

The impacts of biofuel crops on local biodiversity: a global synthesis

Biodiversity and Conservation

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Supplementary Material: Appendix 1

Land-use intensity descriptions by predominant habitat from Hudson et al. (2014).

Predominant Land Use	Minimal use	Light use	Intense use
Primary Forest and Non-Forest	Any disturbances identified are very minor (e.g., a trail or path) or very limited in the scope of their effect (e.g., hunting of a particular species of limited ecological importance).	One or more disturbances of moderate intensity (e.g., selective logging) or breadth of impact (e.g., bushmeat extraction), which are not severe enough to markedly change the nature of the ecosystem. Primary sites in suburban settings are at least Light use.	One or more disturbances that is severe enough to markedly change the nature of the ecosystem; this includes clear-felling of part of the site too recently for much recovery to have occurred. Primary sites in fully urban settings should be classed as Intense use.
Mature Secondary Vegetation (all ages)	As for Primary Vegetation-Minimal use.	As for Primary Vegetation-Light use.	As for Primary Vegetation-Intense use.
Plantation Forest	Extensively managed or mixed timber, fruit/coffee, oil-palm or rubber plantations in which native understorey and/or other native tree species are tolerated, which are not treated with pesticide or fertiliser, and which have	Monoculture fruit/coffee/rubber plantations with limited pesticide input, or mixed species plantations with significant inputs. Monoculture timber plantations of mixed age with no recent (< 20 years) clear-felling. Monoculture	Monoculture fruit/coffee/rubber plantations with significant pesticide input. Monoculture timber plantations with similarly aged trees or timber/oil-palm.

	not been recently (< 20 years) clear-felled.	oil-palm plantations with no recent (< 20 years) clear-felling.	plantations with extensive recent (< 20 years) clear-felling.
Cropland	Low-intensity farms, typically with small fields, mixed crops, crop rotation, little or no inorganic fertiliser use, little or no pesticide use, little or no ploughing, little or no irrigation, little or no mechanisation.	Medium intensity farming, typically showing some but not many of the following: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, no crop rotation, mechanisation, monoculture crop. Organic farms in developed countries often fall within this category, as may high-intensity farming in developing countries.	High-intensity monoculture farming, typically showing many of the following features: large fields, annual ploughing, inorganic fertiliser application, pesticide application, irrigation, mechanisation, no crop rotation.
Pasture	Pasture with minimal input of fertiliser and pesticide, and with low stock density (not high enough to cause significant disturbance or to stop regeneration of vegetation).	Pasture either with significant input of fertiliser or pesticide, or with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).	Pasture with significant input of fertiliser or pesticide, <i>and</i> with high stock density (high enough to cause significant disturbance or to stop regeneration of vegetation).

Urban	Extensive managed green spaces; villages.	Suburban (e.g. gardens), or small managed or unmanaged green spaces in cities.	Fully urban with no significant green spaces.
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Supplementary Material: Appendix 2

Results from our literature review, detailing the biofuel assessment of crops within the PREDICTS database as of March 2018.

Crop name as it appears in the database	Is there evidence for biofuel potential?	Description of use for biofuel	Biofuel generation	Biofuel category	Can use waste as a biofuel?	Reference
<i>Elaeis guineensis</i>	Yes	African oil palm; can use oil from fruit and kernel or waste fronds, shells and trunk	First	Oil palm	Yes	Danielsen et al. (2009) Sukiran et al. (2017)
<i>Ananas comosus</i>	Yes	Pineapple peel	Second	Fruit/vegetable	Yes	Saladini et al. (2016)
<i>Hevea brasiliensis</i>	Yes	Rubber seed oil	Second	Rubber	No	Ikwuagwu et al. (2000)
<i>Annona x atemoya</i>	No					
<i>Dimocarpus longan</i>	Yes	Longan fruit tree wood can be processed to make bioethanol	Second	Fruit/vegetable	Yes	Unpaprom et al. (2019)
<i>Macadamia integrifolia</i>	Yes	Macadamia seed oil	First	Other oil crop	No	Rahman et al. (2016)
<i>Triticum</i> , Wheat, <i>Triticum aestivum</i> , <i>Triticum spelta</i>	Yes	Can use wheat grain or wheat straw, chaff, hull, husk, glumes and stems. Common wheat or spelt wheat.	First	Wheat	Yes	Tishler et al. (2015) Barman et al. (2012) Jansone and Gaile (2013)

						Godin et al. (2013)
<i>Brassica napus</i> , Oil seed rape	Yes	Rapeseed oil	First	Rapeseed oil	No	Malça et al. (2014)
<i>Avena sativa</i>	Yes	Oat grain and residue from processing- oat waste/oat straw	First	Other grain	Yes	Ahlgren et al. (2011)
<i>Solanum tuberosum</i>	Yes	Potato peel waste, potato pulp	Second	Fruit/vegetable	Yes	Liang and McDonald (2014) Gao et al. (2012)
<i>Hordeum vulgare</i> , Barley	Yes	Winter barley and barley straw	First	Other grain	Yes	Ahlgren et al. (2011) Nghiem et al. (2017)
<i>Sinapis alba</i>	Yes	Inedible seed oil from white mustard	Second	Other oil crop	No	Sáez-Bastante et al. (2016)
<i>Linum usitatissimum</i>	Yes	Common flax/linseed oil, seed and oil (edible)	First	Other oil crop	No	Borugadda and Goud (2012)
<i>Cucurbita pepo</i>	Yes	Pumpkin seed oil	First	Other oil crop	No	Schinas et al. (2009)
<i>Vicia faba</i>	Yes	Can use broad bean biomass residue eg. straw, can also use whole crop	First	Fruit/vegetable	Yes	Pakarinen et al. (2011) Petersson et al. (2007)

<i>Coffea arabica</i> , <i>Coffea</i> , Coffee	Yes	Spent coffee grounds	Second	Coffee	Yes	Gómez-de la Cruz et al. (2015)
<i>Secale cereale</i>	Yes	Can grow as winter crop after harvest of main summer crop, can also use rye straw	First	Other grain	Yes	Smuga-Kogut et al. (2017) Shao et al. (2015)
Grapes	Yes	Grape skins or seeds	Second	Fruit/vegetable	Yes	Xu et al. (2009)
<i>Olea europaea</i>	Yes	Olive stone residue, olive pomace, olive oil extraction waste, tree pruning biomass, leaves	Second	Fruit/vegetable	Yes	Mata-Sánchez et al. (2014) Dermeche et al. (2013) Manzanares et al. (2017)
<i>Theobroma cacao</i>	Yes	Cocoa pod husk (residue after extracting pulp), cocoa pulp juice (sweatings) or cocoa pods (residue)	Second	Fruit/vegetable	Yes	Balladares et al. (2016)
<i>Medicago sativa</i> , Alfalfa	Yes	Can use alfalfa stems for biofuel while leaves can still be used as feed for livestock	Second	Perennial grass	Yes	Gonzalez-Garcia et al. (2010)
<i>Zea mays</i> , <i>Zea mays</i> , <i>Zea Mays</i> , Corn, Maize crop	Yes	Maize straw, maize silage (produced from whole plants), sugar, stover (non-grain parts; stalks, leaves and cobs remaining after harvest) and grain	First	Maize	Yes	Zbytek et al. (2016) White et al. (2012) Blanco-Canqui and Lal (2007)

<i>Brassica oleracea</i>	No					
<i>Phaseolus vulgaris</i>	No					
<i>Glycine max</i>	Yes	Soybean oil	First	Soybean	No	Cerri et al. (2017)
<i>Gossypium</i>	Yes	Cotton stalk/post-harvest residue, waste cotton fabric	Second	Cotton	Yes	Christopher et al. (2017) Nikolić et al. (2017)
<i>Manihot esculenta</i>	Yes	Cassava and cassava waste	First	Fruit/vegetable	Yes	Hanif et al. (2017) Veiga et al. (2016)
<i>Colocasia esculenta</i>	Yes	Taro and taro waste, potential in Southeast Asia	First	Fruit/vegetable	Yes	Ben-Iwo et al. (2016)
<i>Musa x paradisiaca</i>	Yes	Common banana; banana lignocellulosic residue, banana peel	Second	Fruit/vegetable	Yes	Guerrero et al. (2018) Oberoi et al. (2011)
<i>Solanum melongena</i>	No					
<i>Solanum lycopersicum</i>	Yes	Tomato pomace (waste skin and seeds), seed oil for biodiesel	Second	Fruit/vegetable	Yes	Allison et al. (2016)
<i>Arachis hypogaea</i>	Yes	Peanut; waste shells, seed oil	First	Other oil crop	Yes	Polachini et al. (2016) Russo and Webber (2012)
<i>Cucumis sativus</i>	Yes	Cucumber pomace containing pulp, peel, seeds, and stem	Second	Fruit/vegetable	Yes	Szymanska-Chargot et al. (2017)

<i>Daucus carota</i>	Yes	Wild carrot pomace, carrots which are discarded due to sizing problems	Second	Fruit/vegetable	Yes	Szymanska-Chargot et al. (2017) Aimaretti et al. (2012)
<i>Apium graveolens</i>	No					
<i>Ribes nigrum</i>	Yes	Blackcurrant pomace obtained after pressing-seeds, peels and pulp	Second	Fruit/vegetable	Yes	Déniel et al. (2016)
<i>Euterpe edulis</i>	No					
<i>Cocos nucifera</i>	Yes	Coconut oil, shell, husk	First	Other oil crop	Yes	Tupufia et al. (2013) Mendu et al. (2012)
<i>Psidium guajava</i>	No					
<i>Mangifera indica</i>	Yes	Mango seed oil, pulp and peel, leaf litter or stem bark residue	First	Fruit/vegetable	Yes	Akhtar et al. (2016) Carrillo-Nieves et al. (2017) Fernando et al. (2014)
<i>Averrhoa carambola</i>	No					
<i>Citrus limon</i>	Yes	Lemon peel waste	Second	Fruit/vegetable	Yes	Boluda-Aguilar and López-Gómez (2013)

<i>Bambuseae</i>	Yes	Bamboo lignocellulosic substrate can be used due to its high growth efficiency	Second	Perennial grass	Yes	He et al. (2014)
<i>Citrus x sinensis</i>	Yes	Orange peel	Second	Fruit/vegetable	Yes	Negro et al. (2017)
<i>Oryza sativa</i>	Yes	Rice straw and husk	Second	Other grain	Yes	Banerjee et al. (2009) Victor et al. (2016)
<i>Ipomoea batatas</i>	Yes	Starch from sweet potato tubers, residues from after separating starch, peel	First	Fruit/vegetable	Yes	Waluyo et al. 2015) Wang et al. (2016)
<i>Ilex paraguariensis</i>	No					
<i>Avena barbata</i>	No					
<i>Trifolium subterraneum</i>	No					
<i>Helianthus annuus</i>	Yes	Common sunflower seed oil is commonly used in Europe, could also be used as a source of lignocellulosic biomass	First	Other oil crop	Yes	Marvey (2008) Ziebell et al. (2013)
<i>Carica papaya</i>	Yes	Papaya peel, waste seed oil, waste fruit puree	Second	Fruit/vegetable	Yes	Dahunsi et al. (2017) Winayanuwattikun et al. (2008) Heller et al. (2015)
<i>Artocarpus altilis</i>	Yes	Breadfruit starch	First	Fruit/vegetable	No	Betiku and Taiwo (2015)

<i>Artocarpus heterophyllus</i>	Yes	Jackfruit woody biomass or stone (stone is edible but most ends up as waste)	Second	Fruit/vegetable	Yes	Dutta et al. (2014) Nuriana and Wuryantoro (2015)
<i>Sorghum bicolor</i>	Yes	Sweet sorghum stalks	First	Other grain	Yes	Chen et al. (2016) Mathur et al. (2017)
<i>Eleusine coracana</i>	No					
<i>Panicum miliaceum</i>	Yes	Proso millet grain (used mainly as bird/livestock feed but can be eaten by humans). Close relative to switchgrass (well-known biofuel crop).	First	Other grain	No	Rose and Santra (2013)
<i>Pennisetum glaucum</i>	Yes	Ground pearl millet (grown mostly for livestock but can be eaten by humans), agricultural waste/hay	First	Other grain	Yes	Chen et al. (2007) Wu et al. (2006)
<i>Setaria italica</i>	Yes	Foxtail millet (grown as human and animal food)	First	Other grain	No	Zhang et al. (2012)
Teak	Yes	Teak wood pellets	Second	Woody crop	No	Tenorio et al. (2015)
<i>Musa textilis</i>	No					
<i>Sechium edule</i>	No					

<i>Sorghum</i>	No					
<i>arundinaceum</i>						
<i>Areca catechu</i>	Yes	Areca nut husk	Second	Woody crop	Yes	Sasmal et al. (2012)
<i>Anacardium</i>	Yes	Cashew nut oil, nut shell liquid (by-product	First	Other oil crop	Yes	Eddy et al. (2011)
<i>occidentale</i>		from nut production), cashew apple juice (apple usually a neglected product), cashew apple bagasse (straw)				Sanjeeva et al. (2014) Deenanath et al. (2015) Rocha et al. (2014)
<i>Inga edulis</i>	No					
<i>Persea americana</i>	Yes	Avocado flesh or seeds	First	Fruit/vegetable	Yes	Adekunle et al. (2016) Aysu and Durak (2015)
<i>Camellia sinensis</i>	Yes	Spent kitchen waste tea can be used for biodiesel, or tea seed oil	Second	Tea	Yes	Demirbas (2010) Mahmood and Hussain (2010)
<i>Ricinus communis</i>	Yes	Castor bean seed oil, castor plant lignocellulosic biomass- leaves and stems	Second	Other oil crop	Yes	Timko et al. (2014) Mathur and Chakraborty (2016)
<i>Jatropha curcas</i>	Yes	Seed oil widely used as biofuel. Could also use husk/shell	Second	Other oil crop	Yes	Abhilash et al. (2011) Makkar and Becker (2009)

<i>Fragaria x ananassa</i>	No					
<i>Prunus persica</i>	Yes	Peach tree wood, bark, branches. Pruning from cultivation; discarded peaches, peels and pulp residues from processing; unsold nectar from distribution; not consumed nectar from consumption.	Second	Fruit/vegetable	Yes	Cichy et al. (2017) De Menna et al. (2015) Ucuncu et al. (2013)
<i>Molinia caerulea</i>	No					
<i>Juncus acutiiflorus</i>	No					
<i>Agrostis canina</i>	No					
<i>Lolium perenne</i>	Yes	Common ryegrass	Second	Perennial grass		Farrar et al. (2012)
<i>Trifolium repens</i>	No					
<i>Protea compacta</i>	No					
<i>Protea cordata</i>	No					
<i>Leucadendron platyspermum</i>	No					
<i>Pisum sativum</i>	Yes	Pea vine waste	Second	Fruit/vegetable	Yes	Xia et al. (2016)
<i>Allium cepa</i>	Yes	Waste onions, juice residue, peel/skin	Second	Fruit/vegetable	Yes	Vazirzadeh et al. (2012) Kim et al. (2017)

<i>Malus domestica</i>	Yes	Apple seeds or pomace (waste from extracting juice)	Second	Fruit/vegetable	Yes	Górnaś and Rudzińska, (2016) Gama et al. (2015)
<i>Prunus salicina</i>	No					
<i>Chrysanthemum cinerariaefolium</i>	No					
<i>Quercus suber</i>	No					
<i>Annona squamosa</i>	Yes	Custard apple seeds	Second	Other oil crop	Yes	Parthiban and Perumalsamy (2016)
<i>Bactris gasipaes</i>	No					
<i>Vigna unguiculata</i>	Yes	Cowpea biomass	Second	Fruit/vegetable	Yes	Foster et al. (2017)
<i>Eucalyptus camaldulensis</i>	Yes	Woody biomass	Second	Woody crop		Acuna et al. (2017)
<i>Khaya senegalensis</i>	No					
<i>Dalbergia sissoo</i>	No					
<i>Cupressus sempervirens</i>	Yes	Mediterranean cypress seed oil	Second	Other oil crop	Yes	Nehdi (2013)
<i>Khaya senegalensis</i>	No					

<i>Brassica rapa</i> var.	No
<i>rapa</i>	

<i>Fagopyrum</i>	No
<i>esculentum</i>	

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Supplementary Material: Appendix 3

Total number of sites from the PREDICTS database for each category of biofuel crop in each region and total number of sites that recorded each taxonomic group for each category of biofuel crop.

Biofuel crop category	Number of sites								
	Africa	Asia	Central & South America	Europe	North America	Oceania	Invertebrates	Plants	Vertebrates
Coffee	90	16	157	0	0	0	105	122	36
Cotton	35	0	0	0	0	0	24	11	0
Fruit/ vegetable	15	92	258	73	9	12	141	40	261
Maize	14	2	138	0	3	0	89	67	1
Mixed crops	682	43	272	94	71	33	175	338	682
Oil palm	0	74	0	0	0	0	28	0	46
Other grain	1	0	0	50	0	0	48	0	3
Other oil crop	4	6	1	4	22	9	29	6	9
Perennial grass	0	0	3	6	5	15	23	6	0
Rapeseed oil	0	1	0	79	0	9	89	0	0
Rubber	0	17	0	0	0	0	16	0	1
Soybean	0	21	70	0	0	0	35	56	0
Wheat	0	14	0	90	11	18	120	11	0

Supplementary Material: Appendix 4

Results from the model with species richness as the response variable and land-use, including biofuel crop category (LandUseCat), as the explanatory variable, with R² values and results table. SS = Source – Study, SSB = Source – Study – Block, SSBS = Source – Study - Block – Site.

Marginal R² = 0.0067 (2 sf) and conditional R² = 0.90 (2 sf). Significance of between 0 and 0.001 = ***, between 0.001 and 0.01= **, between 0.01 and 0.05 = *, between 0.05 and 0.1 = . and between 0.1 and 1 = blank space.

Model parameter					
Random effects	Variance	SD			
SSBS	0.07415	0.2723			
SSB	0.03362	0.1834			
SS	1.39274	1.1801			
Fixed effects	Estimate	Std. Error	z value	Pr(> z)	Significance
(Intercept)	2.52862	0.04490	56.32	< 2e-16	***
LandUseCatCoffee	-0.23339	0.03579	-6.52	6.96e-11	***
LandUseCatCotton	-0.67113	0.10180	-6.59	4.33e-11	***
LandUseCatFruit/vegetable	-0.11646	0.03768	-3.09	0.00200	**
LandUseCatMaize	-0.44717	0.04435	-10.08	< 2e-16	***
LandUseCatMixed crops	-0.29459	0.02135	-13.80	< 2e-16	***
LandUseCatOil palm	-0.36700	0.06060	-6.06	1.39e-09	***
LandUseCatOther grain	-0.17718	0.09641	-1.84	0.06610	.
LandUseCatOther oil crop	-0.27909	0.09623	-2.90	0.00373	**
LandUseCatPasture	-0.16926	0.01222	-13.85	< 2e-16	***
LandUseCatPerennial grass	-0.31261	0.10026	-3.12	0.00182	**
LandUseCatRapeseed oil	-0.19537	0.07611	-2.57	0.01026	*
LandUseCatRubber	-0.04582	0.10552	-0.43	0.66411	
LandUseCatSecondary vegetation	-0.12534	0.01032	-12.14	< 2e-16	***
LandUseCatSoybean	-0.60632	0.06639	-9.13	< 2e-16	***

LandUseCatUrban	-0.25847	0.02368	-10.92	< 2e-16	***
LandUseCatWheat	-0.45508	0.06016	-7.56	3.89e-14	***

Supplementary Material: Appendix 5

Results from the model with total abundance as the response variable and land-use, including biofuel crop category (LandUseCat), as the explanatory variable, with R^2 values and results table. SS = Source – Study, SSB = Source – Study – Block, SSBS = Source – Study - Block – Site.

Marginal $R^2 = 0.0033$ (2 sf) and conditional $R^2 = 0.90$ (2 sf).

Model parameter			
Random effects	Variance	SD	
SSB	0.2240	0.4733	
SS	5.1455	2.2684	
Residual	0.6196	0.7871	
Fixed effects	Estimate	Std. Error	t value
(Intercept)	4.71044	0.09249	50.93
LandUseCatCoffee	-0.32848	0.09917	-3.31
LandUseCatCotton	-1.99779	0.19839	-10.07
LandUseCatFruit/vegetable	-0.08473	0.07772	-1.09
LandUseCatMaize	-0.55408	0.10609	-5.22
LandUseCatMixed crops	-0.14496	0.03764	-3.85
LandUseCatOil palm	-1.01357	0.14475	-7.00
LandUseCatOther grain	-0.45214	0.14508	-3.12
LandUseCatOther oil crop	0.20000	0.25439	0.79
LandUseCatPasture	-0.21506	0.02556	-8.42
LandUseCatPerennial grass	0.46546	0.21685	2.15
LandUseCatRapeseed oil	0.46843	0.15138	3.09
LandUseCatRubber	-0.36355	0.27226	-1.34
LandUseCatSecondary vegetation	-0.17520	0.02219	-7.90
LandUseCatSoybean	-1.25428	0.26514	-4.73
LandUseCatUrban	-0.18306	0.04512	-4.06

LandUseCatWheat	-0.58893	0.10293	-5.72
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Supplementary Material: Appendix 6

Results from the model with total abundance as the response variable and land-use, including biofuel crop generation (LandUseGen), as the explanatory variable, with R^2 values and results table. SS = Source – Study, SSB = Source – Study – Block, SSBS = Source – Study - Block – Site.

Marginal $R^2 = 0.0018$ (2 sf) and conditional $R^2 = 0.90$ (2 sf).

Model parameter			
Random effects	Variance	SD	
SSB	0.2261	0.4754	
SS	5.1661	2.2729	
Residual	0.6225	0.7890	
Fixed effects	Estimate	Std. Error	t value
(Intercept)	4.70825	0.09305	50.60
LandUseGen1st generation	-0.49234	0.06888	-7.15
LandUseGen2nd generation	-0.28983	0.05577	-5.20
LandUseGenPasture	-0.19653	0.02651	-7.41
LandUseGenSecondary vegetation	-0.17679	0.02240	-7.89
LandUseGenUrban	-0.18768	0.04547	-4.13

Supplementary Material: Appendix 7

Results from the model with species richness as the response variable and land-use, including biofuel crop generation (LandUseGen), as the explanatory variable, with R² values and results table. SS = Source – Study, SSB = Source – Study – Block, SSBS = Source – Study - Block – Site.

Marginal R² = 0.0052 (2 sf) and conditional R² = 0.90 (2 sf). Significance of between 0 and 0.001 = ***, between 0.001 and 0.0 = **, between 0.01 and 0.05 = *, between 0.05 and 0.1 = . and between 0.1 and 1 = blank space.

Model parameter					
Random effects	Variance	SD			
SSBS	0.07297	0.2701			
SSB	0.03276	0.1810			
SS	1.40080	1.1836			
Fixed effects	Estimate	Std. Error	z value	Pr(> z)	Significance
(Intercept)	2.52001	0.04517	55.79	<2e-16	***
LandUseGen1st generation	-0.45281	0.02854	-15.87	<2e-16	***
LandUseGen2nd generation	-0.20599	0.02347	-8.78	<2e-16	***
LandUseGenPasture	-0.13778	0.01247	-11.05	<2e-16	***
LandUseGenSecondary	-0.11958	0.01028	-11.63	<2e-16	***
vegetation					
LandUseGenUrban	-0.25190	0.02362	-10.67	<2e-16	***

Supplementary Material: Appendix 8

Results from the model with species richness as the response variable and land-use, including biofuel crop generation (LandUseGen), geographic region and their interaction as the explanatory variables, including R^2 values and results table.

Marginal $R^2 = 0.022$ (2 sf) and conditional $R^2 = 0.90$ (2 sf). Significance of between 0 and 0.001 = ***, between 0.001 and 0.0 = **, between 0.01 and 0.05 = *, between 0.05 and 0.1 = . and between 0.1 and 1 = blank space.

Model parameter					
Random effects	Variance	SD			
SSBS	0.07233	0.2689			
SSB	0.03019	0.1738			
SS	1.37324	1.1719			
Fixed effects	Estimate	Std. Error	z value	Pr(> z)	Significance
(Intercept)	2.390040	0.122233	19.553	< 2e-16	***
LandUseGen1st generation	-0.444477	0.111503	-3.986	6.71e-05	***
LandUseGen2nd generation	-0.276141	0.044443	-6.213	5.19e-10	***
LandUseGenPasture	-0.284353	0.055972	-5.080	3.77e-07	***
LandUseGenSecondary vegetation	-0.107792	0.026971	-3.997	6.42e-05	***
LandUseGenUrban	-0.082235	0.081120	-1.014	0.310702	
RegionAsia	0.402709	0.162717	2.475	0.013327	*

RegionCentral & South America	0.195139	0.149438	1.306	0.191616	
RegionEurope	0.047874	0.151953	0.315	0.752718	
RegionNorth America	-0.123192	0.196178	-0.628	0.530029	
RegionOceania	0.113362	0.194125	0.584	0.559245	
LandUseGen1st generation:RegionAsia	-0.063970	0.122759	-0.521	0.602293	
LandUseGen2nd generation:RegionAsia	0.127612	0.064390	1.982	0.047496	*
LandUseGenPasture:RegionAsia	0.069120	0.147680	0.468	0.639755	
LandUseGenSecondary vegetation:RegionAsia	-0.098217	0.035725	-2.749	0.005973	**
LandUseGenUrban:RegionAsia	-0.673426	0.133107	-5.059	4.21e-07	***
LandUseGen1st generation:RegionCentral & South America	-0.027187	0.125005	-0.217	0.827829	
LandUseGen2nd generation:RegionCentral & South America	0.051698	0.061567	0.840	0.401078	
LandUseGenPasture:RegionCentral & South America	0.163596	0.060684	2.696	0.007021	**
LandUseGenSecondary vegetation:RegionCentral & South America	0.162352	0.034389	4.721	2.35e-06	***
LandUseGenUrban:RegionCentral & South America	-0.416793	0.166678	-2.501	0.012399	*
LandUseGen1st generation:RegionEurope	0.075298	0.124818	0.603	0.546334	
LandUseGen2nd generation:RegionEurope	0.230661	0.083655	2.757	0.005828	**
LandUseGenPasture:RegionEurope	0.157195	0.061616	2.551	0.010735	*
LandUseGenSecondary vegetation:RegionEurope	-0.128369	0.036306	-3.536	0.000407	***

LandUseGenUrban:RegionEurope	-0.223665	0.088725	-2.521	0.011706	*
LandUseGen1st generation:RegionNorth America	0.048959	0.278482	0.176	0.860447	
LandUseGen2nd generation:RegionNorth America	0.006152	0.192933	0.032	0.974562	
LandUseGenPasture:RegionNorth America	-0.075363	0.086385	-0.872	0.382982	
LandUseGenSecondary vegetation:RegionNorth America	0.102169	0.043984	2.323	0.020185	*
LandUseGenUrban:RegionNorth America	-0.101399	0.093512	-1.084	0.278215	
LandUseGen1st generation:RegionOceania	0.071064	0.154608	0.460	0.645774	
LandUseGen2nd generation:RegionOceania	0.068285	0.136288	0.501	0.616348	
LandUseGenPasture:RegionOceania	0.099361	0.061165	1.624	0.104277	
LandUseGenSecondary vegetation:RegionOceania	-0.002824	0.043552	-0.065	0.948307	
LandUseGenUrban:RegionOceania	0.045525	0.161379	0.282	0.777866	

Supplementary Material: Appendix 9

Results from the model with total abundance as the response variable and land-use, including biofuel crop generation (LandUseGen), geographic region and their interaction as the explanatory variables, including R² values and results table.

Marginal R² = 0.022 (2 sf) and conditional R² = 0.90 (2 sf).

Model parameter			
Random effects	Variance	SD	
SSB	0.2154	0.4641	
SS	5.1612	2.2718	
Residual	0.6131	0.7830	
Fixed effects	Estimate	Std. Error	t value
(Intercept)	4.14540	0.26010	15.938
LandUseGen1st generation	-0.44274	0.30092	-1.471
LandUseGen2nd generation	-0.90400	0.15224	-5.938
LandUseGenPasture	-0.39018	0.08931	-4.369
LandUseGenSecondary vegetation	-0.10541	0.05674	-1.858
LandUseGenUrban	0.65901	0.12814	5.143
RegionAsia	0.64724	0.34881	1.856
RegionCentral & South America	0.55443	0.31337	1.769
RegionEurope	0.93837	0.32114	2.922
RegionNorth America	0.09253	0.41082	0.225
RegionOceania	1.26998	0.39832	3.188
LandUseGen1st generation:RegionAsia	-0.62938	0.32615	-1.930
LandUseGen2nd generation:RegionAsia	0.46405	0.19940	2.327
LandUseGenPasture:RegionAsia	0.08827	0.36299	0.243
LandUseGenSecondary vegetation:RegionAsia	-0.10407	0.08374	-1.243
LandUseGenUrban:RegionAsia	-1.71004	0.27131	-6.303

LandUseGen1st generation:RegionCentral & South America	-0.67156	0.37873	-1.773
LandUseGen2nd generation:RegionCentral & South America	0.60569	0.17723	3.417
LandUseGenPasture:RegionCentral & South America	0.34997	0.10020	3.493
LandUseGenSecondary vegetation:RegionCentral & South America	0.21553	0.07110	3.031
LandUseGenUrban:RegionCentral & South America	-1.49846	0.26502	-5.654
LandUseGen1st generation:RegionEurope	-0.14400	0.32161	-0.448
LandUseGen2nd generation:RegionEurope	0.53359	0.19448	2.744
LandUseGenPasture:RegionEurope	-0.07174	0.10443	-0.687
LandUseGenSecondary vegetation:RegionEurope	-0.56198	0.07691	-7.307
LandUseGenUrban:RegionEurope	-1.28504	0.14921	-8.612
LandUseGen1st generation:RegionNorth America	0.30402	0.61347	0.496
LandUseGen2nd generation:RegionNorth America	2.12108	0.38889	5.454
LandUseGenPasture:RegionNorth America	-0.10123	0.14481	-0.699
LandUseGenSecondary vegetation:RegionNorth America	0.31089	0.08956	3.471
LandUseGenUrban:RegionNorth America	-0.74287	0.15427	-4.816
LandUseGen1st generation:RegionOceania	0.37073	0.35965	1.031
LandUseGen2nd generation:RegionOceania	1.07214	0.28005	3.828
LandUseGenPasture:RegionOceania	-0.01691	0.11180	-0.151
LandUseGenSecondary vegetation:RegionOceania	-0.13357	0.09171	-1.456
LandUseGenUrban:RegionOceania	-0.95576	0.25668	-3.724

Supplementary Material: Appendix 10

Results from the model with species richness as the response variable and land-use, including biofuel crop generation (LandUseGen), taxon and their interaction as the explanatory variables, including R² values and results table.

Marginal R² = 0.050 (2 sf) and conditional R² = 0.91 (2 sf). Significance of between 0 and 0.001 = ***, between 0.001 and 0.0 = **, between 0.01 and 0.05 = *, between 0.05 and 0.1 = . and between 0.1 and 1 = blank space.

Model parameter					
Random effects	Variance	SD			
SSBS	0.06778	0.2604			
SSB	0.03364	0.1834			
SS	1.33408	1.1550			
Fixed effects	Estimate	Std. Error	z value	Pr(> z)	Significance
(Intercept)	2.55312	0.06127	41.67	< 2e-16	***
LandUseGen1st generation	-0.37451	0.03973	-9.43	< 2e-16	***
LandUseGen2nd generation	-0.19710	0.04093	-4.82	1.47e-06	***
LandUseGenPasture	-0.14665	0.01894	-7.74	9.70e-15	***
LandUseGenSecondary vegetation	-0.08747	0.01653	-5.29	1.22e-07	***
LandUseGenUrban	-0.17225	0.03147	-5.47	4.40e-08	***
TaxonPlants	0.37441	0.12186	3.07	0.002123	**
TaxonVertebrates	-0.35547	0.10283	-3.46	0.000547	***
LandUseGen1st generation:TaxonPlants	-0.30122	0.06363	-4.73	2.20e-06	***
LandUseGen2nd generation:TaxonPlants	-0.12026	0.05586	-2.15	0.031322	*
LandUseGenPasture:TaxonPlants	0.12277	0.02781	4.41	1.01e-05	***
LandUseGenSecondary vegetation:TaxonPlants	-0.13365	0.02443	-5.47	4.47e-08	***
LandUseGenUrban:TaxonPlants	-0.13112	0.06294	-2.08	0.037227	*

LandUseGen1st	0.03905	0.08070	0.48	0.628425	
generation:TaxonVertebrates					
LandUseGen2nd	0.02807	0.06088	0.46	0.644774	
generation:TaxonVertebrates					
LandUseGenPasture:TaxonVertebrates	-0.20913	0.03626	-5.77	8.06e-09	***
LandUseGenSecondary	-0.01520	0.02593	-0.59	0.557703	
vegetation:TaxonVertebrates					
LandUseGenUrban:TaxonVertebrates	0.04899	0.06907	0.71	0.478175	

Supplementary Material: Appendix 11

Results from the model with total abundance as the response variable and land-use, including biofuel crop generation (LandUseGen), taxon and their interaction as the explanatory variables, including R² values and results table.

Marginal R² = 0.066 (2 sf) and conditional R² = 0.90 (2 sf).

Model parameter			
Random effects	Variance	SD	
SSB	0.2285	0.4780	
SS	4.8461	2.2014	
Residual	0.6120	0.7823	
Fixed effects	Estimate	Std. Error	t value
(Intercept)	5.03754	0.12236	41.17
LandUseGen1st generation	-0.36756	0.07929	-4.64
LandUseGen2nd generation	-0.27573	0.08167	-3.38
LandUseGenPasture	-0.03758	0.03819	-0.98
LandUseGenSecondary vegetation	-0.09210	0.03395	-2.71
LandUseGenUrban	-0.09720	0.05646	-1.72
TaxonPlants	0.15314	0.26414	0.58
TaxonVertebrates	-1.32267	0.20717	-6.38
LandUseGen1st generation:TaxonPlants	0.02696	0.24243	0.11
LandUseGen2nd generation:TaxonPlants	-0.33127	0.15823	-2.09
LandUseGenPasture:TaxonPlants	-0.18037	0.06492	-2.78
LandUseGenSecondary vegetation:TaxonPlants	-0.39992	0.05675	-7.05
LandUseGenUrban:TaxonPlants	-0.26827	0.14549	-1.84
LandUseGen1st generation:TaxonVertebrates	-0.77699	0.20997	-3.70
LandUseGen2nd generation:TaxonVertebrates	0.04455	0.12921	0.34
LandUseGenPasture:TaxonVertebrates	-0.48654	0.06721	-7.24

LandUseGenSecondary	0.00707	0.05351	0.13
vegetation:TaxonVertebrates			
LandUseGenUrban:TaxonVertebrates	0.45410	0.13006	3.49
