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REVIEW

Effect of Agricultural Matrices on the Biodiversity Metrics of Bees (Hymenoptera: Anthophila): A Review

JOSÉ V. A. FERREIRA[1*], JULIANA M. DE ALMEIDA-ROCHA[2], JOSÉ C. MORANTE-FILHO[1], DANIELLE STORCK-TONON[3], MAÍRA BENCHIMOL[1]

1 - Applied Ecology and Conservation Lab, Universidade Estadual de Santa Cruz, Ilhéus-BA, Brazil
2 - The Nature Conservancy, São Paulo-SP, Brazil
3 - Programa de Pós-Graduação em Ambiente e Sistemas de Produção Agrícola (PPGASP), Universidade do Estado de Mato Grosso, Tangará da Serra-MT, Brazil

Supplementary Material

Table S1 - Summary of the 32 studies located and reviewed (including the 14 studies used in the meta-analysis).

Table S2 - Random effect meta-analysis results for the overall effect of the agricultural matrix and each moderator on bee diversity.

Fig S1 - Funnel graph for the general meta-analysis and for the different moderators

Table S1 - Summary of the 32 studies located and reviewed (including the 14 studies used in the meta-analysis), with the study number referring to the ones presented in Fig 2. WOS = Web of Science; DS = Data source; IM = Inclusion in the meta-analysis; Temp. = Temperate; Trop. = Tropical; Peren. = Perennial.

Study	Article Title	DS	IM	Matrix type	Region	Country	Flowering type	Life cycle	Matrix effect[1]	Key results
1	Keystone resources available to wild pollinators in a winter tree crop plantation	WOS	Yes	Almond	Temp.	Australia	Non mass	Peren.	Neutral	Inconclusive
2	Landscape structure shapes the diversity of beneficial insects in coffee producing landscapes	WOS	Yes	Coffee	Trop.	Brazil	Non mass	Peren.	Positive	Bee richness was positively correlated with the amount of native habitat at a landscape scale. But species abundance and richness was greater in the matrix
3	Are orchid bees useful indicators of the impacts of human disturbance?	WOS	Yes	Banana	Trop.	Peru	Non mass	Peren.	Negative	Orchid bees show a clear negative response to human disturbance along a tropical forest-agriculture gradient
4	Prickly pear crops as bee diversity reservoirs and the role of bees in Opuntia fruit production	WOS	Yes	Prickly pear	Trop.	Mexico	Non mass	Peren.	Neutral	There were no significant differences between habitats in any of the bee community parameters (richness, abundance, diversity and species composition)
5	Conservation Value and Permeability of Neotropical Oil Palm Landscapes for Orchid Bees	WOS	Yes	Oil palm	Trop.	Costa Rica	Non mass	Peren.	Negative	Species richness, abundance and community similarity to the forest declined in the agricultural matrix as distance from the forest increased
6	Contribution of the Cerrado as Habitat for Sunflower Pollinating Bees	WOS	Yes	Sunflower	Trop.	Brazil	Mass	Annual	Neutral / Positive	Species richness did not differ between the Cerrado and the sunflower plantation (but bee diversity decreased proportionally as distance from the edge increased) and abundance was greater in sunflower

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Study	Article Title	DS	IM	Matrix type	Region	Country	Flowering type	Life cycle	Matrix effect[1]	Key results
7	Diversity of cavity-nesting bees (Hymenoptera : Apoidea) within apple orchards and wild habitats in the Annapolis Valley, Nova Scotia, Canada	WOS	Yes	Apple	Temp.	Canada	Non mass	Peren.	Neutral	Species richness and numbers of bees in commercially managed orchards, abandoned orchards, and natural habitats were similar, and patterns of species composition were not exclusive to specific habitats
8	Does a coffee plantation host potential pollinators when it is not flowering? Bee distribution in an agricultural landscape with high biological diversity in the Brazilian Campo Rupestre	WOS	Yes	Coffee	Trop.	Brazil	Non mass	Peren.	Negative	There was no temporal difference in species richness or abundance. However, both varied in relation to the type of vegetation and were greater in the native-coffee transition area
9	Effects of habitat type change on taxonomic and functional composition of orchid bees (Apidae: Euglossini) in the Brazilian Amazon	WOS	Yes	Oil palm	Trop.	Brazil	Non mass	Peren.	Negative	Functional diversity has been reduced with land use change caused by palm oil plantations
10	Effects of Plant Diversity, Vegetation Composition, and Habitat Type on Different Functional Trait Groups of Wild Bees in Rural Beijing	WOS	Yes	Peach, Cherry and Apple	Temp.	China	Non mass	Peren.	Negative	Natural shrub areas supported the greatest bee diversity overall, in large bees, solitary bees, and below-ground nesting bees
11	Critical role of native forest and savannah habitats in retaining neotropical pollinator diversity in highly mechanized agricultural landscapes	WOS	Yes	Soybean	Trop.	Brazil	Mass	Annual	Negative	The richness of bee species was significantly lower in the soybean matrix compared to the interior of the forest and the species composition also differed significantly

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12	Landscape forest cover and regional context shape the conservation value of shaded cocoa agroforests for bees and social wasps	WOS	Yes	Cocoa	Trop.	Brazil	Non mass	Peren.	Positive	Species richness was similar between cocoa agroforestry and native forestry
13	*Provisional title*: Taxonomic diversity of orchid bees (Euglossini) in cocoa agroforests and Atlantic Forest remnants in southern Bahia, Brazil	Unpublished	Yes	Cocoa	Trop.	Brazil	Non mass	Peren.	Neutral	Abundance and richness did not differ between cocoa agroforestry and native forest
14	*Provisional title*: Bee diversity in soybean cultivation areas, as well as Cerrado remnants, in the state of Mato Grosso, Brazil	Unpublished	Yes	Soybean	Trop.	Brazil	Mass	Annual	Positive	The abundance and richness of species were significantly greater in the soybean matrix than in the Cerrado remnant
15	Bee (Hymenoptera, Apoidea) diversity and abundance on cranberry in southeastern Massachusetts	WOS	No	Cranberry	Temp.	USA	Non mass	Peren.	Negative	Non-apid bees were more abundant and diverse in abandoned and natural peatlands than in cultivated peatlands
16	Diversity and abundance of native bee pollinators on berry crops and natural vegetation in the lower fraser Valley, British-Columbia	WOS	No	Blueberry, Raspberry and Cranberry	Temp.	Canada	Non mass	Peren.	Negative	The abundance and diversity of native bees was greater in natural vegetation compared to fruit crops
17	Diversity patterns of wild bees in almond orchards and their surrounding landscape	WOS	No	Almond	Temp.	Israel	Non mass	Peren.	Negative	The natural habitats had a significantly higher abundance of wild bees compared to the orchard

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18	Diversity and abundance of bees (Hymenoptera: Apoidea) foraging on highbush blueberry (Vaccinium corymbosum L) in central New York	WOS	No	Highbush blueberry	Temp.	USA	Non mass	Peren.	Neutral	Species richness was high in both cultivated and uncultivated sites
19	Restored native prairie supports abundant and species-rich native bee communities on conventional farms	WOS	No	Mix: corn, berry, soybeans, squash and pumpkins	Temp.	Canada	Mix	Annual	Negative	The restored prairie supported twice as many species and three times as many bees compared to the other cover types
20	Contrasting responses of hoverflies and wild bees to habitat structure and land use change in a tropical landscape (southern Yunnan, SW China)	WOS	No	Rice	Trop.	China	Non massa	Annual	Negative	The richness of wild bees recorded was higher in natural forest sites compared to rice fields
21	The Role of the Agricultural Matrix: Coffee Management and Euglossine Bee (Hymenoptera: Apidae: Euglossini) Communities in Southern Mexico	WOS	No	Coffee	Trop.	Mexico	Non mass	Peren.	Negative	The composition of euglossini bees differed between forest and coffee monocultures and abundance was significantly higher in the native habitat
22	Alpha and beta diversity of plants and animals along a tropical land-use gradient	WOS	No	Cocoa	Trop.	Indonesia	Non mass	Peren.	Neutral / Positive	Species richness varied according to the cultivation system. In intensive systems, species richness was similar to forestry and in less intensive systems (cocoa-native tree association) species richness in the matrix was greater
23	Agricultural intensification with seasonal fallow land promotes high bee diversity in Afrotropical drylands	WOS	No	Mix: maize, beans, sunflower, wheat and barley	Trop.	Tanzania	Mix	Annual	Positive	Bee species richness increased with agricultural intensity and increasing temperature

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Study	Article Title	DS	IM	Matrix type	Region	Country	Flowering type	Life cycle	Matrix effect[1]	Key results
24	Bee assemblage in habitats associated with Brassica napus L.	WOS	No	Canola	Trop.	Brazil	Mass	Annual	Negative	Diversity indices (Shannon, Simpson and Pielou) were higher in pastures and forests than in canola crops
25	Do euglossine males (Apidae, Euglossini) leave tropical rainforest to collect fragrances in sugarcane monocultures?	WOS	No	Sugarcane	Trop.	Brazil	Non mass	Annual	Negative	Species richness in the agricultural matrix showed a drastic reduction, compared to the forest
26	Drivers of diversity and community structure of bees in an agroecological region of Zimbabwe	WOS	No	Mix: mainly cereals	Trop.	Zimbabwe	Non mass	Annual	Neutral	Bee diversity was high, both in fields and natural forests
27	Fragmentation and Management of Ethiopian Moist Evergreen Forest Drive Compositional Shifts of Insect Communities Visiting Wild Arabica Coffee Flowers	WOS	No	Coffee	Trop.	Ethiopia	Non mass	Peren.	Negative	The abundance of non-apis bees and the taxonomic richness of flower-visiting insects decreased significantly in coffee forests compared to natural forests
28	Land-use changes in a neotropical biodiversity hotspot and its effects on Euglossini bees	WOS	No	Soybean	Trop.	Brazil	Mass	Annual	Negative	Few species were recorded in anthropogenic land uses and most had lower abundances in cultivated areas than in native habitats
29	The effect of adjacent habitat on native bee assemblages in a perennial low-input agroecosystem in a semiarid anthropized landscape	WOS	No	Prickly pear	Trop.	Mexico	Non mass	Peren.	Neutral / Positive	Total taxon richness and guild taxon richness were not affected by habitat type, but total native bee abundance was significantly higher in areas of native habitat compared to orchards

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Study	Article Title	DS	IM	Matrix type	Region	Country	Flowering type	Life cycle	Matrix effect[1]	Key results
30	The Utility of Aerial Pan-Trapping for Assessing Insect Pollinators Across Vertical Strata	WOS	No	Mix: mainly oil palm	Trop.	Ghana	Non mass	Peren.	Positive	Bee species richness differed significantly between habitat types and agricultural sites were more diverse than undisturbed forest and regenerating forest
31	Relative contribution of agroforestry, rainforest and openland to local and regional bee diversity	WOS	No	Cocoa	Trop.	Indonesia	Non mass	Peren.	Positive	Local bee density and diversity were highest in open areas, followed by agroforestry systems and were lowest in primary forests
32	Supporting wild pollinators in a temperate agricultural landscape: Maintaining mosaics of natural features and production	WOS	No	Alfafa, Trigo and Canola	Temp.	Australia	Mix	Annual	Neutral	Inconclusive

[1] Refers to the matrix effect (positive, negative or neutral) according to the results observed in each study.

Table S2 - Random effect meta-analysis results for the overall effect of the agricultural matrix and each moderator on bee diversity. CI = Confidence Interval; I^2 = percentage of total heterogeneity observed between studies.

Group	Pairwise	Study	Estimate	CI lower	CI upper	P value	I^2
General effect (bootstrap)	38	14	-0.36	-0.55	-0.18	<0.001	78.73
Abundance	19	14	-0.43	-0.52	-0.34	<0.001	73.99
Richness	19	14	-0.30	-0.38	-0.21	<0.001	78.60
Tropical	28	11	-0.11	-0.26	0.04	0.15	76.67
Temperate	10	3	-1.26	-1.93	-0.59	<0.001	30.18
Annual	12	3	-0.02	-0.48	0.45	0.94	30.56
Perennial	26	11	-0.47	-0.68	-0.26	<0.001	82.26
Mass-flowering	12	3	-0.01	-0.48	0.46	0.96	30.31
Non mass-flowering	26	11	-0.47	-0.68	-0.26	<0.001	82.20

Fig S1 - Funnel graph for the general meta-analysis and for the different moderators: type of response (abundance or richness of bees), type of flowering (massive and no-mass flowering), life-cycle (annual or perennial), biogeographic region (tropical or temperate).