Supplementary material - Understanding the complexity: A meta-analysis of the impact of land use intensification on earthworms in global agroecosystems.

Contents

Supplement 1: List of references and locations where studies were conducted

Reference	Continent	Country	Location
Postma-Blaauw et al. (2012)	Europe	Netherlands	De Bovenbuurt
Ayuke et al. (2011)	East Africa	Kenya	Embu
Ayuke et al. (2011)			Kabete
Ayuke et al. (2011)			Impala
Ayuke et al. (2011)			Nyabeda
Ayuke et al. (2011)		Malawi	Chitala
Ayuke et al. (2011)	West Africa	Nigeria	Ibadan
Ayuke et al. (2011)		Ghana	Tamale
Ayuke et al. (2011)		Niger	Sadore
Ayuke et al. (2011)		Burkina Faso	Farakoba
Ayuke et al. (2011)			Saria
Talavera et al. (2020)	Europe	Portugal	Sao Miguel Island (Azores)
Kernecker et al. (2015)	North America	Canada	Southern Quebec
Dominguez et al. (2009)	South America	Argentina	Gral. Deheza basin, Cordoba
Tondoh et al. (2007)	Africa	Ivory Coast	Oume Region
Andriuzzi et al. (2017)	Europe	France	Lusignan
Rakotomanga et al. (2016)	Africa	Madagascar	Antsirabe
Smith et al. (2008)	North America	United States	SW Michigan
Feijoo et al. (2011)	South America	Colombia	Alcala Valle del Cauca
Ventiņš (2011)	Europe	Latvia	Dobele
Ventiņš (2011)			Priekuii
Zerbino (2012)	South America	Uruguay	Ciudad de Treinta y Tres
Dominguez & Bedano (2016)		Argentina	South of Cordoba province
Dominguez & Bedano (2016)			Buenos Aires Province and Chivilcoy
Juarez-Ramon & Fragoso (2014)	North America	Mexico	Plueba
Juarez-Ramon & Fragoso (2014)			Oaxaca

Reference	Continent	Country	Location
Decaens & Jimenez (2002)	South America	Colombia	Oriental Llanos
Bartz et al. (2014)		Brazil	The West
Bartz et al. (2014)			The Plateau
Yeates et al. (1998)	Oceania	New Zeland	Manawatu
Joshi et al. (2010)	Asia	India	Narayankoti
Boag et al. (1997)	Europe	Scottland	
Wong et al. (2016)	Asia	Malaysia	Jengka Triangle
Guei & Tondoh (2012)	Africa	Ivory coast	Centre-West Region
Kraft et al. (2020)	South America	Brazil	Chapeco
Felten & Emmerling (2011a)	Europe	Germany	Kenner Flur
Felten & Emmerling (2011a)			Halle
Felten & Emmerling (2011a)			Saxony-Anhalt
Rudisser et al. (2020)		Italy	South Tyrol
Tsiafouli et al. (2015)		Sweden	Scania
Tsiafouli et al. (2015)		United Kingdom	Region Chilterns
Tsiafouli et al. (2015)		Czech Republic	Ceske Budejovice
Tsiafouli et al. (2015)		Greece	Kria Brisi
Cluzeau et al. (2012)		France	Brittany
Grosso et al. (2006)	South America	Uruguay	Los Molles, Tacuarembo
Grosso et al. (2006)			Joanico, Canelones
Grosso et al. (2006)			Ciudad de Treinta y Tres
Grosso et al. (2006)			Treinta y Tres Orientales, Florida
Grosso et al. (2006)			Joanico, Canelones
Grosso et al. (2006)			Melilla, Montevideo
Grosso et al. (2006)			Treinta y Tres
Moreno et al. (2016)	Europe	Spain	Tierras de Granadilla district
Fragoso et al. (1997)	South America	Peru	Peruvian Amazonia

Reference	Continent	Country	Location
Fang et al. (1999)	Asia	China	Daqiao
Prendergast-Miller et al. (2021)	Europe	United Kingdom	North Yorkshire
Zou & Gonzalez (1997)	North America	Puerto Rico	Sabana
Lamande et al. (2003)	Europe	France	Western Brittany
Moreno et al. (2016)		Spain	Central Western Spain (Tierras de Granadilla district)
De Valença et al. (2017)	South America	Peru	Quilcas, near Huancayo in the Junin
Felten & Emmerling (2011a)	Europe	Germany	Trier, Rhineland-Palatinate
Haynes & Tregurtha (1999)	Oceania	New Zealand	Pukekohe
Haynes & Tregurtha (1999)			Winchmore Irrigation Research Station, Mid-Canterbury
Emmerling (1995)	Europe	Germany	Wadrill valley and the Blies valley
Franco et al. (2016)	South America	Brazil	Northern, the city of Jatai, Southwestern region of Goias state
Franco et al. (2016)			Central, the city of Valparaiso, West region of Sao Paulo state
Franco et al. (2016)			Southern, the city of Ipaussu, South region of Sao Paulo state
Guariento et al. (2020)	Europe	Italy	South Tyrol
Hendrix et al. (1992)	North America	United States	Georgia Piedmont

Reference	Continent	Country	Location
Mujeeb Rahman et al. (2012)	Asia	India	Nilgiri biosphere reserve of Western Ghats
Peres et al. (2010)	Europe	France	Brittany, Quimper site
Peres et al. (2010)			Brittany, The Rennes site
Kanianska et al. (2016)		Slovakia	Nacina Ves
Kanianska et al. (2016)			Voderady
Kanianska et al. (2016)			Dvorniky
Kanianska et al. (2016)			Moravsky Jan
Kanianska et al. (2016)			Kecovo
Kanianska et al. (2016)			Tajov
Kanianska et al. (2016)			Liptovska Teplicka
Suarez et al. (2021)	South America	Colombia	Western Colombian Amazon
Barros et al. (2003)		Brazil	Embrapa Amazonia Ocidental
Majeed et al. (2018)	Asia	Pakistan	the district Sargodha
Kamdem (2018)	Africa	Cameroon	Adamawa
Kamdem (2018)			North
Kamdem (2018)			Far-North
Vršič et al. (2021)	Europe	Slovenia	University Maribor
Owen & Galbraith (1989)	North America	United States	Central and Eastern Maine
Decaens et al. (2003)	Europe	France	Saint Martin de Boscherville, Upper Normandy
Polo Benito et al. (2008)		Portugal	Rolandia

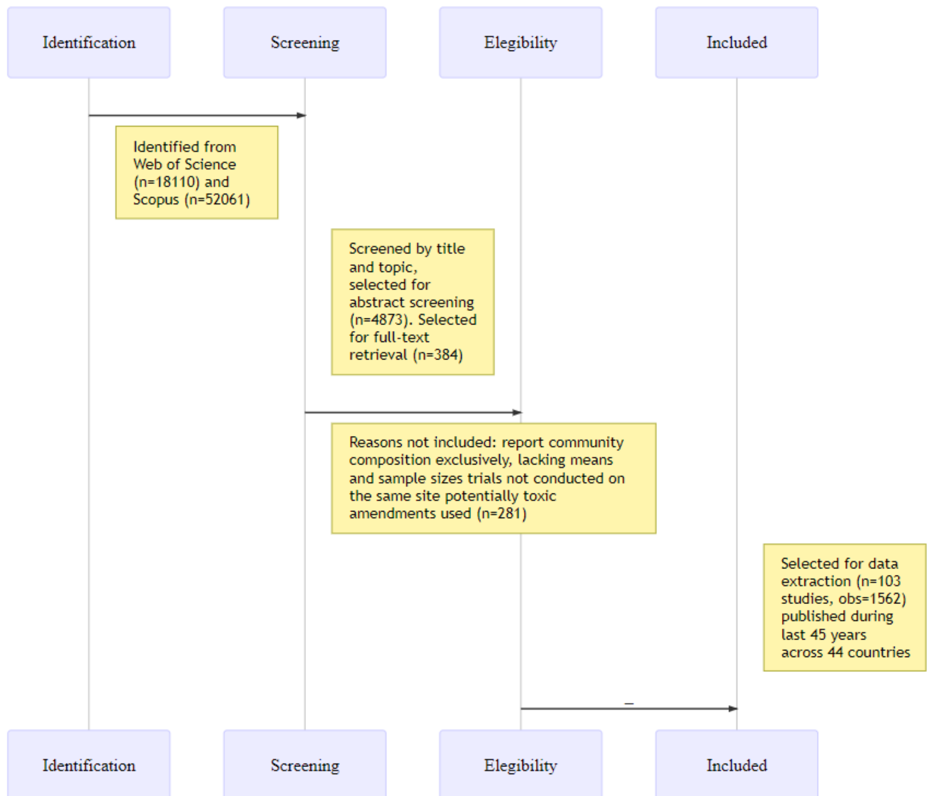
Reference	Continent	Country	Location
W. Demetrio et al. (2020)	South America	Brazil	Curitiba metropolitan area
Cameron et al. (2021)	North America	Canada	Southern Ontario and Southern Quebec
Cameron et al. (2021)	Europe	Czech Republic	South Bohemian region
Singh et al. (2020)	Asia	India	Village Neshta, Punjab
Singh et al. (2020)			Village Lopoke, Punjab
Singh et al. (2020)			Ajnala, Punjab
Singh et al. (2020)			Assam, northeast India
Guei & Tondoh (2012)	Africa	Ivory Coast	Centre-West Region
Albuquerque et al. (2009)	South America	Brazil	Pinheiro Machado
Haynes et al. (2003)	Africa	South Africa	Baynesfield Estate, the KwaZulu-Natal midlands
Haynes et al. (2003)			Cedara Agricultural College/Research Station, the KwaZulu-Natal midlands
Bedano et al. (2016a)	South America	Argentina	Monte Buey, Cordoba province
Fragoso et al. (1999)	Africa	Ivory Coast	Lamto
Fragoso et al. (1999)	Asia	India	Southern Karnataka
Fragoso et al. (1999)			Western Chats, Karnataka
Carnovale et al. (2015)	Australia	Australia	New South Wales

Reference	Continent	Country	Location
Nunes et al. (2006)	South America	Brazil	Region of Jaguapita, Parana State
Rajwar et al. (2022)	Asia	India	Kiccha
Rajwar et al. (2022)			Haldwani
Rajwar et al. (2022)			Ranibag
Rajwar et al. (2022)			Dogaon
Rajwar et al. (2022)			Jeolikot
Brown et al. (2003)	South America	Brazil	Parana
Dominguez et al. (2010a)		Argentina	General Deheza basin
Araujo & Lopez-Hernandez (1999)		Venezuela	Puerto Ayacucho
Bhadauria et al. (2012)	Asia	India	Camoli
W. C. Demetrio et al. (2018)	South America	Brazil	Lapa county (near Curitiba)
W. C. Demetrio et al. (2018)			Parana
Bedano et al. (2016b)		Argentina	Cordoba province
Tondoh et al. (2011)	Africa	Ivory Coast	Foret Classee de la Tene
Jordan et al. (2004)	North America	United States	Sanborn field, University of Missouri
Steinwandter et al. (2017)	Europe	Austria	Kaserstattalm
Felten & Emmerling (2011b)		Germany	Trier
Cornwell (2014)	Central America	Costa Rica	Pueblo Nuevo de villa Franca de Guacimo, in Limon Province
Geissen et al. (2009)		Mexico	Teapa
Fraser et al. (1994)	Oceania	New Zealand	Winchmore Irrigation Research Station in the mid-Canterbury region

Reference	Continent	Country	Location
Nanganoa et al. (2019)	Africa	Cameroon	Fako Division in the Southwest region of Cameroon
Decaens et al. (1994)	South America	Colombia	Carimagua “Altillanura Plana”
Oliveira (1993)		Brazil	Ilha do Careiro
Oliveira (1993)			Embrapa Agropecuaria Oeste, em Dourados, MS
Darmawan et al. (2017)	Asia	Indonesia	Bodogol
Darmawan et al. (2017)			Situ Gunung
Ge et al. (2021)		China	Yellow Sea, Jiangsu
Guariento et al. (2020)	Europe	Italy	South Tyrol
Hernandez et al. (2017)	Central America	Mexico	Paso del Puente de Santa Ana, Puebla
Gormsen et al. (2004)	Europe	Netherlands	
Gormsen et al. (2004)		Sweden	
Gormsen et al. (2004)		United Kingdom	
Gormsen et al. (2004)		Czech Republic	
Dominguez et al. (2010b)	South America	Argentina	General Dehez-abasin,Co´rdoba
Dominguez et al. (2010b)			Cordoba province, Argentina
Feijoo-Martinez et al. (2010)		Colombia	Alcala, Cartago, Circasia, Filandia y Quimbaya.
Silva et al. (2006)		Brazil	Embrapa Agropecuaria Oeste, municipio de Dourados-MS

Reference	Continent	Country	Location
Silva et al. (2006)			Vereda dos Anacletos, localizada no municipio de Esperantina
Rossi & Blanchart (2005)	Asia	India	Sagar Forest Range, Shimoga Division, Karnataka State
Postma-Blaauw et al. (2010)	Europe	Netherlands	De Bovenbuurt
Paoletti et al. (2009)		Italy	Vallevecchia
Ruiz-Cobo et al. (2010)	South America	Colombia	Parque Regional Natural Ucumari y el Santuario de Flora y Fauna Otun-Quimbaya
Høfer et al. (2001)		Brazil	Experimental areas of the Brazilian research institute Embrapa-Amazonia Ocidental
Ponge et al. (2013)	Europe	France	RMQS network
Gonzalez et al. (1996)	Central America	Puerto Rico	Luquillo Experimental Forest
Lavelle & Pashanasi (1989)	South America	Peru	Yurimaguas Experimental Station in the Peruvian Amazonia

Supplement S2. PRISMA flow diagram. *n* refers to the number of research articles and *obs* to the number of pairwise observations



Supplement S3: Meta-analysis diagnostics

Earthworm density

The analysis comprised k=691 pairwise comparisons in total. The response ratios that were observed varied between -18.8059 and 17.7513, with 50% of the estimations being negative. The true outcomes seem to be heterogeneous, based on the Q-test (Q(690)=1160172.8935, $p < 0.0001$, $\tau^2 = 6.9861$, $I^2 = 99.8519\%$). The true outcomes have a 95% prediction interval between -5.0212 and 5.3493. Therefore, even if the average result is predicted to be positive, the genuine result in certain experiments can actually be negative. Several pairwise comparisons (13 datapoints) have values bigger than ± 3.9684 and may represent possible outliers in the context of this model, according to an analysis of the studentized residuals. Several pairwise comparisons (19 datapoints) may be deemed unduly influential based on the Cook's distances. The regression test ($p = 0.6586$) did not reveal funnel plot asymmetry, while the rank correlation test did ($p < 0.0001$).

Earthworm biomass

The analysis comprised k=283 pairwise comparisons in total. The observed response ratios ranged from -14.0079 to 16.0344, and 52% of the estimations were positive. The true outcomes seem to be heterogeneous, based on the Q-test (Q(282)=606565.6053, p<0.0001, $\tau^2 = 9.8804$, $I^2 = 99.7835\%$). The true outcomes have a 95% prediction interval between -5.7368 and 6.6200. Therefore, even if the average result is predicted to be positive, the true outcomes in certain experiments can actually be negative. Seven observations with values greater than ± 3.7502 were found in the studentized residuals, which suggested that they would be possible outliers for this model. Fifteen observations might be deemed excessively important based on the Cook's distances. The rank correlation test indicated funnel plot asymmetry ($p < 0.0001$) but not the regression test ($p = 0.6510$).

Earthworm diversity

The analysis comprised k=468 pairwise comparisons in total. The response ratios that were observed varied from -3.3322 to 14.5087, with 52% of the estimations being negative. Based on the random-effects model, the estimated average response ratio was -0.1408 (95% CI: -0.2195 to -0.0621). As a result, the average outcome (z=-3.5075, p=0.0005) was substantially different from zero. The true outcomes seem to be heterogeneous based on the Q-test (Q(467)=83299.6178, p<0.0001, $\tau^2 = 0.3788$, $I^2 = 99.6910\%$), and have a 95% prediction interval between -1.3497 and 1.0680. Therefore, even though the average result is predicted to be negative, the true outcomes may actually be positive in some instances. Upon analyzing the studentized residuals, it was found that all the observations had values less than or equal to ± 3.7714. Therefore, there was no evidence of outliers within the framework of this model. Seven observations may be deemed unduly important based on Cook's distances. The regression test ($p = 0.6779$) did not reveal funnel plot asymmetry, but the rank correlation test did ($p < 0.0001$).

Supplement S4. Sensitivity analyses

Within-study correlations

Sensitivity analysis of the assumed constant correlations between effect size estimates from each study (Density: n = 990 observations; Biomass: n = 312 observations). The log response ratio are the aggregated estimates of the correlated and hierarchical effects model, using the different correlation (r) values used for the imputation of a block-diagonal covariance matrix using the R package clubSandwich (Pustejovsky & Tipton, 2022). The log response ratio is the pooled estimate of 20 imputed datasets. The Aikaike information criteria (AIC) was used for the selection of the correlation value. For diversity outcomes, we used only the diagonal elements from 'vi' argument as the sampling variances, hence, no correlation was assumed for this outcome.

Outcome	Assumed correlation	Log response ratio	Standard error	$p-value$
Density	r = 0.1	0.256	0.269	0.341
Density	r = 0.3	0.318	0.282	0.260
Density	r = 0.5	0.403	0.296	0.174
Density	r = 0.7	0.513	0.296	0.083
Density	r = 0.9	0.734	0.320	0.022
Biomass	r = 0.1	0.379	0.342	0.268
Biomass	r = 0.3	0.416	0.354	0.241
Biomass	r = 0.5	0.468	0.357	0.191
Biomass	r = 0.7	0.558	0.357	0.119
Biomass	r = 0.9	0.816	0.355	0.022

Random-effects hierarchical structure

Sensitivity analysis of the assumed hierarchical correlated structure of the random effects of the model (Density: n = 990 observations; Biomass: n = 312 observations). Constant correlation assumed: r = 0.1. The log response ratio are the aggregated estimates of the correlated and hierarchical effects model, using the different the different hierarchical structures for the random effects, with the R package clubSandwich (Pustejovsky & Tipton, 2022). For diversity outcomes, we used only the diagonal elements from 'vi' argument as the sampling variances, hence, no hierarchical structure was assumed for this outcome. The Aikaike information criteria (AIC) was used for the selection of the hierarchical structure for the model.

Outcome	Random effects structure	Log response ratio	Standard error
Density	Observation within study	0.063	0.239

Outcome	Random effects structure	Log response ratio	Standard error
Density	Study level	0.256	0.951
Density	Observation level	2.041	0.617
Biomass	Observation within study	0.289	0.350
Biomass	Study level	0.379	0.342
Biomass	Observation level	3.431	1.655

Multivariate imputation

Sensitivity of the missing-at-random assumption

Sensitivity analysis to the missing-at-random assumption of the earthworm density data using multiple imputation with delta adjustment (Leacy et al., 2017).

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 iter imp variable
  1   1  dat.vi
  1   2  dat.vi
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Imputation	δ	Log response ratio	Standard error	Conf. Int. (lower)	Conf. Int. (upper)	τ^2
1	0	0.016	0.145	-0.269	0.301	14.622
	2	-0.016	0.151	-0.311	0.279	15.106
	5	-0.013	0.148	-0.302	0.277	14.847
	10	0.013	0.146	-0.272	0.299	14.626
	50	-0.006	0.146	-0.292	0.279	14.601
	100	0.026	0.142	-0.253	0.306	13.107
2	0	-0.003	0.147	-0.291	0.286	13.554
	2	0.000	0.145	-0.283	0.284	13.315
	5	0.024	0.143	-0.255	0.304	13.111
	10	0.006	0.143	-0.274	0.286	13.094
	50	0.043	0.139	-0.230	0.315	11.367
	100	0.017	0.143	-0.264	0.298	11.743
3	0	0.020	0.141	-0.257	0.296	11.542
	2	0.041	0.139	-0.232	0.314	11.373
	5	0.025	0.140	-0.249	0.298	11.367
	10	0.066	0.138	-0.204	0.335	9.814
	50	0.046	0.141	-0.230	0.321	10.075
	100	0.048	0.139	-0.225	0.320	9.935
4	0	0.064	0.138	-0.206	0.334	9.820
	2	0.052	0.138	-0.218	0.322	9.827
	5	0.124	0.149	-0.168	0.417	8.959
	10	0.117	0.150	-0.178	0.412	9.034
	50	0.118	0.150	-0.176	0.411	8.994
	100	0.123	0.149	-0.169	0.416	8.962
5	0	0.119	0.149	-0.174	0.412	8.972
	2	0.140	0.156	-0.166	0.445	9.220
	5	0.136	0.157	-0.171	0.443	9.264
	10	0.136	0.156	-0.170	0.442	9.241
	50	0.139	0.156	-0.166	0.445	9.222
	100	0.137	0.156	-0.169	0.443	9.229

Sensitivity analysis to the missing-at-random assumption of the earthworm biomass data using multiple imputation with delta adjustment (Leacy et al., 2017).

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 iter imp variable
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Imputation	δ	Log response ratio	Standard error	Conf. Int. (lower)	Conf. Int. (upper)	τ^2
1	0	0.296	0.211	-0.117	0.709	12.758
	2	0.330	0.211	-0.084	0.744	12.860
	5	0.319	0.211	-0.095	0.733	12.880
	10	0.318	0.211	-0.096	0.732	12.877
	50	0.312	0.211	-0.102	0.726	12.879
	100	0.316	0.210	-0.096	0.729	11.800
2	0	0.346	0.211	-0.067	0.759	11.876
	2	0.336	0.211	-0.077	0.749	11.892
	5	0.335	0.211	-0.078	0.748	11.890
	10	0.330	0.211	-0.083	0.743	11.891
	50	0.345	0.212	-0.070	0.760	10.887
	100	0.368	0.212	-0.048	0.783	10.931
3	0	0.360	0.212	-0.056	0.776	10.942
	2	0.360	0.212	-0.056	0.776	10.941
	5	0.355	0.212	-0.060	0.771	10.941
	10	0.381	0.218	-0.045	0.808	10.251
	50	0.397	0.218	-0.030	0.823	10.268
	100	0.391	0.218	-0.035	0.818	10.274
4	0	0.391	0.218	-0.035	0.818	10.273
	2	0.388	0.218	-0.038	0.815	10.272
	5	0.474	0.250	-0.016	0.963	10.516
	10	0.476	0.250	-0.014	0.966	10.516
	50	0.475	0.250	-0.014	0.965	10.517
	100	0.475	0.250	-0.014	0.965	10.517
5	0	0.475	0.250	-0.015	0.964	10.516
	2	0.501	0.264	-0.017	1.018	10.990
	5	0.501	0.264	-0.016	1.019	10.990
	10	0.501	0.264	-0.016	1.019	10.990
	50	0.501	0.264	-0.016	1.019	10.990
	100	0.501	0.264	-0.017	1.018	10.989

Sensitivity analysis to the missing-at-random assumption of the earthworm diversity data using multiple imputation with delta adjustment (Leacy et al., 2017).

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 iter imp variable
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Imputation	δ	Log response ratio	Standard error	Conf. Int. (lower)	Conf. Int. (upper)	τ^2
1	0	-0.114	0.058	-0.228	-0.001	1.333
	2	-0.090	0.043	-0.174	-0.007	0.633
	5	-0.224	0.032	-0.288	-0.161	0.384
	10	-0.106	0.051	-0.206	-0.007	1.116
	50	-0.248	0.033	-0.312	-0.184	0.404
	100	-0.165	0.033	-0.230	-0.100	0.168
2	0	-0.161	0.033	-0.225	-0.098	0.159
	2	-0.177	0.032	-0.239	-0.114	0.153
	5	-0.165	0.032	-0.229	-0.102	0.162
	10	-0.180	0.032	-0.243	-0.118	0.153
	50	-0.172	0.034	-0.238	-0.106	0.160
	100	-0.170	0.034	-0.236	-0.104	0.159
3	0	-0.175	0.033	-0.240	-0.109	0.158
	2	-0.172	0.033	-0.238	-0.107	0.159
	5	-0.176	0.033	-0.241	-0.110	0.158
	10	-0.174	0.034	-0.241	-0.107	0.161
	50	-0.174	0.034	-0.241	-0.107	0.161
	100	-0.175	0.034	-0.242	-0.108	0.161
4	0	-0.174	0.034	-0.241	-0.108	0.161
	2	-0.175	0.034	-0.242	-0.109	0.161
	5	-0.176	0.035	-0.245	-0.108	0.165
	10	-0.176	0.035	-0.245	-0.108	0.165
	50	-0.176	0.035	-0.245	-0.108	0.165
	100	-0.176	0.035	-0.245	-0.108	0.165
5	0	-0.177	0.035	-0.245	-0.108	0.165
	2	-0.177	0.035	-0.245	-0.108	0.165
	5	-0.177	0.035	-0.245	-0.108	0.165
	10	-0.177	0.035	-0.246	-0.108	0.165
	50	-0.177	0.035	-0.245	-0.108	0.165
	100	-0.177	0.035	-0.246	-0.108	0.165

Sensitivity of the imputation method

Sensitivity analysis of the multivariate imputation by chained equations used to estimate missing standard deviations for control and treatment observations (Van Buuren & Groothuis-Oudshoorn, 2011). Assumptions: Constant correlation r = 0.1; Hierarchical correlated structure of random effects. m corresponds to the number of imputed datasets over which a pooled estimate of the effect size (log response ratio) will be obtained.

Outcome	Imputation method	m	Log response ratio	Standard error
Density	Without imputation	Not applicable	0.201	0.405
Density	**Predictive mean matching**	**20**	**0.267**	**0.281**
Density	Predictive mean matching	50	0.279	0.287
Density	Predictive mean matching	100	0.263	0.276
Density	Classification and regression trees	20	0.221	0.266
Density	Classification and regression trees	50	0.224	0.277
Density	Classification and regression trees	100	0.224	0.276
Biomass	Without imputation	Not applicable	0.224	0.439
Biomass	**Predictive mean matching**	**20**	**0.388**	**0.351**
Biomass	Predictive mean matching	50	0.345	0.358
Biomass	Predictive mean matching	100	0.357	0.355
Biomass	Classification and regression trees	20	0.449	0.312
Biomass	Classification and regression trees	50	0.497	0.372
Biomass	Classification and regression trees	100	0.505	0.371
Diversity	Without imputation	Not applicable	-0.175	0.122
Diversity	**Predictive mean matching**	**20**	**-0.165**	**0.043**
Diversity	Predictive mean matching	50	-0.164	0.049

Outcome	Imputation method	m	Log response ratio	Standard error
Diversity	Predictive mean matching	100	-0.183	0.151
Diversity	Classification and regression trees	20	-0.168	0.043
Diversity	Classification and regression trees	50	-0.172	0.043
Diversity	Classification and regression trees	100	-0.170	0.042

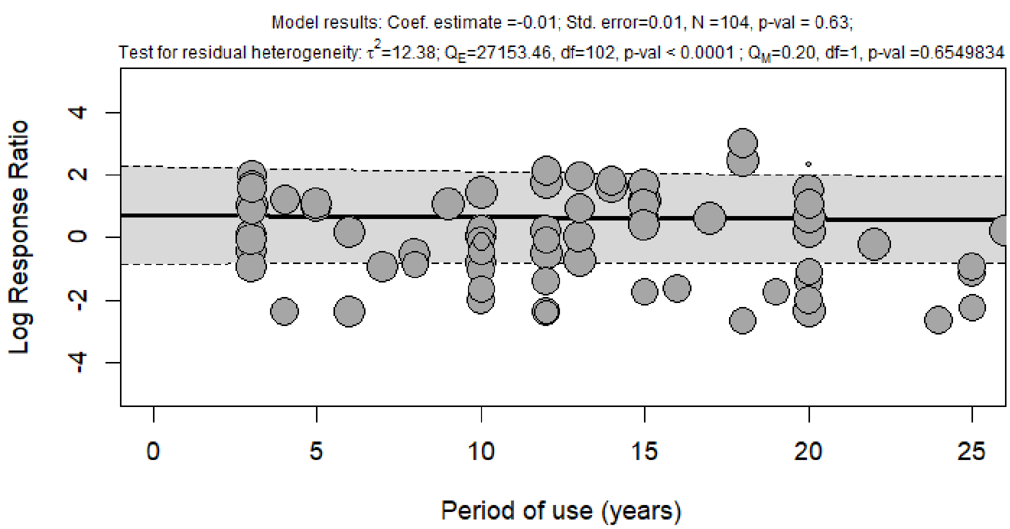
Note: The imputation method selected for meta-analyses is highlighted in bold.

Supplement S5. Additional meta-analyses on management, soil and climatic related factors that can affect earthworm response to intensification

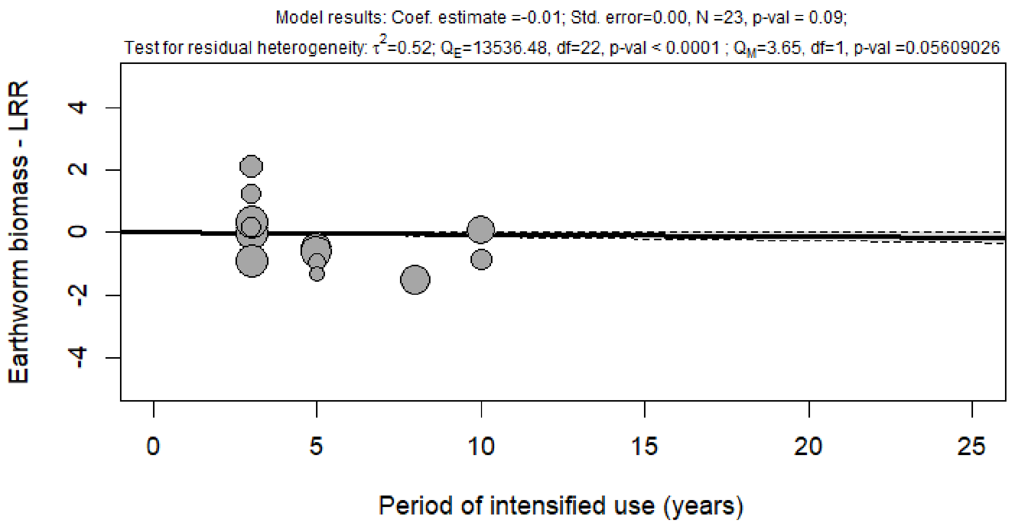
Period of use

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness in relation to the soil period of intensified use documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.

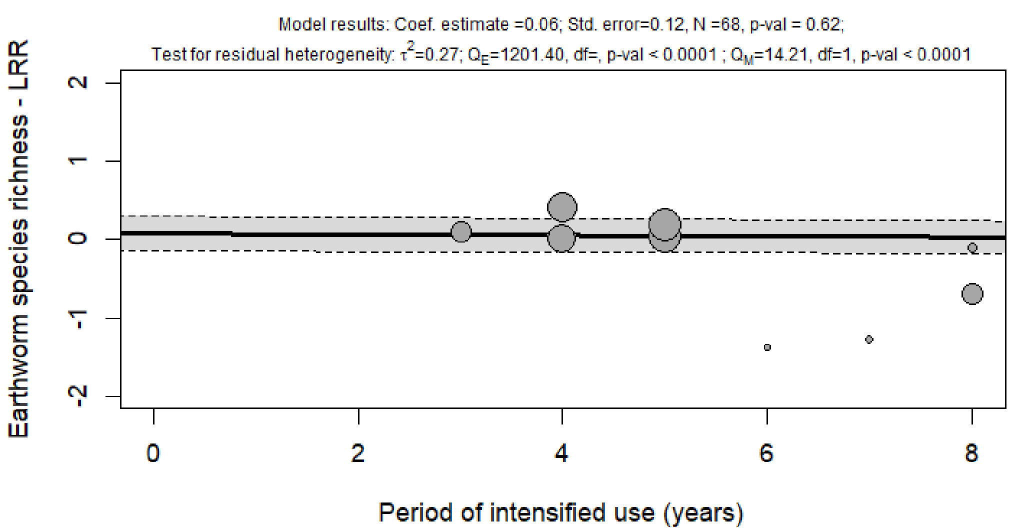
a)



b)


Model results: Coef. estimate =-0.01; Std. error=0.00, N =23, p-val = 0.09;
Test for residual heterogeneity: τ^2=0.52; Q_E=13536.48, df=22, p-val < 0.0001 ; Q_M=3.65, df=1, p-val =0.05609026
Earthworm biomass - LRR
4
2
0
-2
-4
0
5
10
15
20
25
Period of intensified use (years)

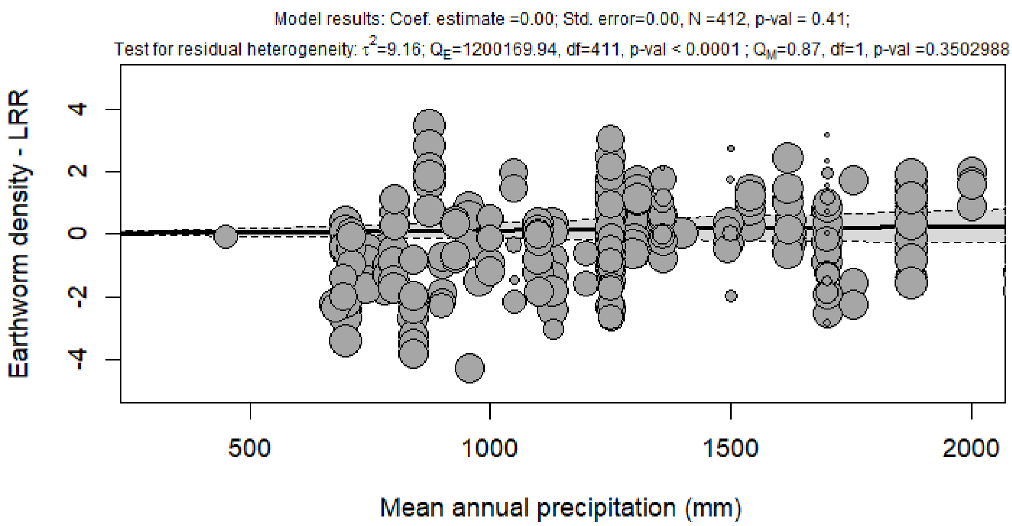
c)


Model results: Coef. estimate =0.06; Std. error=0.12, N =68, p-val = 0.62;
Test for residual heterogeneity: τ^2=0.27; Q_E=1201.40, df=, p-val < 0.0001 ; Q_M=14.21, df=1, p-val < 0.0001
Earthworm species richness - LRR
2
1
0
-1
-2
0
2
4
6
8
Period of intensified use (years)

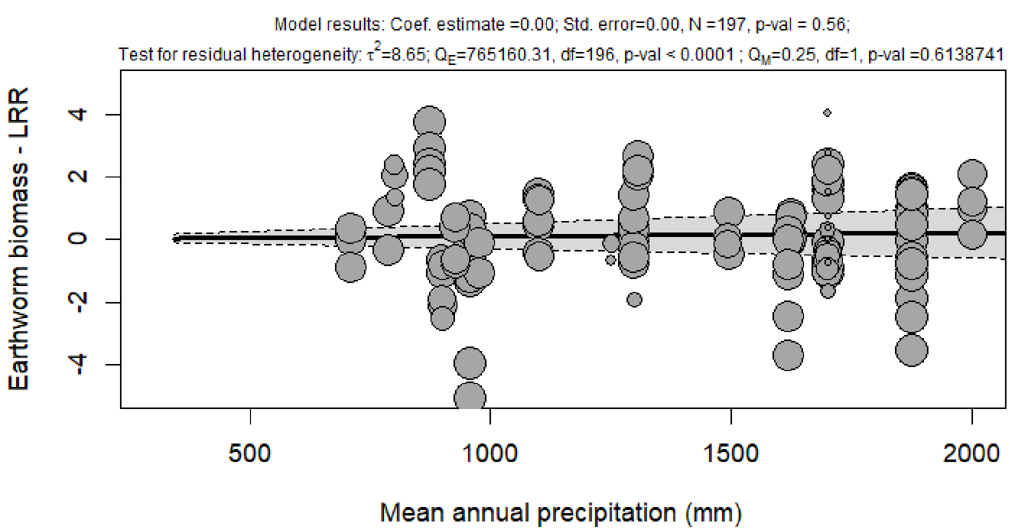
Mean annual precipitation

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness in relation to the mean annual precipitation documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.

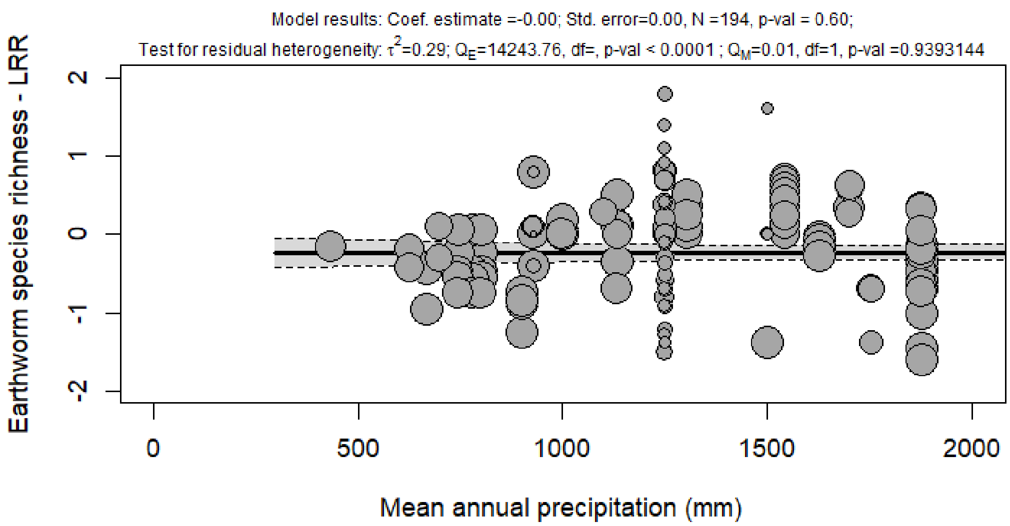
a)



b)



c)

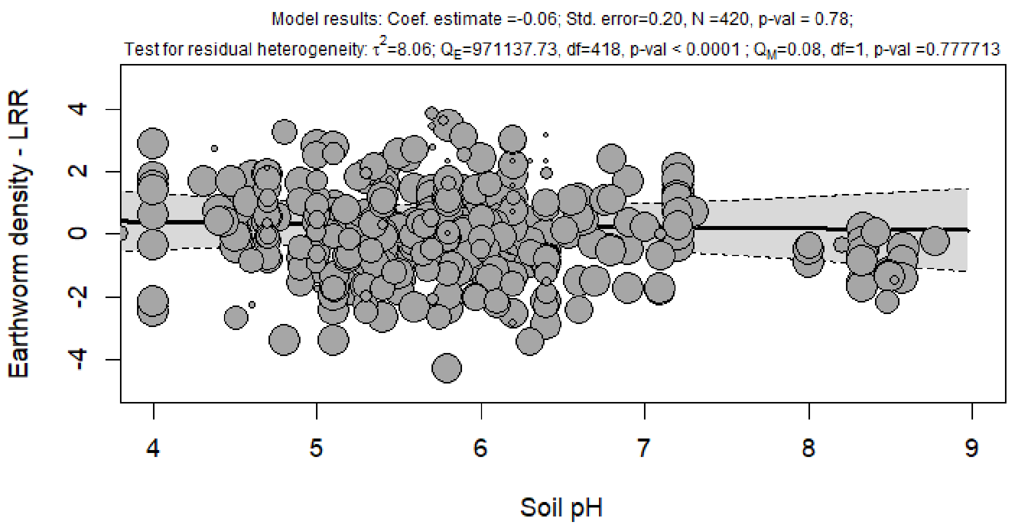


Model results: Coef. estimate =-0.00; Std. error=0.00, N =194, p-val = 0.60;
Test for residual heterogeneity: τ²=0.29; Q_E=14243.76, df=, p-val < 0.0001 ; Q_M=0.01, df=1, p-val =0.9393144
Earthworm species richness - LRR
2
1
0
-1
-2
0
500
1000
1500
2000
Mean annual precipitation (mm)

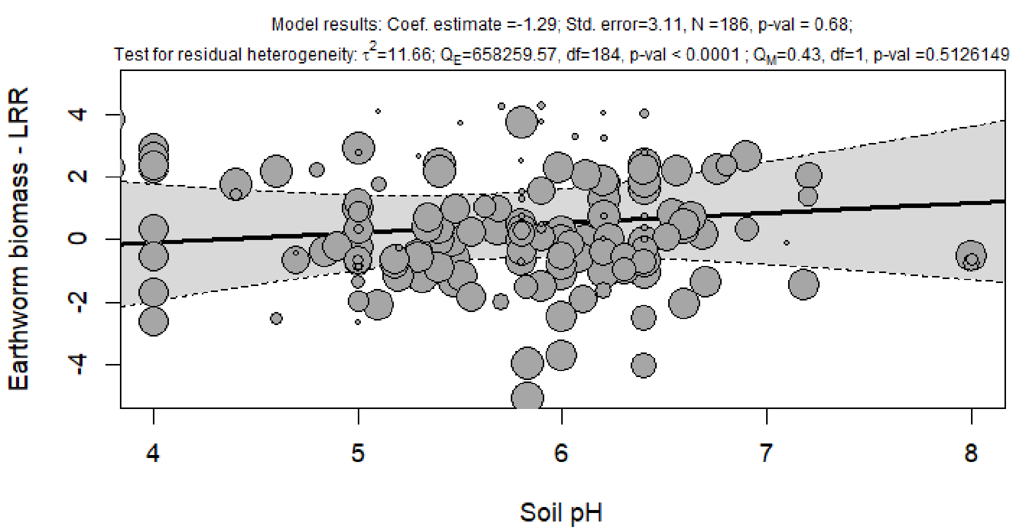
Soil pH

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness in relation to the soil pH documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.

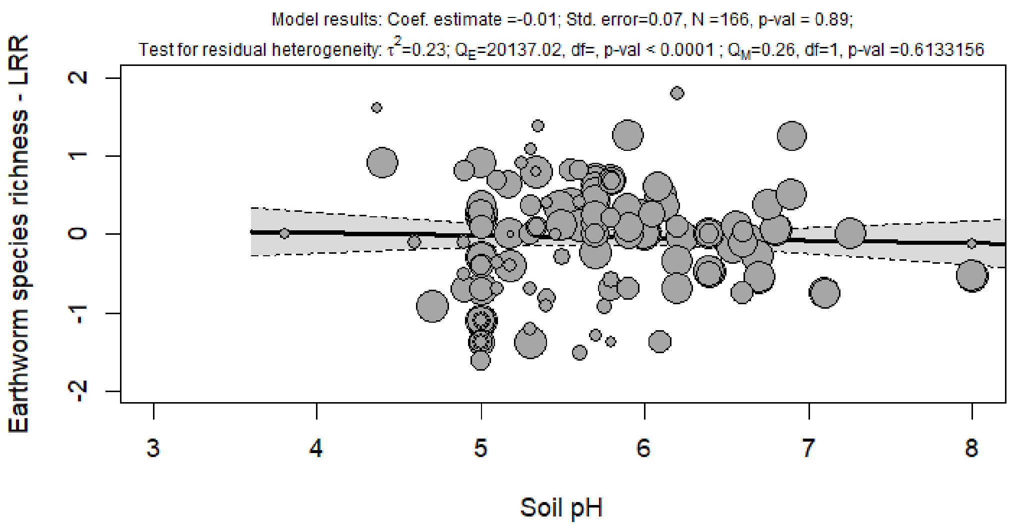
a)



b)



c)

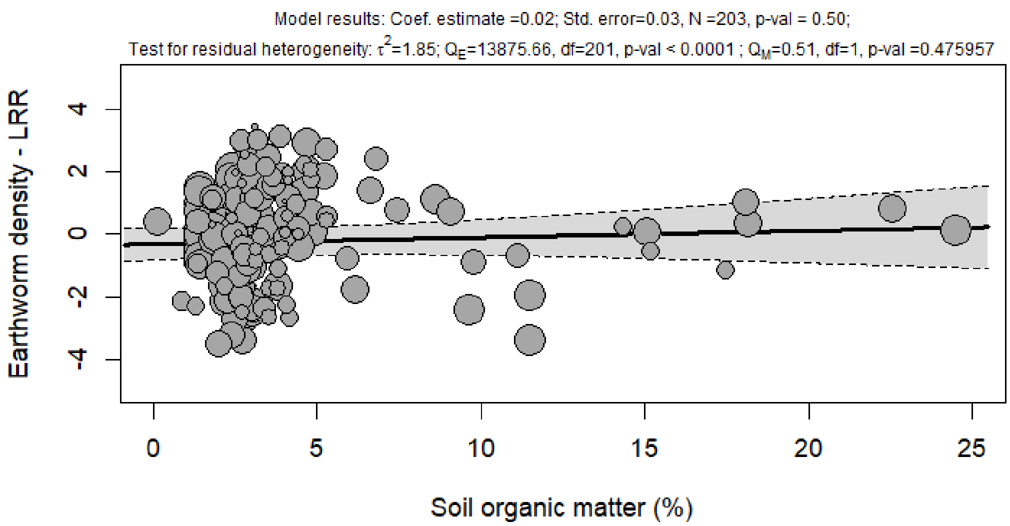


Model results: Coef. estimate =-0.01; Std. error=0.07, N =166, p-val = 0.89;
Test for residual heterogeneity: τ2=0.23; QE=20137.02, df=, p-val < 0.0001 ; QM=0.26, df=1, p-val =0.6133156
Earthworm species richness - LRR
2
1
0
-1
-2
3
4
5
6
7
8
Soil pH

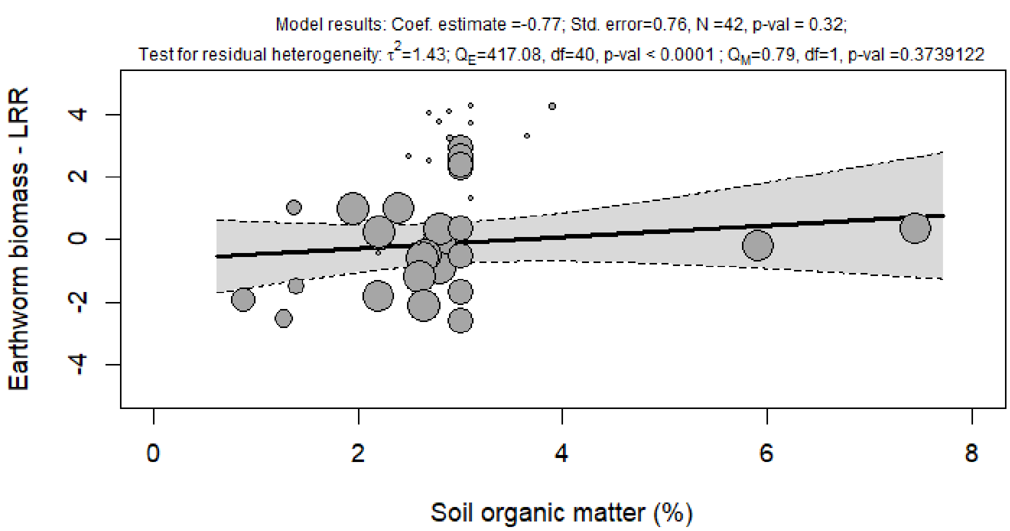
Soil organic matter

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness in relation to the soil organic matter documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.

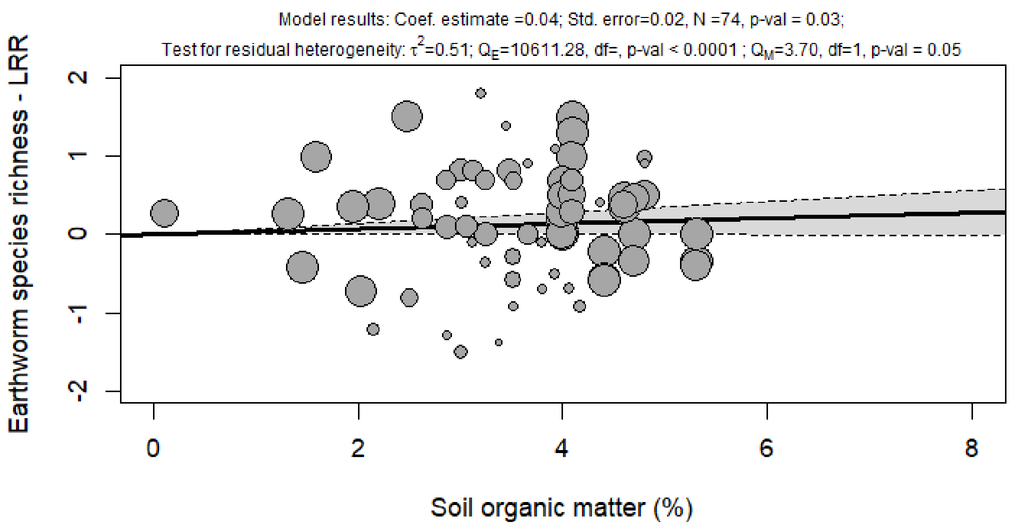
a)



b)



c)

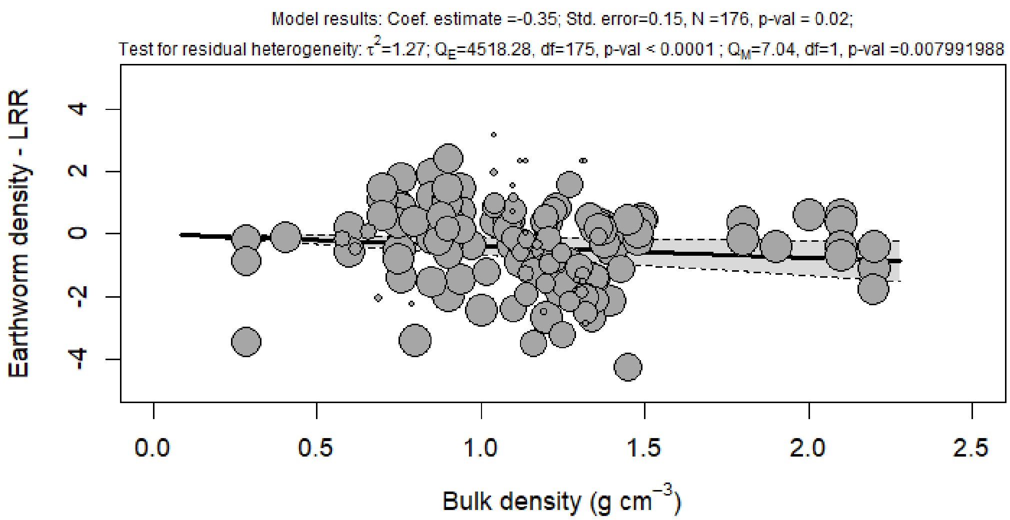


Model results: Coef. estimate =0.04; Std. error=0.02, N =74, p-val = 0.03;
Test for residual heterogeneity: τ^2=0.51; Q_E=10611.28, df=, p-val < 0.0001 ; Q_M=3.70, df=1, p-val = 0.05
Earthworm species richness - LRR
2
1
0
-1
-2
0
2
4
6
8
Soil organic matter (%)

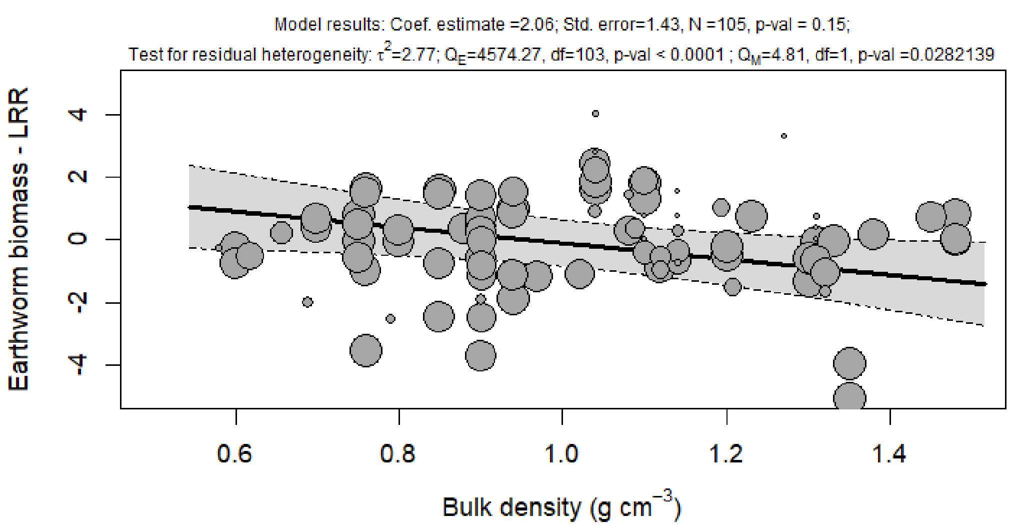
Soil bulk density

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness in relation to the soil bulk density documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.

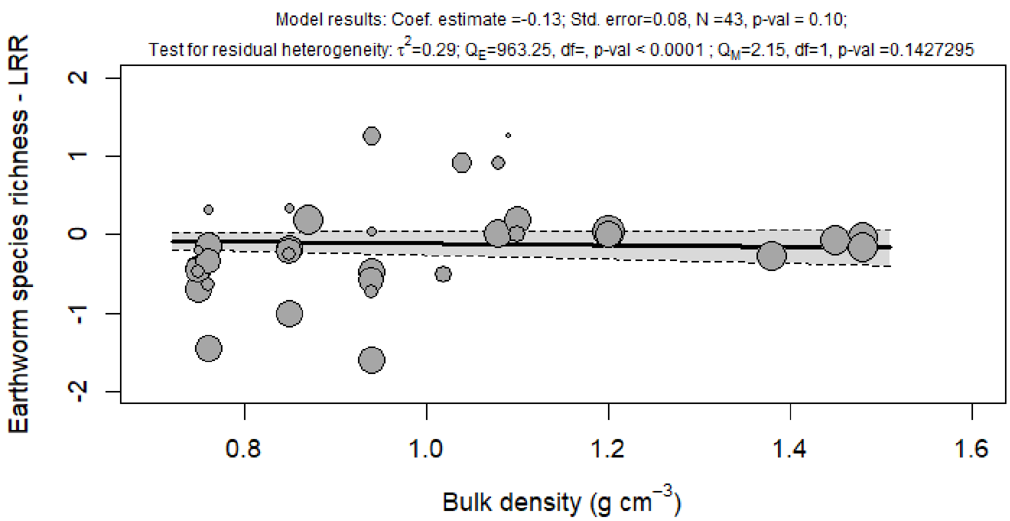
a)



b)



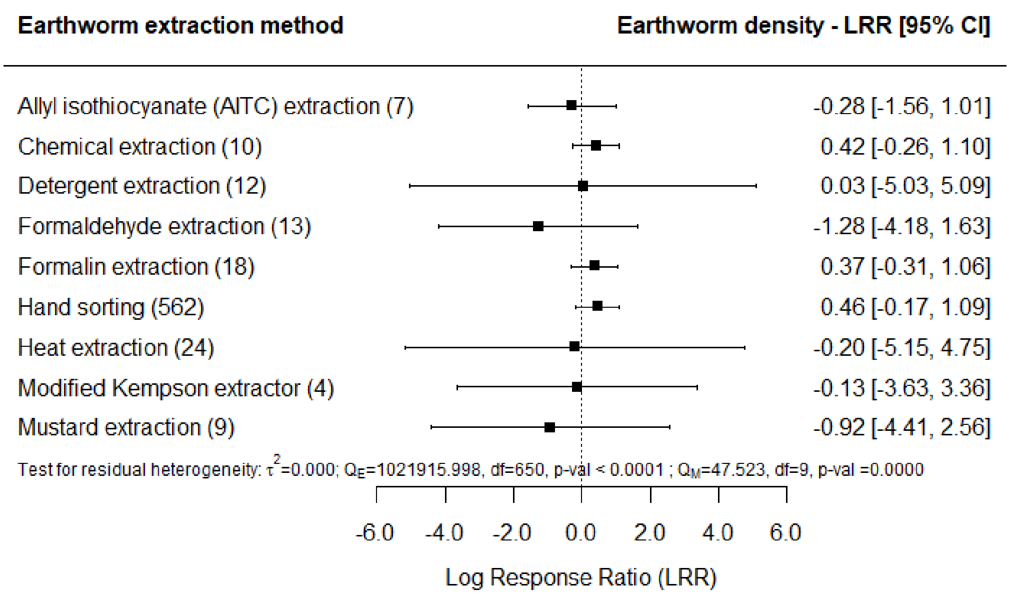
c)


Model results: Coef. estimate =-0.13; Std. error=0.08, N =43, p-val = 0.10;
Test for residual heterogeneity: τ^2=0.29; Q_E=963.25, df=, p-val < 0.0001 ; Q_M=2.15, df=1, p-val =0.1427295
Earthworm species richness - LRR
2
1
0
-1
-2
0.8
1.0
1.2
1.4
1.6
Bulk density (g cm^{-3})

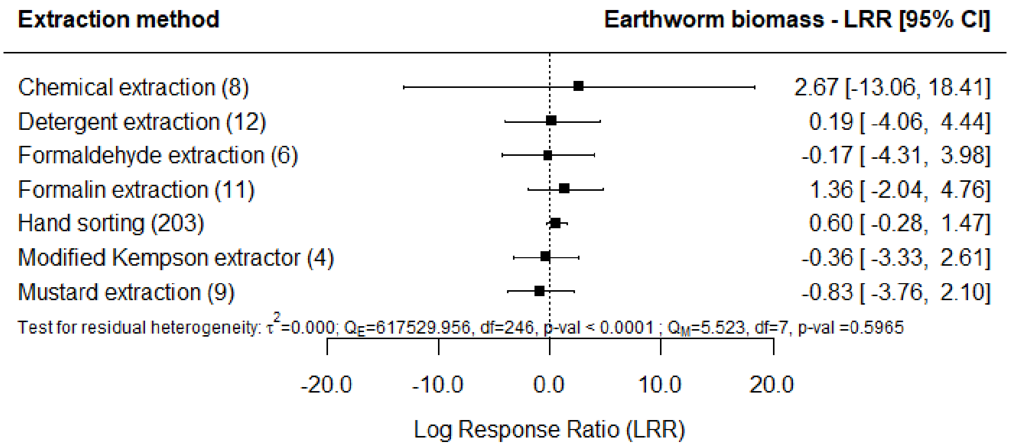
Earthworm extraction method

Effect of intensified land use on earthworm a) density, b) biomass and c) species richness, for the various earthworm extraction methods documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.

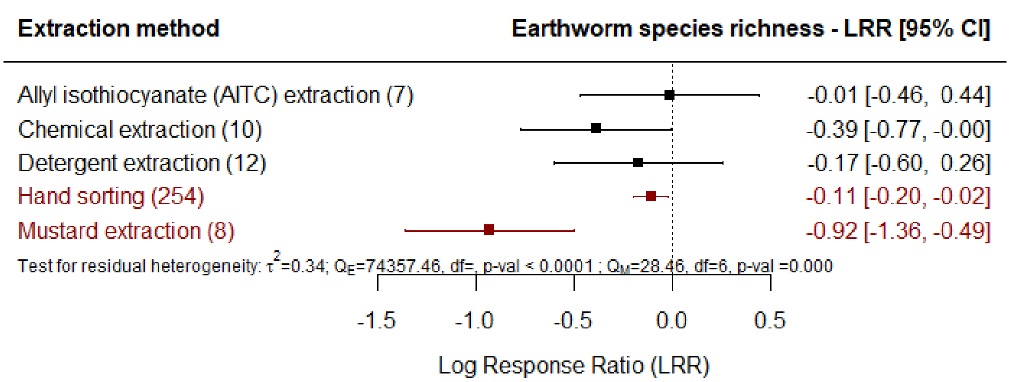
a)



b)


Extraction method
Earthworm biomass - LRR [95% CI]
Chemical extraction (8)
Detergent extraction (12)
Formaldehyde extraction (6)
Formalin extraction (11)
Hand sorting (203)
Modified Kempson extractor (4)
Mustard extraction (9)
2.67 [-13.06, 18.41]
0.19 [-4.06, 4.44]
-0.17 [-4.31, 3.98]
1.36 [-2.04, 4.76]
0.60 [-0.28, 1.47]
-0.36 [-3.33, 2.61]
-0.83 [-3.76, 2.10]
Test for residual heterogeneity: τ²=0.000; Q_E=617529.956, df=246, p-val < 0.0001 ; Q_M=5.523, df=7, p-val =0.5965
-20.0
-10.0
0.0
10.0
20.0
Log Response Ratio (LRR)

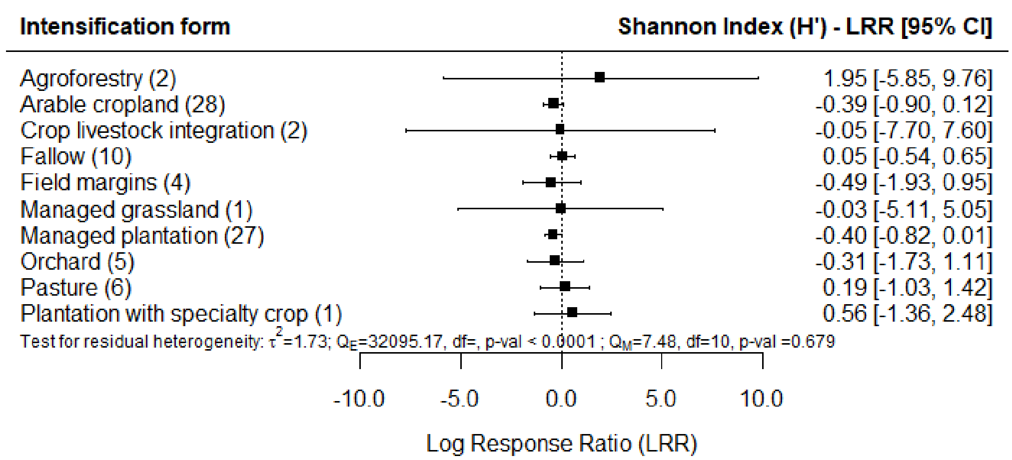
c)


Extraction method
Earthworm species richness - LRR [95% CI]
Allyl isothiocyanate (AITC) extraction (7)
Chemical extraction (10)
Detergent extraction (12)
Hand sorting (254)
Mustard extraction (8)
-0.01 [-0.46, 0.44]
-0.39 [-0.77, -0.00]
-0.17 [-0.60, 0.26]
-0.11 [-0.20, -0.02]
-0.92 [-1.36, -0.49]
Test for residual heterogeneity: τ²=0.34; Q_E=74357.46, df=, p-val < 0.0001 ; Q_M=28.46, df=6, p-val =0.000
-1.5
-1.0
-0.5
0.0
0.5
Log Response Ratio (LRR)

Supplement S6. Intensification effects on earthworm diversity reported as Shannon Index (H')

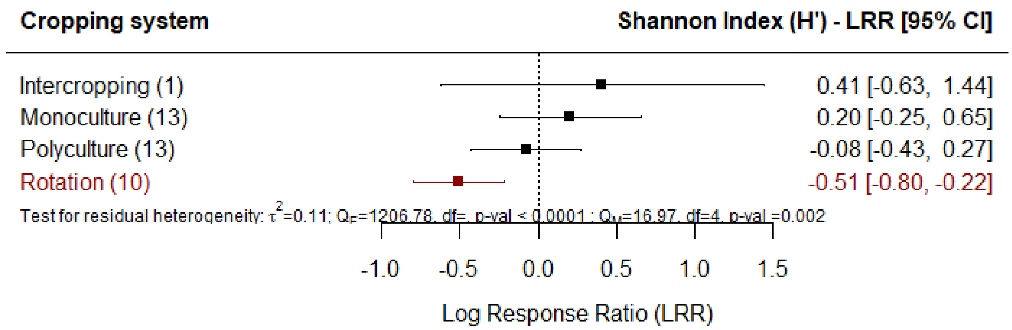
Intensification form

Effect of intensified land use on earthworm diversity reported as Shannon Index (H'), for the various forms of intensification documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



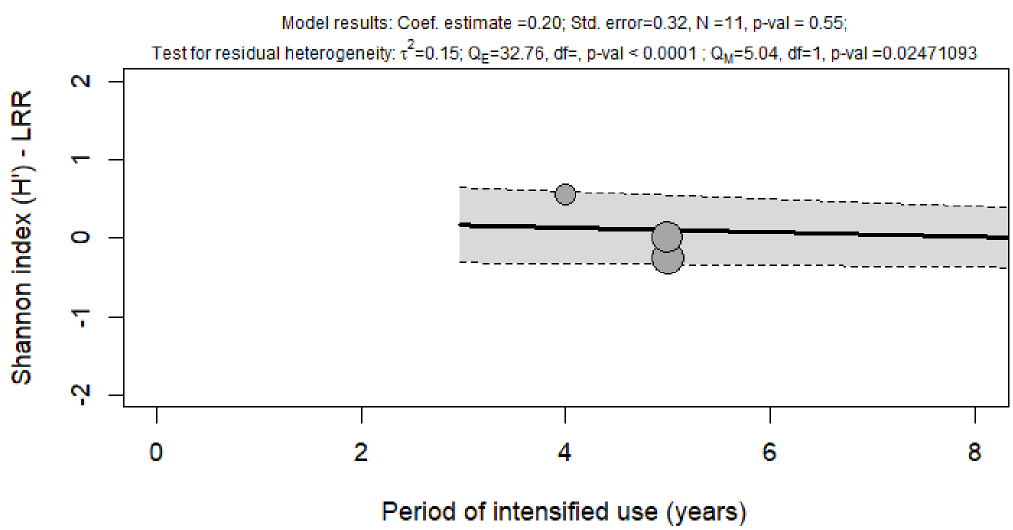
Cropping system

Effect of intensified land use on earthworm diversity reported as Shannon Index (H'), for the various cropping systems documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



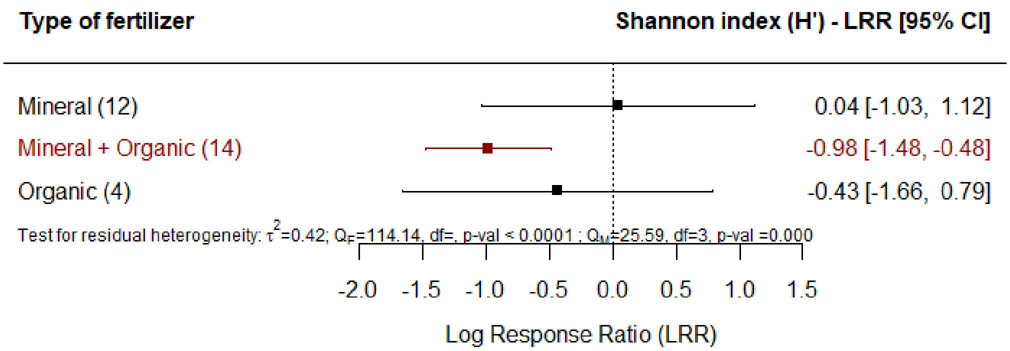
Period of intensified use

Effect of intensified land use on earthworm diversity reported as Shannon Index (H') in relation to the period of intensified use documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.



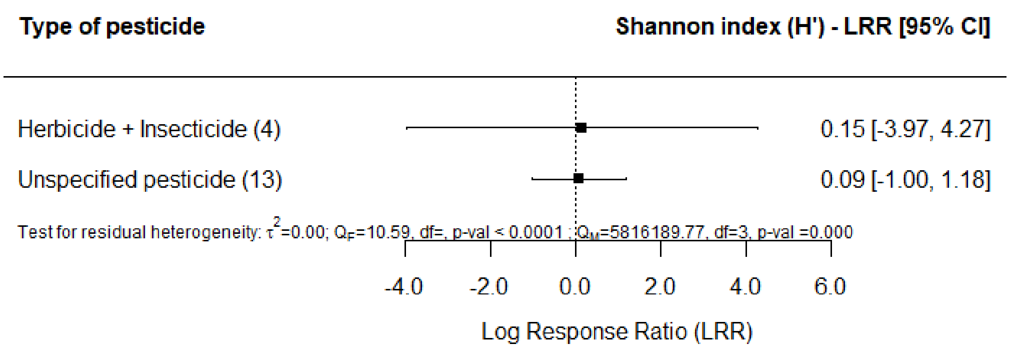
Types of fertilizer

Effect of intensified land use on earthworm diversity reported as Shannon Index (H'), for the various types of fertilizer documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



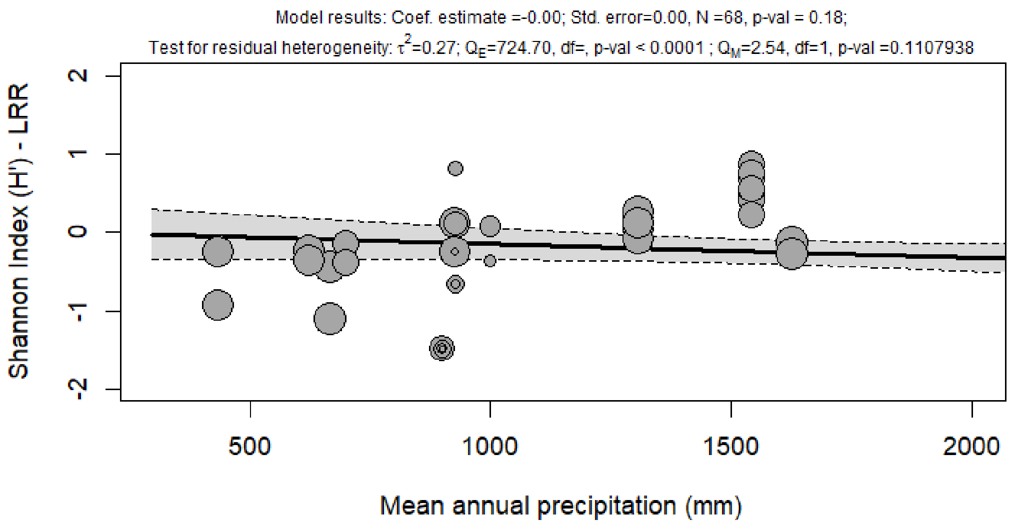
Types of pesticide

Effect of intensified land use on earthworm diversity reported as Shannon Index (H'), for the various types of pesticide documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



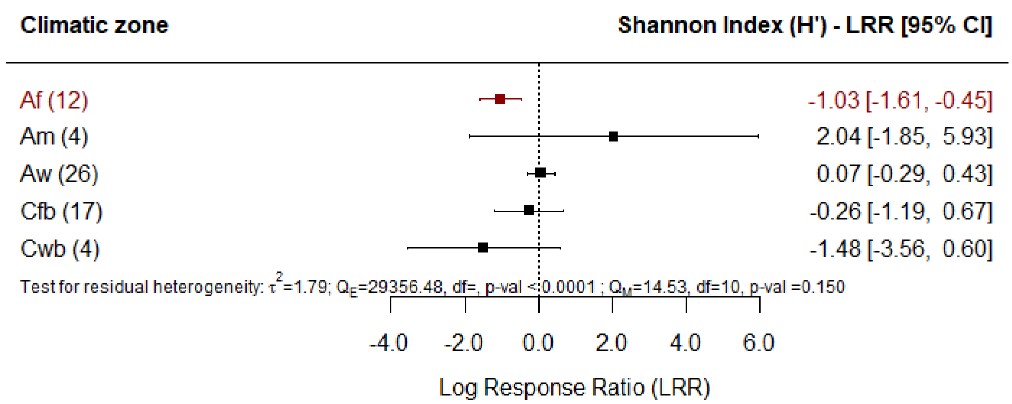
Mean annual precipitation

Effect of intensified land use on earthworm diversity reported as Shannon Index (H') in relation to the mean annual precipitation documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.



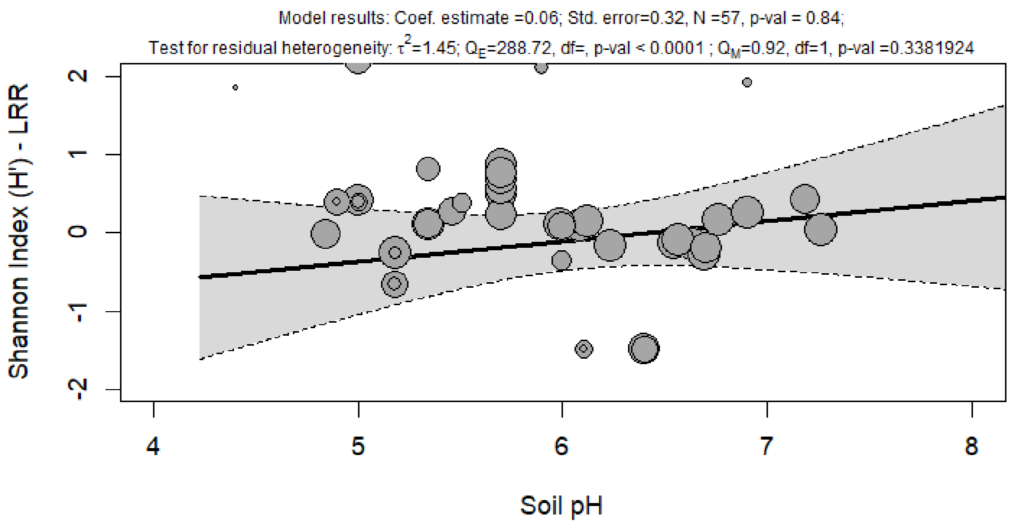
Climatic zone

Effect of intensified land use on earthworm diversity reported as Shannon Index (H'), for the various climatic zones documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



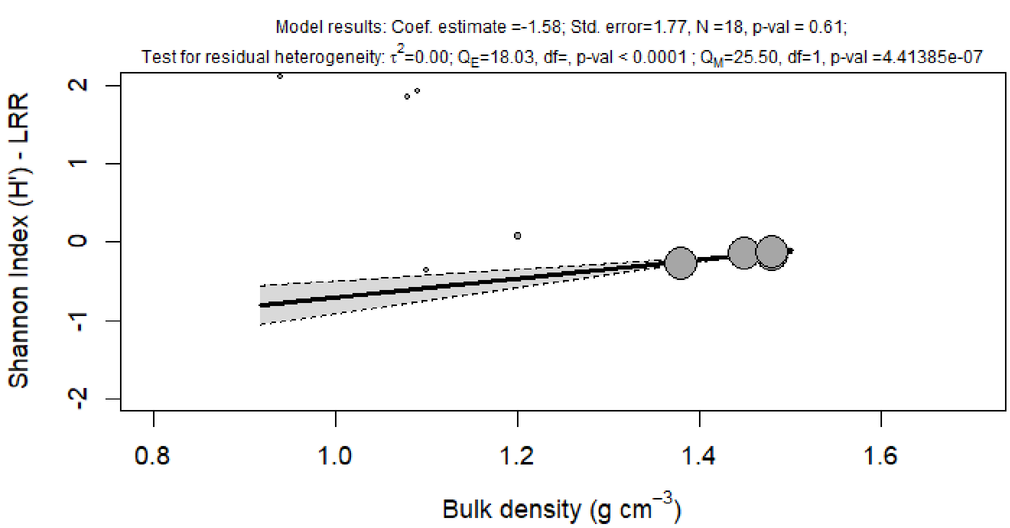
Soil pH

Effect of intensified land use on earthworm diversity reported as Shannon Index (H') in relation to the soil pH documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.



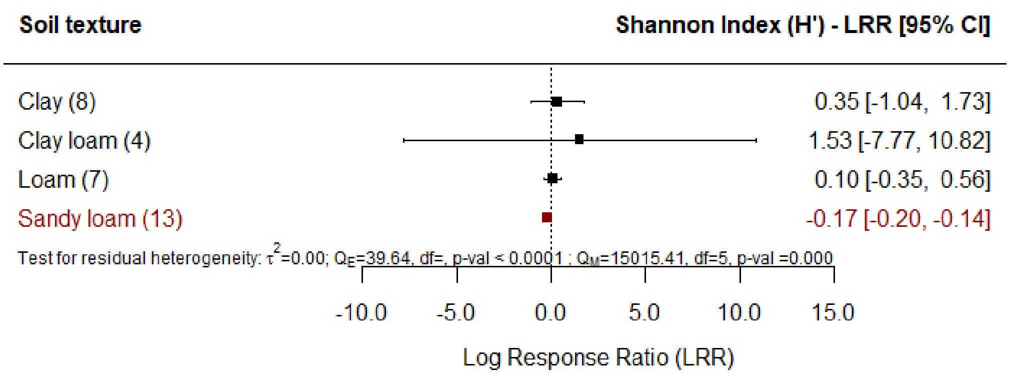
Soil bulk density

Effect of intensified land use on earthworm diversity reported as Shannon Index (H') in relation to the soil bulk density documented in the studies. The size of a regression bubble indicates the weight of each observation in the model and displays the mean effects. Gray, dotted lines indicate the bounds of the confidence interval over the regression line.



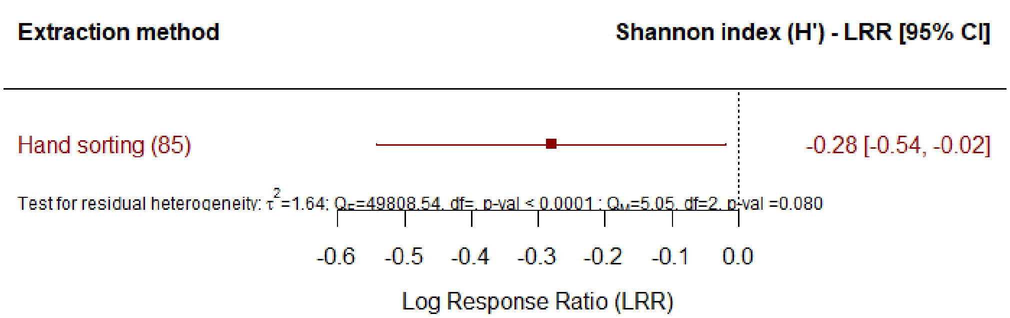
Soil texture

Effect of intensified land use on earthworm diversity reported as Shannon Index (H’), for the various soil textures documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



Earthworm extraction methods

Effect of intensified land use on earthworm diversity reported as Shannon Index (H’), for the various earthworm extraction methods documented in the studies. Forest plot illustrates the average effect, with the 95% confidence intervals presented in brackets, and the sample sizes for each group enclosed in parentheses.



Supplement S7. Intensification effects on earthworm density per study

Citation	Estimate	Std.error	p-value	Observations
Andriuzzi et al. (2017)	-0.4063	0.0903	<0.0001	8
Araujo & Lopez-Hernandez (1999)	1.5127	0.5885	0.0104	2
Ayuke et al. (2011)	-0.1062	0.238	0.6632	16
Barros et al. (2003)	1.62	0.2165	<0.0001	4
Bartz et al. (2013)	0.8047	0.2657	0.0026	34
Bartz et al. (2014)	1.663	0.8199	0.092	16
Bedano et al. (2016b)	-1.0246	0.0729	<0.0001	3
Bedano et al. (2016a)	-1.1079	0.0879	<0.0001	2
Bhadauria et al. (2012)	0.5547	0.7145	0.4562	36
Boag et al. (1997)	-0.3471	0.1451	0.0171	1
Brown et al. (2003)	0.9595	0.1379	<0.0001	8
Cameron et al. (2021)	-0.7056	0.0652	<0.0001	5
Carnovale et al. (2015)	-0.1289	0.486	0.7961	4
Cluzeau et al. (2012)	1.7953	0.284	<0.0001	2
Cornwell (2014)	-0.1675	1.422	0.9063	5
Darmawan et al. (2017)	0.7308	0.24	0.0249	12
Oliveira (1993)	12.7691	353201.1819	0.9996	4
Aquino et al. (2008)	-0.6273	0.0787	<0.0001	4
Albuquerque et al. (2009)	0.9808	29.8362	0.9738	1
De Valença et al. (2017)	-1.0395	0.0824	<0.0001	12

Citation	Estimate	Std.error	p-value	Observations
Decaens & Jimenez (2002)	0.5208	0.8467	0.5447	12
Decaens et al. (2003)	0.7253	0.3179	0.0391	3
W. C. Demetrio et al. (2018)	1.0768	6.3977	0.8664	4
W. Demetrio et al. (2020)	-0.0333	0.2166	0.8777	3
Dominguez et al. (2009)	-1.4489	0.3815	0.0004	2
Dominguez et al. (2010a)	-1.6135	0.4759	0.0011	2
Dominguez et al. (2010b)	-1.631	0.4238	0.0002	2
Dominguez et al. (2014)	-3.452	0.1704	<0.0001	3
Dominguez & Bedano (2016)	-2.467	0.3227	<0.0001	6
Emmerling (1995)	0.1143	0.1893	0.5608	8
Falco et al. (2015)	0.319	0.5161	0.5368	2
Fang et al. (1999)	-0.5202	0.2911	0.0744	8
Feijoo-Martinez et al. (2010)	0.3899	0.1493	0.0094	12
Feijoo et al. (2011)	0.3006	0.1049	0.0043	16
Felten & Emmerling (2011b)	-0.9274	0.0946	<0.0001	5
Felten & Emmerling (2011a)	-0.8905	0.0882	<0.0001	10
Fragoso et al. (1999)	-0.3141	0.2853	0.3083	7
Franco et al. (2016)	1.188	0.2463	<0.0001	6
Fraser et al. (1994)	0.8505	0.2704	0.029	4
Ge et al. (2021)	-0.9953	2.5122	0.6921	3
Geissen et al. (2009)	0.3198	0.1283	0.0164	4

Citation	Estimate	Std.error	p-value	Observations
Gonzalez et al. (1996)	-0.6331	0.0365	<0.0001	2
Gormsen et al. (2004)	0.0518	0.5307	0.9254	12
Grosso et al. (2006)	0.054	0.0673	0.4227	12
Guariento et al. (2020)	-0.0763	0.2278	0.7379	24
Guei & Tondoh (2012)	-0.0128	0.1037	0.9017	8
Haynes & Tregurtha (1999)	-0.4114	0.345	0.2713	8
Haynes et al. (2003)	8.6736	0.0122	<0.0001	12
Hendrix et al. (1992)	-0.9227	0.187	0.0001	5
Hernandez et al. (2017)	-0.1288	0.9876	0.8966	3
Jordan et al. (2004)	2.657	0.7667	0.003	13
Joshi et al. (2010)	-1.2476	0.263	<0.0001	1
Juarez-Ramon & Fragoso (2014)	0.1586	0.4486	0.7238	4
Kamdem (2018)	-0.5274	0.0613	<0.0001	6
Kanianska et al. (2016)	-4.2132	0.1244	<0.0001	6
Kernecker et al. (2015)	-0.5674	0.1116	<0.0001	6
Kraft et al. (2020)	3.3521	3.9809	0.4001	6
Lamande et al. (2003)	-0.9899	0.6936	0.1582	2
Lavelle & Pashanasi (1989)	0.1569	0.1543	0.3095	9
Lima et al. (2010)	15.9343	0.1164	<0.0001	6
Majeed et al. (2018)	-0.0625	0.7037	0.9292	1
Moreno et al. (2016)	0.0465	0.329	0.8914	14
Mujeeb Rahman et al. (2012)	-0.1787	0.0734	0.0151	11

Citation	Estimate	Std.error	p-value	Observations
Nanganoa et al. (2019)	0.2919	0.7472	0.7017	4
Nunes et al. (2006)	2.9749	1.1676	0.0383	28
Peres et al. (2010)	-2.2825	0.398	<0.0001	5
Polo Benito et al. (2008)	-0.2646	1.3526	0.8501	9
Ponge et al. (2013)	-0.3283	0.0295	<0.0001	3
Prendergast-Miller et al. (2021)	-0.321	0.2111	0.129	3
Rajkhowa et al. (2015)	-0.1517	0.0533	0.0046	2
Rajwar et al. (2022)	-0.7616	0.1421	<0.0001	15
Rakotomanga et al. (2016)	0.9339	0.8452	0.3027	12
Rossi & Blanchart (2005)	-0.6112	0.2674	0.0226	25
Rudisser et al. (2020)	-0.2979	0.1935	0.1242	2
Ruiz-Cobo et al. (2010)	1.1186	0.2193	0.0003	3
Silva et al. (2006)	-0.3604	0.5656	0.5653	24
Singh et al. (2020)	-0.2106	0.0611	0.0006	3
Smith et al. (2008)	-1.0814	0.097	<0.0001	4
Steinwandter et al. (2017)	0.0188	0.2597	0.9424	2
Suarez et al. (2021)	1.1742	0.0536	<0.0001	5
Talavera et al. (2020)	0.3566	0.2354	0.1303	4
Tondoh et al. (2007)	0.933	0.1669	<0.0001	8
Tondoh et al. (2011)	1.2851	0.135	<0.0001	5
Ventiņš (2011)	1.0369	0.5703	0.3768	28

Citation	Estimate	Std.error	p-value	Observations
Vršič et al. (2021)	-0.3075	0.033	<0.0001	4
Yeates et al. (1998)	0.293	0.1521	0.0545	5
Zerbino (2012)	0.2764	0.056	0.0006	14
Zou & Gonzalez (1997)	2.8735	0.6783	0.0001	2

Supplement S8. Intensification effects on earthworm biomass per study

Citation	Estimate	Std.error	p-value	Observations
Araujo & Lopez-Hernandez (1999)	2.393	1.510.574	0.9874	2
Barros et al. (2003)	12.381	0.3622	0.0007	4
Bhadauria et al. (2012)	11.673	10.143	0.2674	36
Brown et al. (2003)	-0.7808	0.2431	0.0015	7
Cameron et al. (2021)	-0.4671	0.0625	<0.0001	5
Carnovale et al. (2015)	-0.1006	11.263	0.9289	4
Cornwell (2014)	-0.5802	94.879	0.9513	5
Aquino et al. (2008)	-0.7773	0.0922	<0.0001	4
Decaens & Jimenez (2002)	0.3084	79.443	0.9691	12
Decaens et al. (2003)	17.918	28.998	0.5372	3
Emmerling (1995)	0.9369	0.2674	0.0008	8
Fang et al. (1999)	0.6661	0.3453	0.0549	8
Feijoo-Martinez et al. (2010)	0.2448	0.2088	0.2426	12
Feijoo et al. (2011)	0.282	0.1384	0.0427	16
Fragoso et al. (1997)	12.916	22.514	0.5669	9
Fragoso et al. (1999)	-0.9676	16.623	0.5611	10
Fraser et al. (1994)	0.156	0.6045	0.7975	4
Geissen et al. (2009)	10.705	16.138	0.5078	4
Gonzalez et al. (1996)	-0.7134	0.0311	<0.0001	2

Citation	Estimate	Std.error	p-value	Observations
Gormsen et al. (2004)	0.1453	0.4908	0.7689	12
Guei & Tondoh (2012)	0.4083	0.1133	0.0004	8
Haynes et al. (2003)	84.496	0.0131	<0.0001	12
Hendrix et al. (1992)	-0.3732	124.158	0.976	2
Hernandez et al. (2017)	-0.0135	117.603	0.9991	3
Heyer et al. (2003)	-0.7326	0.4307	0.0923	4
Høfer et al. (2001)	-0.7157	0.4348	0.101	2
Jordan et al. (2004)	31.032	12.883.156	0.9981	13
Joshi et al. (2010)	0.1144	0.137	0.4046	3
Juarez-Ramon & Fragoso (2014)	0.0599	0.2376	0.8013	4
Kamdem (2018)	-0.1549	0.087	0.0762	6
Kanianska et al. (2016)	-27.149	0.1419	<0.0001	7
Lavelle & Pashanasi (1989)	10.001	0.4915	0.043	9
Owen & Galbraith (1989)	29.746	76.889	0.6993	8
Prendergast-Miller et al. (2021)	-0.103	0.2409	0.6693	2
Rajkhowa et al. (2015)	-0.0532	0.0532	0.3182	2
Rudisser et al. (2020)	-0.0402	0.2192	0.8545	2
Ruiz-Cobo et al. (2010)	12.361	0.5838	0.0357	3
Smith et al. (2008)	-11.445	0.1686	<0.0001	4
Tondoh et al. (2011)	22.634	0.0925	<0.0001	5
Vršič et al. (2021)	0.0234	0.0396	0.5555	4

Citation	Estimate	Std.error	p-value	Observations
Yeates et al. (1998)	-21.888	0.063	<0.0001	11
Zou & Gonzalez (1997)	20.008	20.377	0.3272	2

Supplement S9. Intensification effects on earthworm species richness per study

Citation	Estimate	Std.error	p-value	Observations
Bartz et al. (2013)	0.1113	0.187	0.5521	34
Bartz et al. (2014)	0.2832	0.1116	0.0118	24
Carnovale et al. (2015)	0.07	0.3384	0.8365	8
Darmawan et al. (2017)	-0.6804	0.1353	<0.0001	12
Decaens & Jimenez (2002)	-0.5355	0.137	0.0001	24
W. C. Demetrio et al. (2018)	-0.113	0.5848	0.8481	4
W. Demetrio et al. (2020)	-0.8999	0.3137	0.0045	3
Falco et al. (2015)	0.0598	0.2417	0.8046	4
Fang et al. (1999)	0.2877	0.6258	0.6461	1
Feijoo et al. (2011)	-0.4708	0.108	<0.0001	20
Felten & Emmerling (2011b)	-0.3822	0.2122	0.0728	5
Felten & Emmerling (2011a)	-0.382	0.1516	0.0123	10
Fragoso et al. (1997)	-1.1947	0.2492	<0.0001	9
Fragoso et al. (1999)	0.074	0.2133	0.7289	6
Fraser et al. (1994)	0.4273	0.3368	0.2069	4
Geissen et al. (2009)	1.0858	0.2732	0.0001	4
Gonzalez et al. (1996)	-1.2285	0.3987	0.0023	2
Gormsen et al. (2004)	-0.1647	0.1787	0.3574	12

Citation	Estimate	Std.error	p-value	Observations
Grosso et al. (2006)	-1.106	0.1853	0.0001	9
Guei & Tondoh (2012)	-0.131	0.135	0.3326	12
Haynes et al. (2003)	9.565	5274.1667	0.9986	4
Joshi et al. (2010)	0.3748	0.3276	0.2536	2
Kernecker et al. (2015)	-0.0505	0.196	0.7968	6
Moreno et al. (2016)	-0.105	0.0905	0.2473	28
Nunes et al. (2006)	0.9928	0.1889	<0.0001	7
Paoletti et al. (2009)	-0.0717	0.3289	0.8288	6
Prendergast-Miller et al. (2021)	-0.1127	0.2814	0.6891	3
Rudisser et al. (2020)	-0.3848	0.3619	0.2886	2
Singh et al. (2020)	0.0792	2.7868	0.9773	2
Smith et al. (2008)	-0.9249	0.1681	<0.0001	8
Talavera et al. (2020)	0.4688	0.2682	0.0816	4
Tondoh et al. (2007)	0.3847	0.1323	0.0039	16
Tondoh et al. (2011)	0.2592	0.1995	0.1951	6
Tsiafouli et al. (2015)	-0.3736	0.1934	0.0544	7

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