APPENDICES

Appendix A PREDICTS

This appendix shows the definition of the different land use classes used in this study and derived from the definition of the PREDICTS project (Purvis et al. 2017).

A.1 Land Use and Land Use Intensity classes

Table 3 Land Use classes and land use intensities

Land Use classes and Land Use intensities used for this study and from the PREDICTS database (Hudson et al. 2017).

Predominant Land Use	Definition	Minimal Use	Light Use	Intense Use
Natural / Semi-natural Vegetation	Result from the collapse of the PREDICTS classes Primary vegetation and Secondary vegetation (Hudson et al. 2017). Primary vegetation is considered native vegetation that is not known to have ever been changed, destroyed, by human actions or by extreme natural events that do not belong to the ecosystem dynamics. Secondary vegetation is where the original vegetation was completely destroyed, and now the ecosystem is recovering its initial state.			
Cropland	Land occupied by herbaceous crops. If it is abandoned, it becomes Secondary vegetation	Low-intensity farms, with mixed crops, crop rotation. Without pesticide use, fertilizers, ploughing,	Medium intensity farming, there is an increase in the use of pesticides, fertilizers, annual ploughing…etc	High-intensity monoculture farming, showing large fields, annual ploughing, inorganic fertilizers,

		irrigation, and machinery.	irrigation, machinery and without crop rotation
Pasture	Land where livestock is known to be grazed regularly or permanently		
Urban	Human-dominated lands where the Primary vegetation has been removed, is typically covered by buildings.		

Appendix B FRAGSTATS metric

This appendix defines the Simpson's diversity index used in this research as an index of the heterogeneity of the landscape. It was calculated with the software FRAGSTATS (McGarigal et al. 2012) for each 2 km buffer around the PREDICTS sites.

B.1 Simpson's Diversity Index (SIDI)

"Simpson's Diversity Index is equals to 1 minus the sum, across all patch types, of the proportional abundance of each patch type squared. SIDI = 0 when the landscape contains only 1 patch (i.e., no diversity). SIDI approaches 1 as the number of different patch types (i.e., patch richness, PR) increases and the proportional distribution of area among patch types become more equitable" (McGarigal et al. 2012).

Pi = proportion of the landscape occupied by patch type (class) i.

Eq. A- 1

$$SIDI = 1 - \sum_{i=1}^{m} P_i^2$$

Appendix C InVEST model

This appendix describes the various equations used in the InVEST model for the calculation of the accessible floral resources and the potential pollinator abundance. The complete model and further information can be found in http://www.naturalcapitalproject.org/

C.1 List of variables

- xx - a pixel coordinate.
- XX - set of all pixels in the landcover map.
- ss - bee species.
- nn - nesting type (ground, cavity).
- NN - set of all nesting types.
- jj - season (fall, spring, etc).
- JJ - set of all seasons (ex: {fall, spring}).
- αsαs - mean foraging distance for species s.
- ns(s,n)ns(s,n) - nesting suitability preference for species ss in nesting type nn.
- HN(x,s)HN(x,s) - habitat nesting suitability at pixel xx for species ss [0.0, 1.0].
- N(l,n)N(l,n) - the nesting substrate index for landcover type ll for substrate type nn in the range [0.0,1.0][0.0,1.0].
- RA(l,j)RA(l,j) - index of relative abundance of floral resources on landcover type ll during season jj. [0.0,1.0][0.0,1.0]
- fa(s,j)fa(s,j) - relative foraging activity for species ss during season jj.
- FR(x,s)FR(x,s) - accessible floral resources index at pixel xx for species ss.
- D(x,x′)D(x,x′) - euclidean distance between the centroid of pixel xx and x′x′.
- PS(x,s)PS(x,s) - pollinator supply index at pixel xx for species ss.
- PA(x,s,j)PA(x,s,j) - pollinator abundance at pixel ss for species ss.

C.2 Pollinator supply

$$PPPP(xx,\ ss) = FFFF(xx,\ ss)HHHH(xx,\ ss)ssss(ss) \qquad \text{Eq. A- 2}$$

C.3 Accessible floral resources

$$FFFF(xx,\ ss) = \frac{\sum_{xx' \in XX} eeeeee(-SS(xx,\ xx')/\alpha\alpha_{ss}) \sum_{jj \in JJ} FFRR(ll(xx'), jj) ffff(ss, jj)}{\sum_{xx' \in XX} eexxee(-SS(xx,\ xx')/\alpha\alpha_{ss})} \qquad \text{Eq. A- 3}$$

C.4 Habitat nesting suitability

$$HHHH(xx,ss) = \max_{nn \in NN}[HH(ll(xx),\ nn)nnss(ss,\ nn)] \qquad \text{Eq. A- 4}$$

C.5 Pollinator abundance index

$$PPPP(xx,\ ss, jj) = \frac{FFPP(ll(xx), jj)ffss(ss, jj)}{FFFF(xx,\ ss)} \frac{\sum_{xx' \in XX} PPPP(xx',\ ss)\exp(-DD(xx,\ xx')/\alpha\alpha_{ss})}{\exp(-DD(xx,\ xx')/\alpha\alpha_{ss})} \qquad \text{Eq. A- 5}$$

C.6 Inputs information

Table 4 Biophysical attributes for the Corine land cover classes

Table that contains information about the nesting availability and the floral resources for each Corine land cover class. This table is one of the necessary inputs for the InVEST crop pollination model.

Corine class name	LC-code	Nesting cavity availability index	Nesting ground availability index	Floral resources all-year index
Continuous urban fabric	1	0.1	0.1	0.05
Discontinuous urban fabric	2	0.3	0.3	0.3
Industrial or commercial units	3	0.1	0.1	0.05
Road and rail networks and associated land	4	0.3	0.3	0.25
Port areas	5	0.3	0.3	0
Airports	6	0.3	0.3	0.1
Mineral extraction sites	7	0.3	0.3	0.05
Dump sites	8	0.05	0.05	0
Construction sites	9	0.1	0.1	0
Green urban areas	10	0.3	0.3	0.25
Sport and leisure facilities	11	0.3	0.3	0.05

Non-irrigated arable land	12	0.2	0.2	0.2
Permanently irrigated land	13	0.2	0.2	0.05
Rice fields	14	0.2	0.2	0.05
Vineyards	15	0.4	0.4	0.6
Fruit trees and berry plantations	16	0.4	0.4	0.9
Olive groves	17	0.4	0.4	0.2
Pastures	18	0.3	0.3	0.2
Annual crops associated with permanent crops	19	0.4	0.4	0.5
Complex cultivation patterns	20	0.4	0.4	0.4
Land principally occupied by agriculture, with significant areas of natural vegetation	21	0.7	0.7	0.75
Agro-forestry areas	22	1	1	0.5
Broad-leaved forest	23	0.8	0.8	0.9
Coniferous forest	24	0.8	0.8	0.3
Mixed forest	25	0.8	0.8	0.6
Natural grasslands	26	0.8	0.8	1
Moors and heathland	27	0.9	0.9	1
Sclerophyllous vegetation	28	0.9	0.9	0.75
Transitional woodland-shrub	29	1	1	0.85
Beaches, dunes, sands	30	0.3	0.3	0.1
Bare rocks	31	0	0	0
Sparsely vegetated areas	32	0.7	0.7	0.35
Burnt areas	33	0.3	0.3	0.2
Glaciers and perpetual snow	34	0	0	0
Inland marshes	35	0.3	0.3	0.75
Peat bogs	36	0.3	0.3	0.5
Salt marshes	37	0.3	0.3	0.55
Salines	38	0	0	0
Intertidal flats	39	0	0	0
Water courses	40	0	0	0
Water bodies	41	0	0	0
Coastal lagoons	42	0.2	0.2	0
Estuaries	43	0	0	0
Sea and ocean	44	0	0	0

Table 5 Bee species information

Information about the studies species, their ability of nesting in ground or cavities, their foraging activity period and their foraging range (Alpha)

Species	Nesting suitability cavity index	Nesting suitability ground index	Foraging activity spring index	Foraging activity summer index	Alpha
Bombus sp.	1	1	0.8	1	2000

Appendix D GLMM's

This appendix contains the process for the selection of the best-candidate model for the explanation of the total abundance in the PREDICTS sites, as well as the whole summary of estimates and the validation of the best-candidate model.

D.1 Candidates models

Table 6 Ranking of all candidate models

Ranking of the best candidates for the final model with the random structure of Study Site and Study Site Block. The best-ranked model with an AIC of 4913 was the most complicated one with interactions between LUI and all the variables and also the interaction of ACF and Connectivity, and 49 degrees of freedom (df)

Explanatory variables	df	AIC
LUI	9	5206.43
ACF	21	5119.83
Connectivity	21	5142.74
Simpson	21	5141.69
Only variables (no LUI)	18	5178.80
Without interactions	45	4983.87
With interactions (between LUI and variables)	49	4913.01

D.2 Best candidate estimates

Table 7 Full summary of the best candidate model

A complete summary of the best candidate model, it shows the estimates of each parameter that is included in the fixed effects for the explanation of the local-total abundance of bees. Each component is compared to the intercept (baseline) of Natural / Semi-natural Vegetation.

Response variable: Total abundance of bees	**Estimate**	**SE**	**df**	**t-value**	**p-value**	
(Intercept) Natural / Semi natural Vegetation	2.66	0.22	67.42	11.83	0.00	***
Cropland Intense use	0.55	0.16	1196.12	3.53	0.00	***
Cropland Light use	0.13	0.18	1337.35	0.75	0.45	
Cropland Minimal use	0.58	0.22	1487.76	2.57	0.01	*
Pasture	0.68	0.19	1523.39	3.60	0.00	***
Urban	0.88	1.08	1433.94	0.82	0.41	
poly(ACF, 2)1	-14.21	4.66	1654.13	-3.05	0.00	**
poly(ACF, 2)2	10.15	3.81	1682.84	2.67	0.01	**
poly(Connectivity, 2)1	3.51	6.20	1196.09	0.57	0.57	
poly(Connectivity, 2)2	-1.31	3.62	1489.05	-0.36	0.72	
poly(Simpson, 2)1	3.68	3.31	1696.38	1.11	0.27	
poly(Simpson, 2)2	0.05	2.86	1684.40	0.02	0.98	
Cropland Intense use:poly(ACF, 2)1	20.58	5.46	1653.53	3.77	0.00	***
Cropland Light use:poly(ACF, 2)1	25.94	6.75	1671.30	3.84	0.00	***
Cropland Minimal use:poly(ACF, 2)1	10.81	10.12	1688.42	1.07	0.29	
Pasture:poly(ACF, 2)1	-0.84	8.75	1594.65	-0.10	0.92	
Urban:poly(ACF, 2)1	-33.07	35.28	1413.62	-0.94	0.35	
Cropland Intense use:poly(ACF, 2)2	-6.94	4.73	1580.79	-1.47	0.14	
Cropland Light use:poly(ACF, 2)2	1.10	5.33	1593.64	0.21	0.84	
Cropland Minimal use:poly(ACF, 2)2	-5.76	8.10	1672.56	-0.71	0.48	
Pasture:poly(ACF, 2)2	-4.27	7.25	1584.27	-0.59	0.56	

Urban:poly(ACF, 2)2	-12.93	36.20	1507.44	-0.36	0.72	
Cropland Intense use:poly(Connectivity, 2)1	-0.35	6.42	1354.58	-0.05	0.96	
Cropland Light use:poly(Connectivity, 2)1	-11.20	7.01	1405.66	-1.60	0.11	
Cropland Minimal use:poly(Connectivity, 2)1	7.52	8.38	826.68	0.90	0.37	
Pasture:poly(Connectivity, 2)1	-9.47	6.94	1671.86	-1.36	0.17	
Urban:poly(Connectivity, 2)1	-0.36	19.61	1521.23	-0.02	0.99	
Cropland Intense use:poly(Connectivity, 2)2	1.98	4.84	1154.66	0.41	0.68	
Cropland Light use:poly(Connectivity, 2)2	-10.46	5.70	1252.32	-1.83	0.07	.
Cropland Minimal use:poly(Connectivity, 2)2	-5.31	11.11	700.57	-0.48	0.63	
Pasture:poly(Connectivity, 2)2	-10.11	4.05	1666.65	-2.50	0.01	*
Urban:poly(Connectivity, 2)2	5.37	9.33	1601.53	0.58	0.57	
Cropland Intense use:poly(Simpson, 2)1	-10.29	3.95	1683.61	-2.60	0.01	**
Cropland Light use:poly(Simpson, 2)1	-1.85	4.64	1688.10	-0.40	0.69	
Cropland Minimal use:poly(Simpson, 2)1	6.92	10.13	1659.04	0.68	0.49	
Pasture:poly(Simpson, 2)1	-5.41	6.42	1654.55	-0.84	0.40	
Urban:poly(Simpson, 2)1	12.19	61.72	1459.46	0.20	0.84	
Cropland Intense use:poly(Simpson, 2)2	4.05	3.37	1687.87	1.20	0.23	
Cropland Light use:poly(Simpson, 2)2	-9.46	3.87	1689.30	-2.45	0.01	**
Cropland Minimal use:poly(Simpson, 2)2	-6.92	8.46	1658.37	-0.82	0.41	
Pasture:poly(Simpson, 2)2	0.41	5.21	1535.88	0.08	0.94	
Urban:poly(Simpson, 2)2	12.53	47.29	1456.78	0.27	0.79	
poly(ACF, 2)1:poly(Connectivity, 2)1	-412.52	93.25	722.98	-4.42	0.00	***
poly(ACF, 2)2:poly(Connectivity, 2)1	51.06	77.79	1151.44	0.66	0.51	
poly(ACF, 2)1:poly(Connectivity, 2)2	-6.93	107.17	916.31	-0.06	0.95	
poly(ACF, 2)2:poly(Connectivity, 2)2	331.36	77.67	1336.52	4.27	0.00	***

D.3 Model validation

Section describing the validation of the best-ranked model. Diagnostic plots (Figure 5), Pearson correlation between the explanatory continuous variables (Table 7), and the variance inflation factor (Table 8), were used to validate the model.

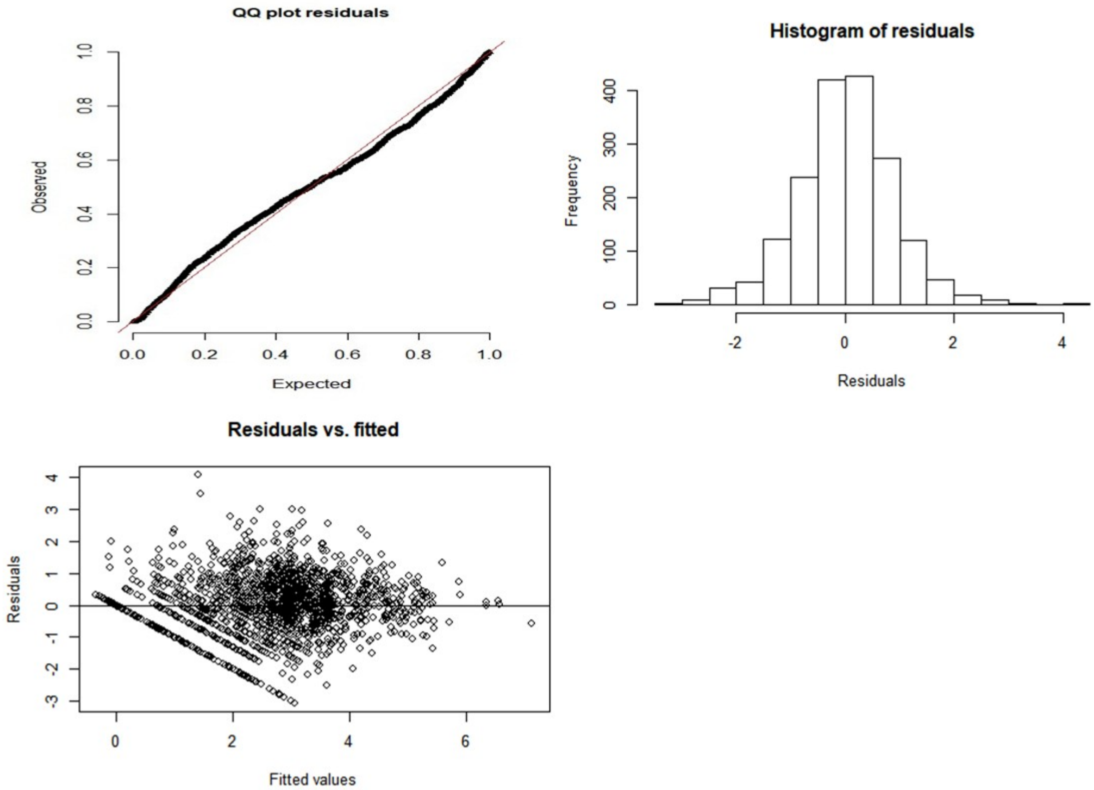

Figure 5 Diagnostic plots

Diagnostic plots for the best-ranked model. The Q-Q plot shows a small deviation from the theoretical normal line. The residuals show a normal distribution. And there is no clear pattern in the representation of the residuals vs fitted values. So this reveals that there is no violation of the assumptions of normality and homogeneity.

Table 8 Pearson correlation between explanatory continuous variables

Table showing the Pearson correlation between the continuous variables used to explain the total abundance of bees in the models. Typically, values above 0.7 are considered an indicator of collinearity between variables (Zuur et al. 2009).

Pearson correlation	ACF	Simpson	Connectivity
ACF	1.00	0.55	0.35
Simpson	0.55	1.00	0.10
Connectivity	0.35	0.10	1.00

Table 9 Variance inflation factors for each explanatory variable

Variance inflation factors (corvif function, Zuur et al. 2009) for the dataset used to model the effect of the landscape context on total abundance of bees. GVIF is the generalized variance inflation factor. Collinearity between the explanatory variables can cause an inflation of the SE, GVIF scaled by the degrees of freedom provides an indication of how much this is likely to happen, values above 3 indicates a medium degree of collinearity between variables.

Explanatory variable	GVIF	Df	$GVIF^{0.5Df}$
LUI	1.17	5	1.02
ACF	1.79	1	1.34
Simpson	1.49	1	1.22
Connectivity	1.20	1	1.10

Appendix E PREDICTS data sources

This is the list of references that provided data for the PREDICTS database and were used in this study as a source of information on biodiversity of bees.

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