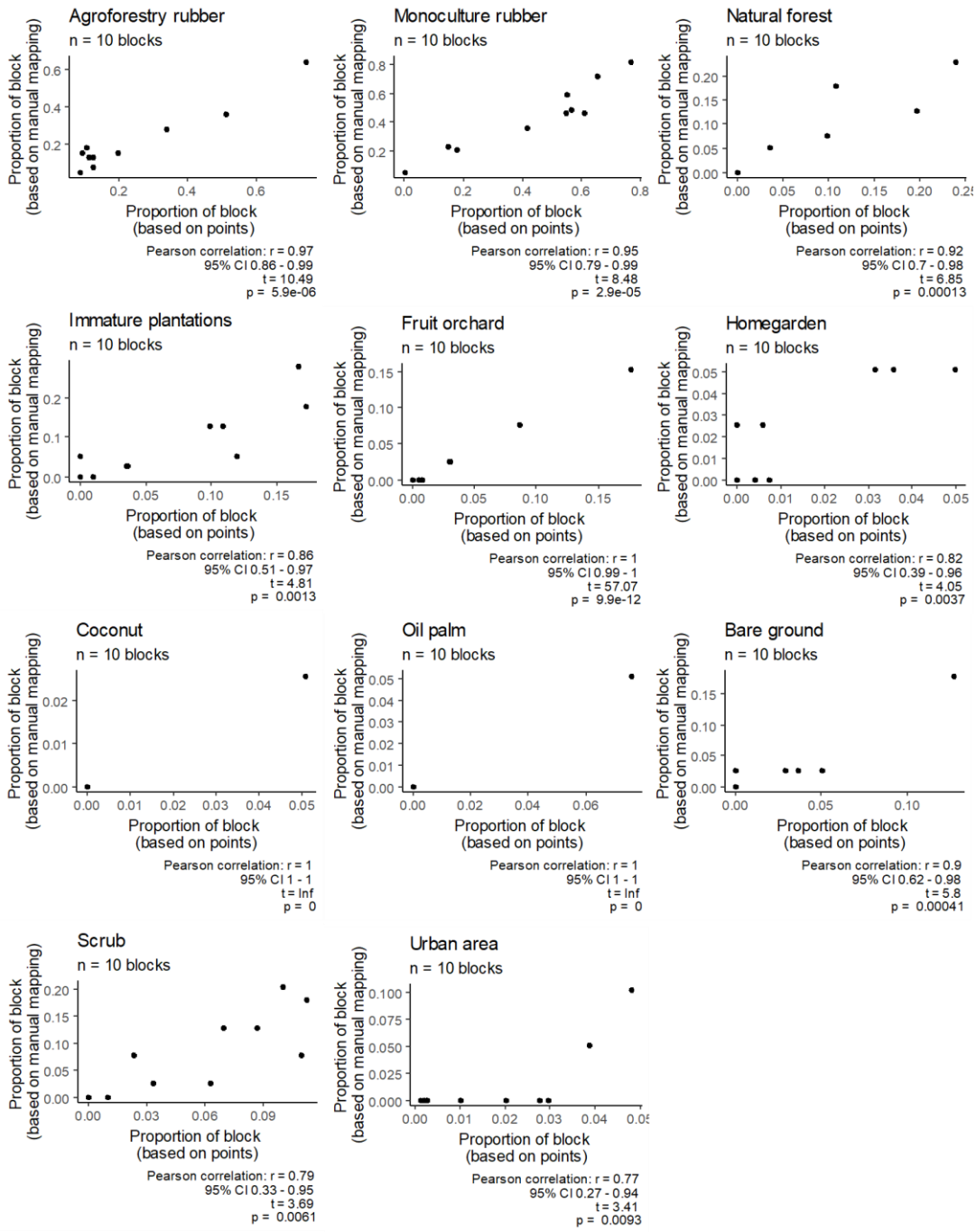


Figure S6:

Rubber stem density in biodiversity and yield datasets.

Panels show rubber stem density of a) all plots, b) AF plots and c) MO plots, showing the ΔAICc of the null model relative to a Generalised Linear Model incorporating plot type (AF and MO). Boxplot format as for Figure S5.

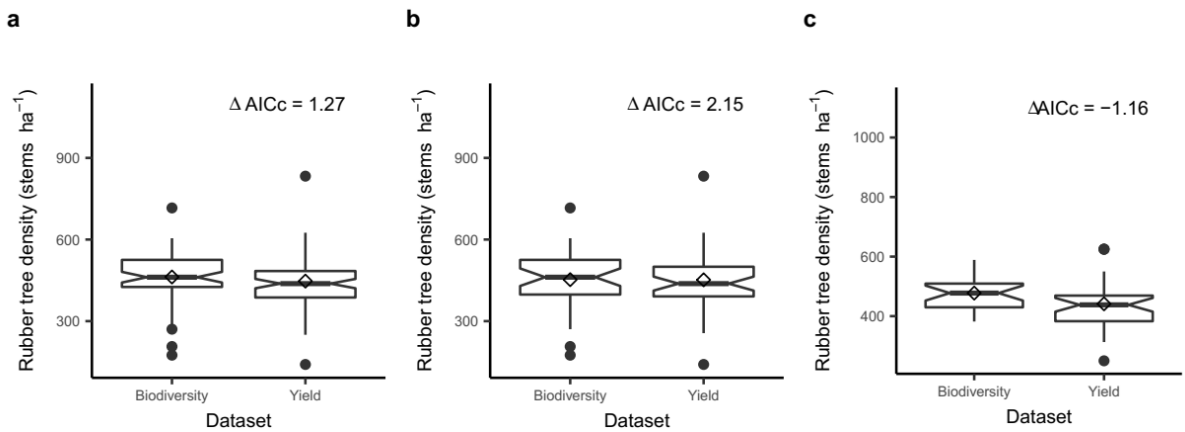


Figure S7:

Comparison of a) agrodiversity, b) fruit tree stem density and c) timber tree stem density of agroforestry plots between yield and biodiversity datasets.

The ΔAICc of the null model, relative to a Generalised Linear Model comparing each variable between the yield and biodiversity datasets, is shown on each panel. All variables were square-root transformed before analysis. Boxplot format as for Figure S5.

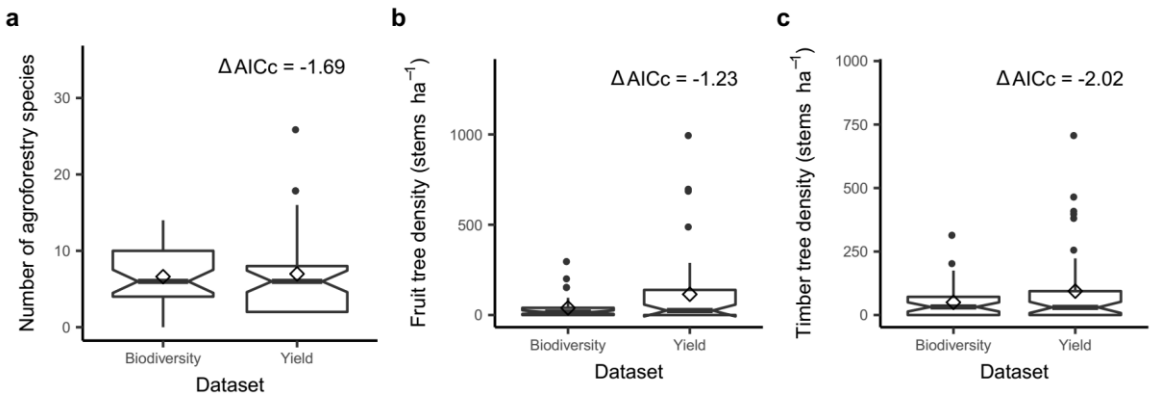


Figure S8:

Variation in species richness among districts, analysed to decide whether to include district as a random effects in models of species richness response.

Panels show species richness per plot of a) birds, b) reptiles and c) butterflies, with the ΔAICc of the Generalised Linear Model (Poisson distribution, log link function) comparing species richness response to district, relative to a null model, on each panel. A frequentist approach was then used to identify statistically significant pairwise differences ($p \leq 0.05$) between the districts, which are represented by letters above box labels, tested using Tukey's honestly significant difference. Boxplots show median (central line), upper and lower quartiles (box bounds) and 1.5x inter-quartile range (whiskers). District had an effect on species richness of butterflies, but no effect on birds or reptiles.

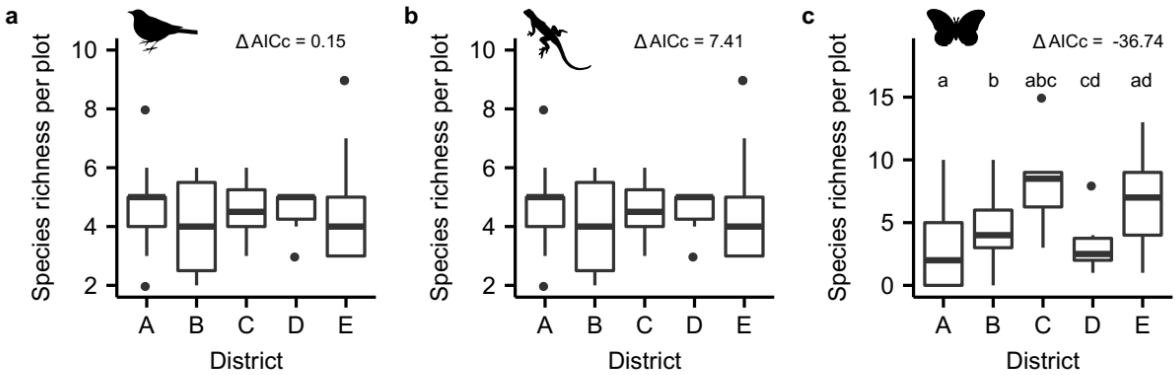


Figure S9:

Influence of rainfall on butterfly species richness, analysed to decide whether to include rainfall as a random effect in models of species richness response.

Panels show species richness of a) all plots, b) AF plots and c) MO plots, showing the ΔAICc of the Generalised Linear Model (Poisson distribution, log link function) of the response to rainfall, relative to a null model, on each panel. A frequentist approach was then used to identify statistically significant pairwise differences ($p \leq 0.05$) between the levels of rainfall, which are represented by letters above box labels, tested using Tukey's honestly significant difference. Rainfall had an effect on species richness across all plots and in MO plots, but no effect in AF plots. Boxplot format as for Figure S5.

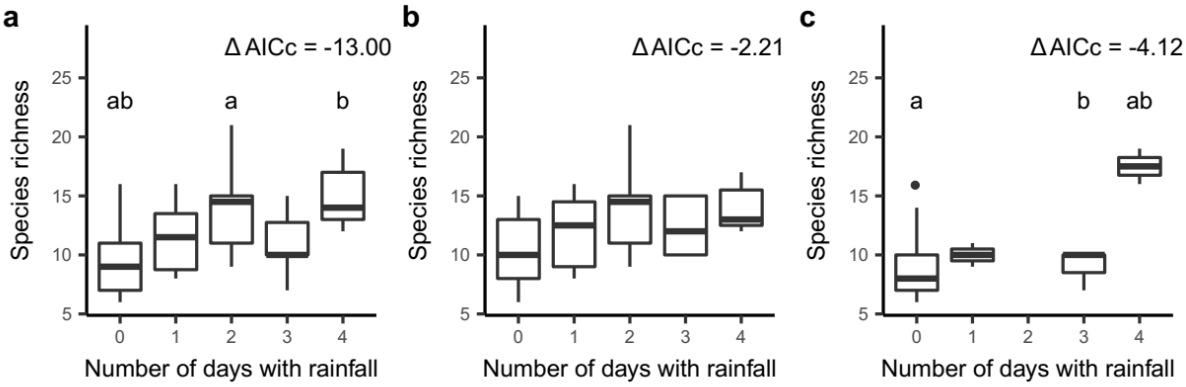


Figure S10:

Influence of sampling trap-days on butterfly species richness, analysed to decide whether to include trap-days as a random effect in models of species richness response.

Butterfly species richness of a) all plots, b) AF plots and c) MO plots, showing the ΔAICc of a Generalised Linear Model (Poisson distribution, log link function) of response to number of trap-days relative to a null model, with model prediction and 95% CI. The model including trap-days was not better than the null in any case.

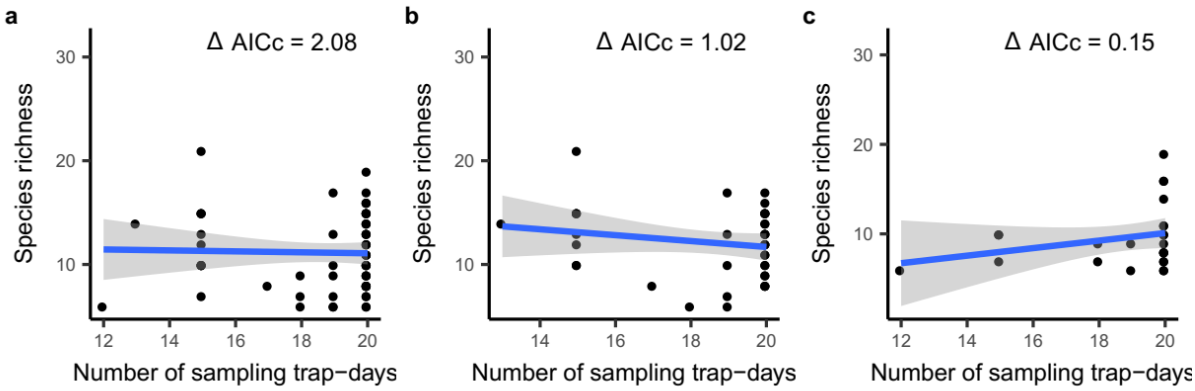
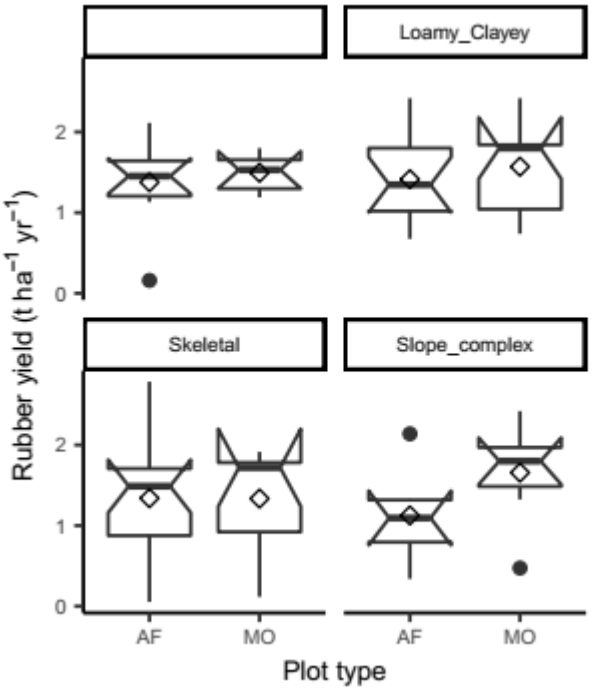


Figure S11:

Comparison of rubber yields in AF and MO plots within soil types. Rubber yields compared a) between AF and MO within each soil type, including plots with no data, and b) among soil types, within AF and MO

a)



b)

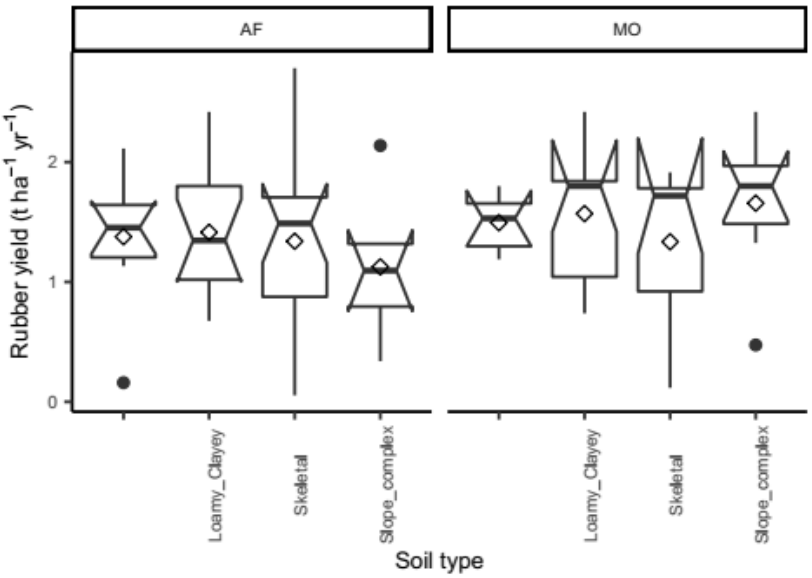


Figure S12:

Habitat structure measures of rubber agroforests (AF) and monocultures (MO) in biodiversity dataset plots.

Boxes bound 25% and 75% quartiles, lines show median, notches give approximate 95% confidence interval around median, diamonds show mean, whiskers extend to 1.5x the interquartile range; outliers are shown as dots. The ΔAICc for each Generalised Linear Model of response to plot type (AF and MO) relative to the null model is shown on each panel. Where the AICc of the plot type model was more than two AICc smaller than that of the null model, an asterisk is shown above the boxplots. The following variables were square-root transformed before analysis: fruit and timber tree species richness, timber, fruit and native tree density timber tree basal area and density of small stems.

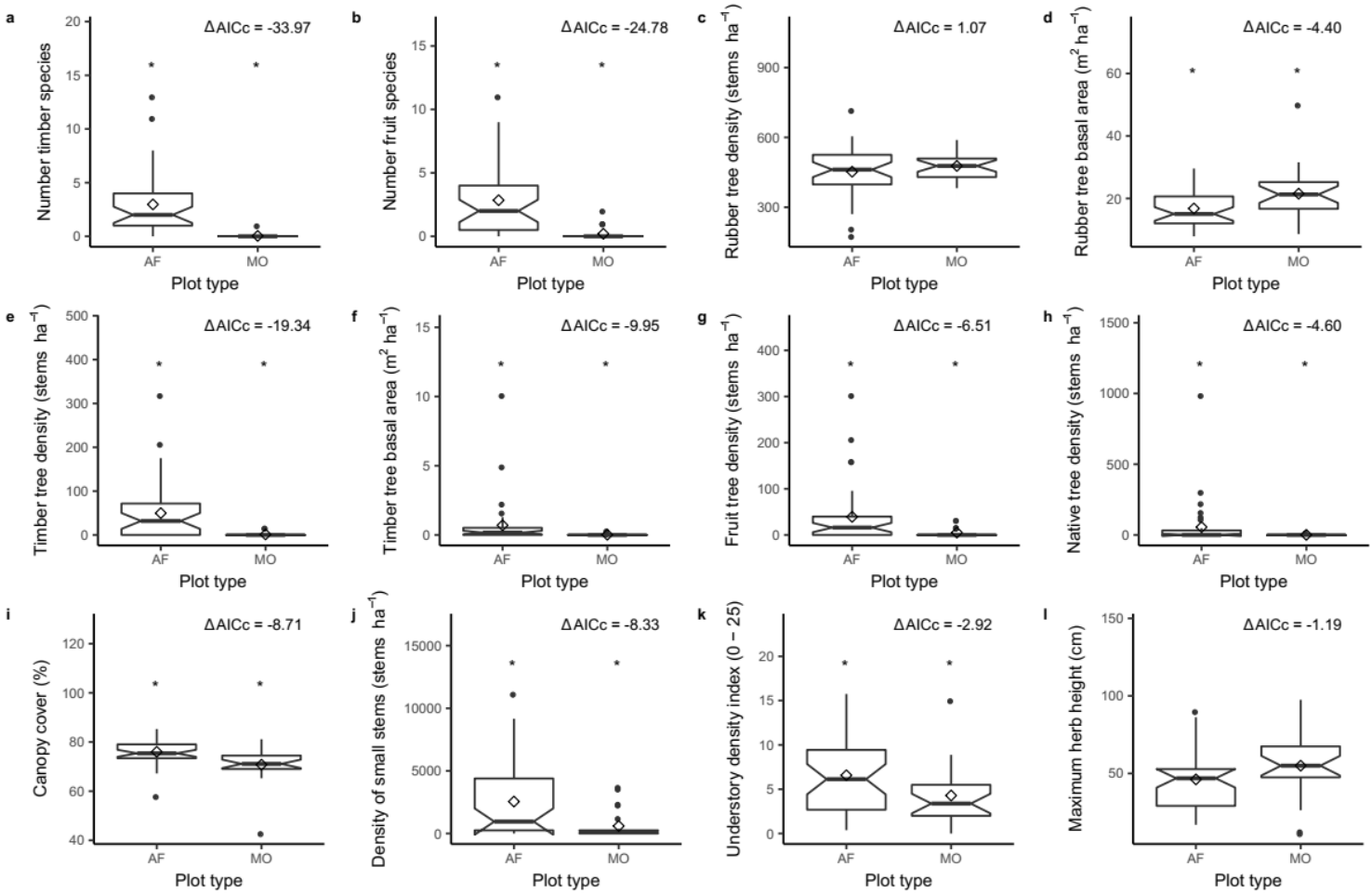


Figure S13:

Sampling completeness of biodiversity surveys.

Panels show a) estimated species richness (mean of Jack1, Jack2, Bootstrap and Mmean, error bars = 95% confidence interval of the mean) and b) percentage of mean estimated species richness observed in samples, compared between AF and MO plots using a Mann-Whitney U test for each taxon; error bars = SD around the mean.

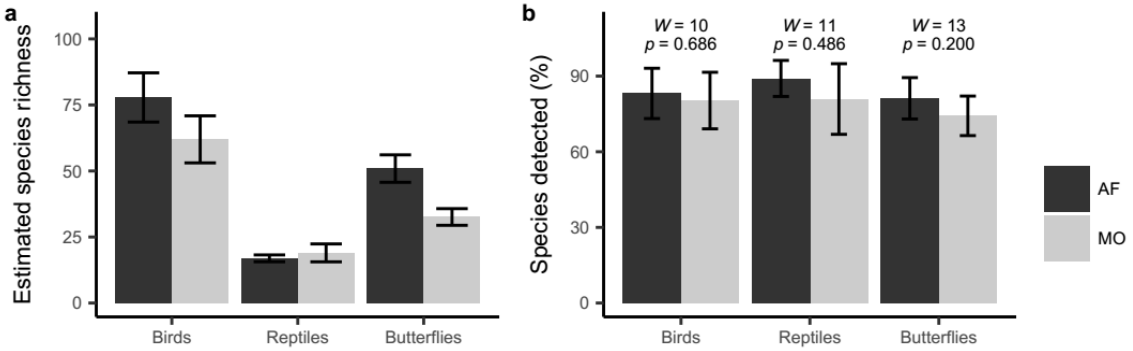


Figure S14:

Comparison of detections of birds, reptiles and butterflies in agroforests and monocultures.

The ΔAICc for each Generalised Linear Model of response to plot type (AF and MO) relative to the null model is shown on each panel.

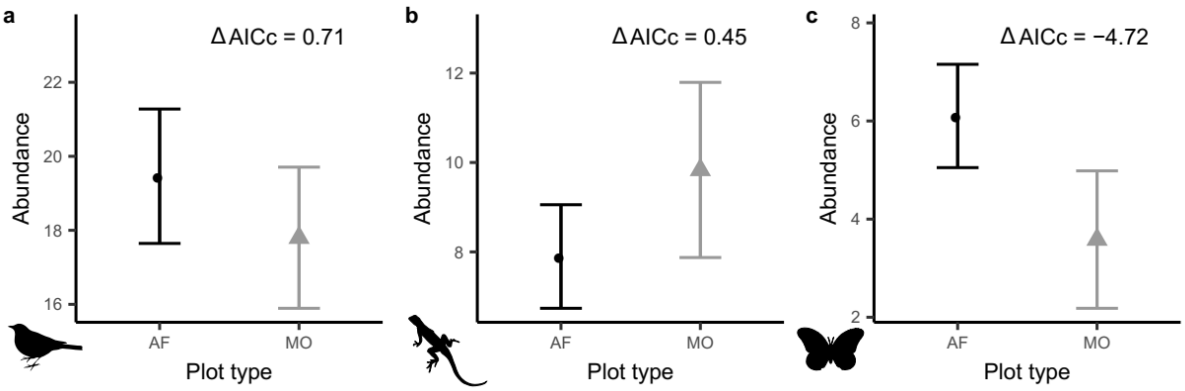


Figure S15:

Correlation between proportion of natural forest in block and density of non-rubber trees in rubber plots

Linear model and 95% CI shown as fitted line and grey shading; result of Pearson correlation between paired measurements shown on panel.

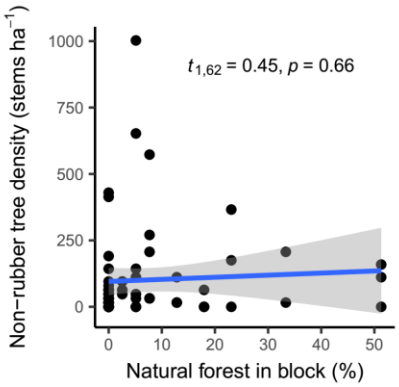


Figure S16:

RDA of butterfly species composition response within AF plots (a) and MO plots (b).

Excludes rare species.

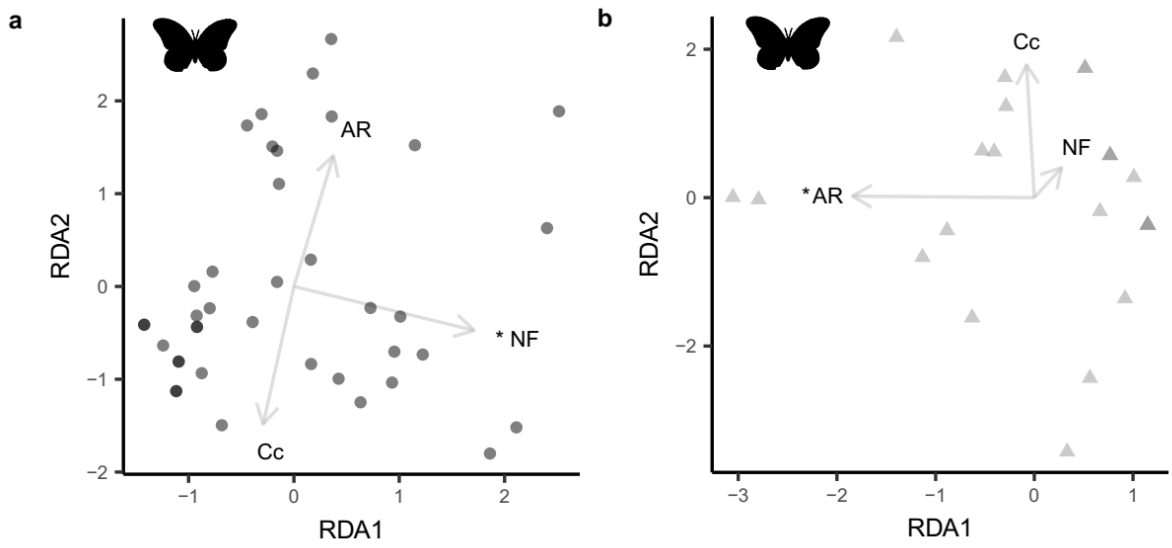


Table S1:

Soil types of plots in the yield and biodiversity datasets

Soil data from the Soil Map of Thailand (2002) is published as part of a comprehensive 1:250,000-scale physical database produced by the Royal Thai Survey Department (RTSD), with soil data provided by the Department of Land Development (DLD), using the US soil classification system (USDA 1999; Department of Land Development 2002). Soil type at the centroid of each plot in each of the yield and biodiversity datasets is shown in the table. The percentage of all plots in loamy/clayey vs skeletal soils, and the percentage of AF vs MO plots in these soils types within each dataset, is shown. Skeletal soils are considered marginal, and may produce lower yields than other soil types (Land Development Department 2014).

	Biodiversity		**Yield**	
	AF	**MO**	**AF**	**MO**
Loamy Paleudults	5	-	2	1
Loamy Paleudults/Clayey Paleaquults	2	3	12	12
Loamy Tropudults	-	-	-	1
% plots with Loamy/Clayey soils in AF/MO	70%	30%	50%	50%
% plots in dataset with Loamy/Clayey soils	22%		53%	
Skeletal Paleudults	9	10	-	-
Skeletal Paleudults/Skeletal Tropudults	2	-	16	9
Skeletal Tropudults	4	2	-	-
Skeletal Tropudults/Loamy Dystropopts	7	2	-	-
% plots with Skeletal soils in AF/MO	61%	39%	64%	36%
% plots in dataset with Skeletal soils	78%		47%	
No Data	22	14	16	9
Slope Complex	10	7	6	8

Table S2:
List of non-rubber plant species identified in rubber agroforests

Scientific name	Common name (English)	Common name (Thai)	Type of plant	Part of plant used	Use	IUCN status
Aquilaria crassna	Agar Wood; Eagle Wood	กฤษณา	Tree	Wood	Timber/resin for perfume	CR
Azadirachta indica	Neem	สะเดา	Tree	Wood	Timber	
Casuarina equisetifolia	-	สน	Tree	Wood	Timber	
Cotylelobium lanceolatum	-	เคี่ยม	Tree	Wood	Timber	VU
Dalbergia cochinchinensis	Siamese Rosewood	พยูง	Tree	Wood	Timber	VU
Dipterocarpus alatus	Keruing; Yang	ยางนา	Tree	Wood	Timber	EN
Eugenia grandis	-	ชะเมา	Tree	Wood	Timber	
Hopea odorata	Thingan; Merawan	ตะเคียน	Tree	Wood	Timber	VU
Intsia bijuga	Borneo Teak; Moluccan Ironwood	หลุมพอ	Tree	Wood	Timber	VU
Litsea grandis	-	ทัง	Tree	Wood	Timber	
Microcos tomentosa	-	ฉับพลา	Tree	Wood	Timber	
Pterocarpus indicus	Burmese Rosewood	ประดู่	Tree	Wood	Timber	VU
Shorea roxburghii	White Meranti	พะยอม	Tree	Wood	Timber	EN
Swietenia macrophylla	Big Leaf Mahogany	มะฮอกกานี	Tree	Wood	Timber	VU
Ternstroemia wallichiana	-	ตำเสา	Tree	Wood	Timber	VU
Ananas comosus	Pineapple	สับปะรด	Herb	Fruit	Fruit	

Scientific name	Common name (English)	Common name (Thai)	Type of plant	Part of plant used	Use	IUCN status
Artocarpus heterophyllus	Jackfruit	ขนุน	Tree	Fruit	Fruit	
Bouea microphylla	-	มะปริง	Tree	Fruit	Fruit	
Citrus aurantifolia	Lime	มะนาว	Tree	Fruit	Fruit	
Cocos nucifera	Coconut	มะพร้าว	Palm	Fruit	Fruit	
Durio zibethinus	Durian	ทุเรียน	Tree	Fruit	Fruit	
Ficus sp.	-	มะเดื่อ	Tree	Fruit	Fruit	
Garcinia mangostana	Mangosteen	มังคุด	Tree	Fruit	Fruit	
Hylocereus undatus	Dragon fruit	แก้วมังกร	Tree	Fruit	Fruit	DD
Lansium domesticum	Longkong	ลองกอง	Tree	Fruit	Fruit	
Mangifera foetida	Horse Mango	มะมุด	Tree	Fruit	Fruit	LC
Mangifera indica	Mango	มะม่วง	Tree	Fruit	Fruit	DD
Musa sapientum	Banana	กล้วย	Herb	Fruit	Fruit	
Nephelium lappaceum	Rambutan	เงาะ	Tree	Fruit	Fruit	LC
Parinari anamensis	-	กะท้อนรอก	Tree	Fruit	Fruit	
Salacca zalacca	Snake fruit	สละ	Palm	Fruit	Fruit	
Sandoricum koetjape	-	กระท้อน	Tree	Fruit	Fruit	
Syzygium jambos	Wax apple	ชมพู่	Tree	Fruit	Fruit	
Tamarindus indica	Tamarind	มะขาม	Tree	Fruit	Fruit	
Anacardium occidentale	Cashew	มะม่วงหิมพานต์	Tree	Fruit + nut	Fruit, nut	

Scientific name	Common name (English)	Common name (Thai)	Type of plant	Part of plant used	Use	IUCN status
Artocarpus lacucha	Monkey fruit	มะหาด	Tree	Fruit	Cosmetics	
Areca catechu	Areca nut	หมาก	Palm	Fruit	Dye	
Bambuseae	Bamboo	ไผ่	Grass	Stem	Food, incense, others	
Thysanolaena sp.	Tiger grass	หญ้าไม้กวาด	Grass	Stem, seed head	Brooms/brushes	
-	-	ซิง	Tree	Leaf	Cigarette paper	
Elateriospermum tapos	-	ประ	Tree	Nut	Nut	
Livistona saribus	Taraw Palm	สิเหรง	Palm	Leaf	Roof thatch	
Alpinia conchigera	-	ข่าลิง	Herb	Root	Spice	
Cinnamomum iners	Cinnamon	เชียด	Tree	Bark	Spice	
Archidendron bubalinum	-	เนียงนก	Tree	Bean	Vegetable	
Archidendron pauciflorum	-	เนียง	Tree	Bean	Vegetable	
Garcinia atroviridis	-	ส้มแขก	Tree	Fruit	Vegetable	
Garcinia cowa	-	ซะมวง	Tree	Leaf	Vegetable	
Gnetum gnemon	-	ผักเหรียง	Shrub	Leaf	Vegetable	LC
Parkia speciosa	Stink bean; Bitter bean	สะตอ	Tree	Bean	Vegetable	
Licuala paludosa	Swamp Fan Palm	กะพ้อ	Palm	Leaf	Wrapping sticky rice	

Table S3:

Species abundances of birds, reptiles and butterflies in AF and MO, IUCN status and habitat specialisation.

Bird species only include those recorded within 50m of point count location; forest interior specialist and open habitat specialist bird species categorisation based on HBW Alive (del Hoyo et al. 2017); reptile categorisation based on A Field Guide to the Reptiles of Thailand (Chan-ard et al. 2015) and habitat description on the IUCN Red List where available (IUCN 2016). Mean abundances are per plot.

* Non-breeding migratory species

IUCN Red List status based on species level taxonomic classification, not subspecies

˜ Abundance of *Mycalesis* species is for males only; note that presence/absence data was used in most analyses, abundance data is given here only as background.

		AF	**MO**			
Scientific name	**Common name**	**Mean abundance (± 95% CI)**	**Mean abundance (± 95% CI)**	**IUCN**	**Forest interior specialist**	**Open habitat specialist**
Birds		**19.46 ± 9.39**	**17.8 ± 9.54**			
Abroscopus superciliaris	Yellow-bellied Warbler	-	0.04 ± 0.08	LC		
Acridotheres grandis	Great Myna	0.03 ± 0.05	-	LC		x
Acridotheres tristis	Common Myna	0.08 ± 0.08	-	LC		x
Aegithina lafresnayei	Great Iora	0.03 ± 0.05	-	LC		
Aegithina tiphia	Common Iora	0.62 ± 0.22	0.52 ± 0.32	LC		
Aethopyga siparaja	Crimson Sunbird	0.03 ± 0.05	-	LC		
Anthreptes malacensis	Brown-throated Sunbird	0.18 ± 0.14	0.08 ± 0.11	LC		
Arachnothera longirostra	Little Spiderhunter	0.28 ± 0.19	0.20 ± 0.16	LC		
Arachnothera modesta	Grey-breasted Spiderhunter	0.03 ± 0.05	-	LC		
*Ardeola bacchus**	Chinese Pond Heron	0.03 ± 0.05	-	LC		x
Cacomantis merulinus	Plaintive Cuckoo	0.10 ± 0.10	-	LC		
Cacomantis sonneratii	Banded Bay Cuckoo	0.10 ± 0.10	-	LC		
Caprimulgus macrurus	Large-tailed Nightjar	0.03 ± 0.05	-	LC		
Centropus sinensis	Greater Coucal	0.26 ± 0.20	0.36 ± 0.25	LC		
Chalcoparia singalensis	Ruby-cheeked Sunbird	0.03 ± 0.05	0.08 ± 0.16	LC		
Chrysococcyx minutillus	Little Bronze Cuckoo	0.05 ± 0.07	0.20 ± 0.20	LC		
Cinnyris jugularis	Olive-backed Sunbird	1.36 ± 0.34	1.32 ± 0.42	LC		
Copsychus saularis	Oriental Magpie Robin	0.23 ± 0.15	0.48 ± 0.26	LC		
Corvus macrorhynchos	Large-billed Crow	-	0.04 ± 0.08	LC		
Cyornis tickelliae	Tickell's Blue Flycatcher	0.13 ± 0.13	0.08 ± 0.11	LC		x
Dendrocopos canicapillus	Grey-capped Pygmy Woodpecker	0.23 ± 0.15	0.36 ± 0.25	LC		x
Dicaeum cruentatum	Scarlet-backed Flowerpecker	0.56 ± 0.25	0.40 ± 0.25	LC		

		AF	MO			
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Dicaeum trigonostigma	Orange-bellied Flowerpecker	1.92 ± 0.26	1.68 ± 0.27	LC		
Dicrurus leucophaeus	Ashy Drongo	-	0.08 ± 0.11	LC		
Eudynamys scolopaceus	Asian Koel	0.03 ± 0.05	0.04 ± 0.08	LC		x
Eurylaimus ochromalus	Black-and-yellow Broadbill	0.03 ± 0.05	-	NT		
*Ficedula elisae**	Green-backed Flycatcher	-	0.04 ± 0.08	LC		
*Ficedula zanthopygia**	Yellow-rumped Flycatcher	0.08 ± 0.08	0.04 ± 0.08	LC		
Geopelia striata	Zebra Dove	0.05 ± 0.07	-	LC		x
Gerygone sulphurea	Golden-bellied Gerygone	0.79 ± 0.15	1.04 ± 0.14	LC		
Halcyon smyrnensis	White-throated Kingfisher	0.41 ± 0.21	0.40 ± 0.25	LC		
Hemipus picatus	Bar-winged Flycatcher-shrike	0.10 ± 0.12	0.16 ± 0.24	LC		
Hypothymis azurea	Black-naped Monarch	0.05 ± 0.10	-	LC		
Leptocoma brasiliana	Van Hasselt's Sunbird	0.13 ± 0.13	0.08 ± 0.11	LC		
Loriculus galgulus	Blue-crowned Hanging Parrot	0.05 ± 0.07	-	LC		
Macronus gularis	Pin-striped Tit Babbler	0.79 ± 0.44	0.40 ± 0.32	LC		
Malacocincla abbotti	Abbott's Babbler	0.18 ± 0.14	0.04 ± 0.08	LC		
Megalaima lineata	Lineated Barbet	0.26 ± 0.16	0.16 ± 0.19	LC		
Megalaima mystacophanos	Red-throated Barbet	0.03 ± 0.05	-	NT		
*Merops philippinus**	Blue-tailed Bee-eater	0.03 ± 0.05	-	LC		x
Merops viridis	Blue-throated Bee-eater	0.08 ± 0.11	-	LC		x
Micropternus brachyurus	Rufous Woodpecker	0.08 ± 0.15	-	LC		
*Muscicapa dauurica**	Asian Brown Flycatcher	0.03 ± 0.05	0.20 ± 0.16	LC		
Orthotomus atrogularis	Dark-necked Tailorbird	0.85 ± 0.28	0.20 ± 0.16	LC		
Orthotomus sutorius	Common Tailorbird	1.54 ± 0.30	1.20 ± 0.49	LC		
Pachycephala cinerea	Mangrove Whistler	0.10 ± 0.12	0.28 ± 0.21	LC		
Pellorneum ruficeps	Puff-throated Babbler	1.46 ± 0.39	1.28 ± 0.47	LC		
*Pericrocotus divaricatus**	Ashy Minivet	0.08 ± 0.08	0.16 ± 0.15	LC		x
Phaenicophaeus tristis	Green-billed Malkoha	0.05 ± 0.07	-	LC		
*Phylloscopus borealis**	Arctic Warbler	0.21 ± 0.13	0.24 ± 0.17	LC		x
Picus puniceus	Crimson-winged Woodpecker	0.05 ± 0.07	-	LC		
Pitta moluccensis	Blue-winged Pitta	0.15 ± 0.11	0.16 ± 0.15	LC		
Prinia rufescens	Rufescent Prinia	1.82 ± 0.39	2.52 ± 0.57	LC		x
Prionochilus maculatus	Yellow-breasted Flowerpecker	0.23 ± 0.20	0.20 ± 0.16	LC		
Prionochilus percussus	Crimson-breasted Flowerpecker	0.08 ± 0.11	0.04 ± 0.08	LC		
Psilopogon duvaucelii	Black-eared Barbet	0.05 ± 0.07	-	LC		
Pycnonotus atriceps	Black-headed Bulbul	1.00 ± 0.31	1.00 ± 0.45	LC		
Pycnonotus blanfordi	Streak-eared Bulbul	0.08 ± 0.11	0.08 ± 0.16	LC		x
Pycnonotus brunneus	Asian Red-eyed Bulbul	0.21 ± 0.19	0.04 ± 0.08	LC		

		AF	MO			
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Pycnonotus finlaysoni	Stripe-throated Bulbul	0.79 ± 0.27	0.80 ± 0.28	LC		
Pycnonotus goiavier	Yellow-vented Bulbul	0.10 ± 0.10	0.04 ± 0.08	LC		x
Pycnonotus plumosus	Olive-winged Bulbul	0.64 ± 0.29	0.52 ± 0.28	LC		
Sasia abnormis	Rufous Piculet	0.03 ± 0.05	0.04 ± 0.08	LC		
Spilopelia chinensis	Spotted Dove	0.03 ± 0.05	0.12 ± 0.13	LC		
Surniculus lugubris	Asian Drongo Cuckoo	0.05 ± 0.07	0.04 ± 0.08	LC		
Tephrodornis virgatus	Large Woodshrike	0.21 ± 0.40	0.04 ± 0.08	LC		
Terpsiphone paradisi	Asian Paradise-flycatcher	0.13 ± 0.13	0.08 ± 0.11	LC	x	
Todiramphus chloris	Collared Kingfisher	-	0.04 ± 0.08	LC		x
Zosterops everetti	Everett's White-eye	0.08 ± 0.15	0.16 ± 0.31	LC		
Reptiles		**7.90 ± 3.03**	**9.83 ± 4.43**			
Ahaetulla prasina	Asian Vine Snake	0.03 ± 0.05	-	LC		
Calotes emma	Emma Gray's Forest Lizard	1.08 ± 0.49	0.75 ± 0.49	NA	x	
Calotes versicolor	Oriental Garden Lizard	2.10 ± 0.50	2.88 ± 0.74	NA		
Dendrelaphis pictus	Painted Bronzeback	0.03 ± 0.05	0.04 ± 0.08	NA	x	
Draco blandfordii	Blandford's Gliding Lizard	-	0.13 ± 0.25	NA	x	
Draco maculatus	Spotted Gliding Lizard	0.49 ± 0.27	0.50 ± 0.29	LC		
Draco taeniopterus	Barred Flying Dragon	0.05 ± 0.07	0.04 ± 0.08	LC		
Draco sumatranus	Common Gliding Lizard	0.51 ± 0.25	0.71 ± 0.38	NA		
Eutropis macularia	Bronze Grass Skink	2.13 ± 0.52	2.83 ± 0.66	NA		
Eutropis multifasciata	Common Sun Skink	0.31 ± 0.15	0.38 ± 0.23	NA		
Hemidactylus frenatus	Common House Gecko	0.18 ± 0.12	0.21 ± 0.17	LC		
Hemidactylus platyurus	Flat-Tailed House Gecko	0.05 ± 0.07	0.08 ± 0.11	NA		
Lygosoma bowringii	Bowring's Supple Skink	0.79 ± 0.30	1.04 ± 0.63	NA		
Lygosoma quadrupes	Short-Limbed Supple Skink	0.05 ± 0.07	0.04 ± 0.08	NA	x	
Naja kaouthia	Monocled Cobra	-	0.04 ± 0.08	LC		
Ptyas korros	Indochinese Rat Snake	0.08 ± 0.08	0.17 ± 0.15	NA	x	
Takydromus sexlineatus	Asian Grass Lizard	0.03 ± 0.05	-	LC		x
Butterflies#		**15.38 ± 3.32**	**8.70 ± 4.52**			
Amathusia masina malaya	The Rusty Palmking	0.18 ± 0.19	0.12 ± 0.17	NA		
Ariadne ariadne pallidior	The Angled Castor	0.08 ± 0.11	0.12 ± 0.17	NA		
Athyma larymna siamensis	The Great Siam Sergeant	0.03 ± 0.05	-	NA		
Athyma perius perius	The Common Sergeant	0.03 ± 0.05	-	NA		
Charaxes athama	The Common Nawab	0.26 ± 0.22	0.04 ± 0.08	NA		
Charaxes bernardus crepax	The Common Tawny Rajah	0.08 ± 0.08	-	NA		

		AF	MO			
Scientific name	**Common name**	**Mean abundance (± 95% CI)**	**Mean abundance (± 95% CI)**	**IUCN**	**Forest interior specialist**	**Open habitat specialist**
Charaxes hebe chersonesus	The Southern Nawab	0.08 ± 0.08	-	NA		
Charaxes moori moori	The Malayan Yellow Nawab	0.03 ± 0.05	-	NA		
Coelites epiminthia epiminthia	The Straight Banded Catseye	-	0.04 ± 0.08	NA		
Discophora sondaica despoliata	The Common Duffer	0.08 ± 0.08	-	NA		
Elymnias hypermnestra tinctoria	The Common Palmfly	0.13 ± 0.13	0.12 ± 0.13	NA		
Elymnias nesaea lioneli	The Tiger Palmfly	0.05 ± 0.07	0.04 ± 0.08	NA		
Euthalia aconthea gurda	The Mango Baron	0.05 ± 0.07	0.04 ± 0.08	NA		
Euthalia alpheda yamuna	The Streaked Baron	0.03 ± 0.05	-	NA		
Euthalia djata siamica	The Red Spot Baron	-	0.04 ± 0.08	LC		
Euthalia evelina compta	The Red Spot Duke	0.51 ± 0.33	0.04 ± 0.08	NA		
Euthalia malaccana malaccana	The Malay Red Baron	0.08 ± 0.11	0.08 ± 0.11	LC		
Euthalia monina monina	The Malay Baron	0.03 ± 0.05	0.04 ± 0.08	NA		
Euthalia recta montilis	The Red Spot Marquis	0.33 ± 0.35	-	NA		
Euthalia teuta	The Banded Marquis	0.62 ± 0.45	-	NA		
Herona marathus angustata	The Yellow Pasha	0.08 ± 0.08	-	NA		
Hypolimnas bolina jacintha	The Great Eggfly	0.36 ± 0.29	0.08 ± 0.11	NA		
Junonia atlites atlites	The Grey Pansy	0.03 ± 0.05	0.08 ± 0.11	NA		
Junonia iphita iphita	The Chocolate Pansy	0.21 ± 0.18	0.16 ± 0.19	NA		
Lebadea martha malayana	The Knight	0.05 ± 0.07	-	NA		
Lexias pardalis dirteana	The Common Archduke	0.05 ± 0.07	-	NA		
Melanitis leda leda	The Common Evening Brown	3.56 ± 0.94	2.04 ± 1.13	NA		
Melanitis phedima abdullae	The Dark Evening Brown	0.15 ± 0.21	-	NA		
Moduza procris milonia	The Common Commander	0.03 ± 0.05	-	NA		
Mycalesis distanti-intermedia˜	Bushbrown	3.90 ± 1.23	2.38 ± 1.45	-		
Mycalesis mineus	The Dark Branded Bushbrown	0.97 ± 0.47	0.96 ± 0.70	-		
Mycalesis perseoides	The Burmese Bushbrown	1.08 ± 0.78	0.79 ± 0.53	-		
Mycalesis visala phamis	The Long-Branded Bushbrown	0.03 ± 0.05	-	-		
Neptis hylas papaja	The Common Sailor	-	0.04 ± 0.08	NA		
Rhinopalpa polynice eudoxia	The Wizard	0.05 ± 0.10	-	NA		
Tanaecia clathrata violaria	The Violet-Bordered Viscount	0.03 ± 0.05	-	NA		
Tanaecia flora andersonii	The Blue Count	0.18 ± 0.14	0.20 ± 0.25	NA		

		AF	MO			
Scientific name	**Common name**	**Mean abundance (± 95% CI)**	**Mean abundance (± 95% CI)**	**IUCN**	**Forest interior specialist**	**Open habitat specialist**
Tanaecia iapis puseda	The Horsfield's Baron	0.18 ± 0.14	0.04 ± 0.08	NA		
Tanaecia julii	The Common Earl	1.36 ± 0.55	0.72 ± 0.67	NA		
Tanaecia pelea pelea	The Malay Viscount	0.23 ± 0.20	-	LC		
Telinga janardana	The Lesser Bushbrown	0.92 ± 0.41	0.48 ± 0.41	LC		
Ypthima baldus newboldi	The Common Fivering	0.03 ± 0.05	-	NA		
Ypthima nebulosa	The Malayan Fivering	0.05 ± 0.07	0.08 ± 0.11	NA		
Zeuxidia amethystus amethystus	The Common Saturn	0.03 ± 0.05	-	NA		

Table S4:

Partial Redundancy Analysis (pRDA) assessing species composition response to plot type (agroforest AF, monoculture MO), after partialling out the effect of block, excluding rare species.

Variance, F and p values are reported for the whole model which contained plot type as the only environmental variable, and Block as a conditioning variable. Species abundance was scaled before analysis, so inertia is equivalent to the number of species in the ordination.

Taxon		**Df**	**Variance**	**F**	**Pr (>F)**	**Inertia**	**Proportion inertia explained**
Birds	Total					47	1
	Conditional (Block)					21.45	0.46
	Constrained					0.66	0.01
	Unconstrained					24.89	0.53
	Model (Plot type)	1	0.66	1.06	0.372		
Reptiles	Total					13	1
	Conditional (Block)					7.53	0.58
	Constrained					0.05	0
	Unconstrained					5.42	0.42
	Model (Plot type)	1	0.05	0.37	0.972		
Butterflies	Total					28	1
	Conditional (Block)					12.62	0.45
	Constrained					0.41	0.01
	Unconstrained					14.97	0.53
	Model (Plot type)	1	0.41	1.07	0.377		

Table S5:

Results of Redundancy Analysis (RDA) of species composition response to the best model of plot type, rubber plot management variables and landscape composition variables, excluding rare species.

Variance, F and p values are for sequential addition of terms into the model. Variance Inflation Factor was <10 for all terms in all models, and thus terms can be considered non-collinear, and the order of inclusion in the model unimportant. Analysis excludes rare species (total abundance or sum of presences less than three). Species abundance was scaled before analysis, so inertia is equivalent to the number of species in the ordination.

Taxon		Df	Variance	Pseudo- F	Pr (>F)	Inertia	Proportion inertia explained
Birds	Total					47.00	1.00
	Constrained					7.35	0.16
	Unconstrained					39.65	0.84
	RDA1	1	2.23	3.20	0.000		0.05
	RDA2	1	1.52	2.19	0.000		0.03
	Model	6	7.35	1.76	<0.001		
	Residual	57	39.65				
	Herb height (cm)	1	1.04	1.49	0.022		
	Non-rubber tree stem density (stems ha^{-1})	1	1.20	1.73	0.040		
	Land use Shannon diversity	1	1.00	1.43	0.051		
	Proportion rubber (%)	1	1.47	2.11	0.003		
	Proportion natural forest (%)	1	1.43	2.06	0.000		
	Proportion open habitat (%)	1	1.22	1.75	0.004		
Reptiles	Total					13.00	1.00
	Constrained					1.76	0.14
	Unconstrained					11.24	0.86
	RDA1	1	1.01	5.12	0.000		0.08
	RDA2	1	0.46	2.33	0.016		0.04
	Model	5	1.76	1.79	0.005		
	Residual	57	11.24				
	Canopy cover (%)	1	0.43	2.18	0.041		
	Land use Shannon diversity	1	0.31	1.60	0.106		
	Proportion natural forest (%)	1	0.21	1.06	0.342		
	AF:MO ratio	1	0.32	1.62	0.124		
	Proportion open habitat (%)	1	0.49	2.47	0.008		
Butterflies	Total					28	1.00
	Constrained					4.10	0.15
	Unconstrained					23.90	0.85
	RDA1	1	1.69	4.03	0.000		
	RDA2	1	1.05	2.51	0.003		
	Model	5	4.10	1.95	<0.001		
	Residual	57	23.90				
	Plot type	1	0.80	1.91	0.009		
	Canopy cover (%)	1	0.93	2.23	0.014		
	Proportion natural forest (%)	1	0.84	1.99	0.025		
	AF:MO ratio	1	0.66	1.57	0.094		
	Plot type : AF:MO ratio	1	0.86	2.06	0.051		

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