Supplementary Information

Temporally staggered cropping co-benefits beneficial insects and pest control globally

This file includes:

Figures S1 to S10
Table S1 to S2

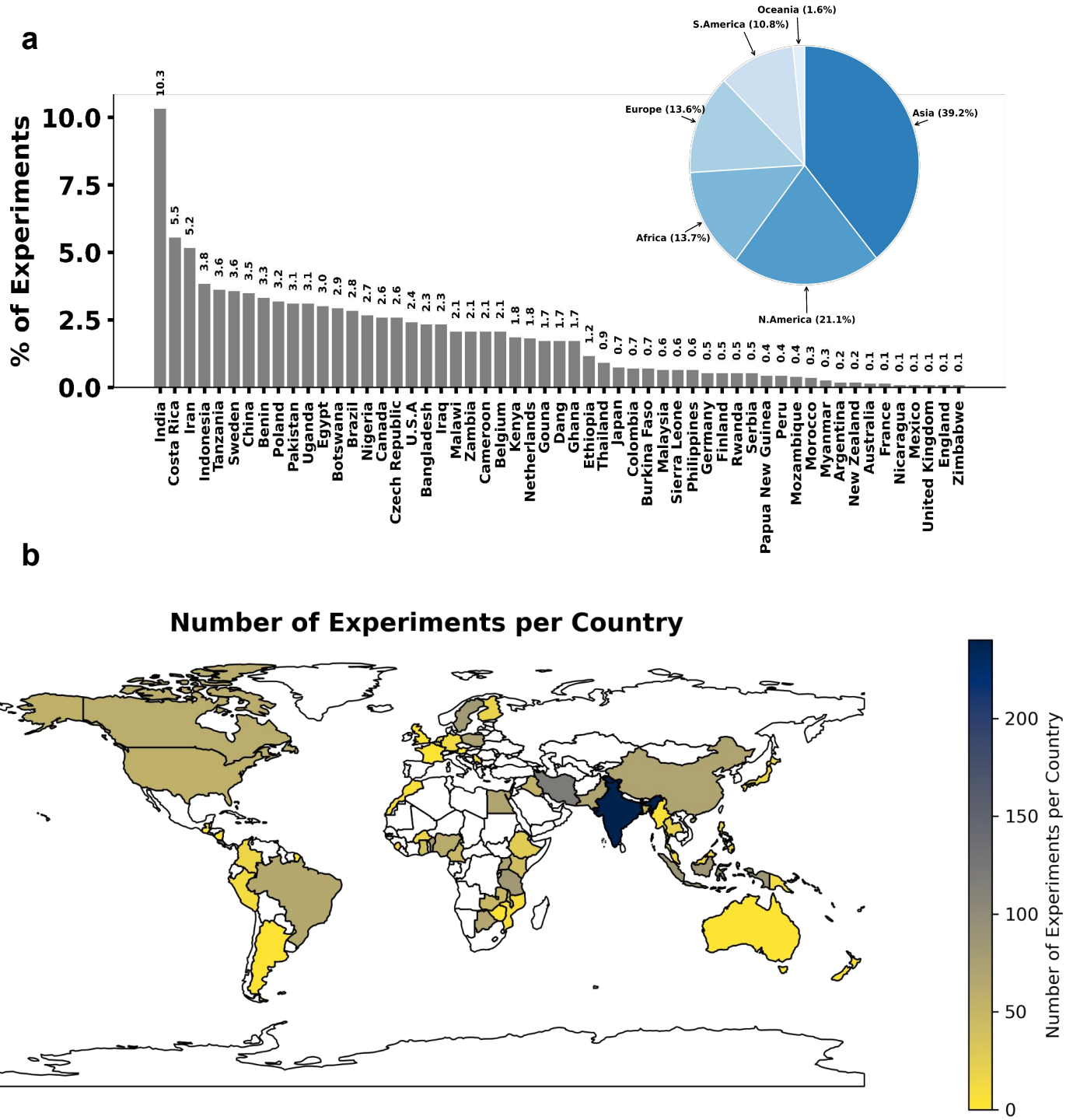


Fig. S1| Geographical distribution of experiments included in the database. a, Percentage of experiments by country and continent. **b,** Spatial distribution of number of experiments recorded in each country.

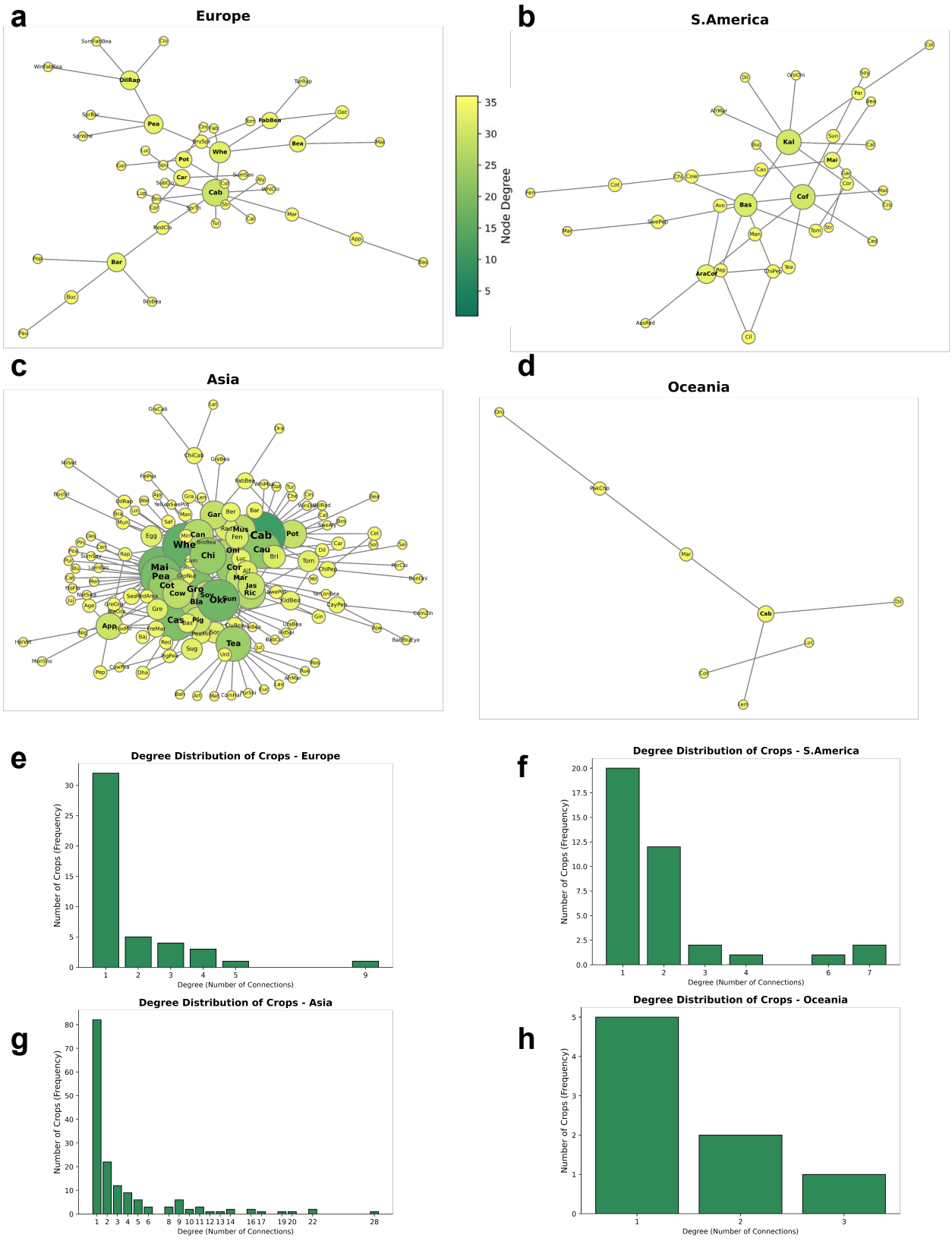


Fig. S2| Patterns of crop interactions in agroecosystems. Crop interaction networks for Europe **(a)**, South America **(b)**, Asia **(c)**, and Oceania **(d)** with nodes representing crops and edges showing intercropping pairs. Node size and color correspond to the number of intercropping connections, highlighting the degree (connection) of each crop within the network. Bar plots show degree distribution of same continents **(e-h)**.

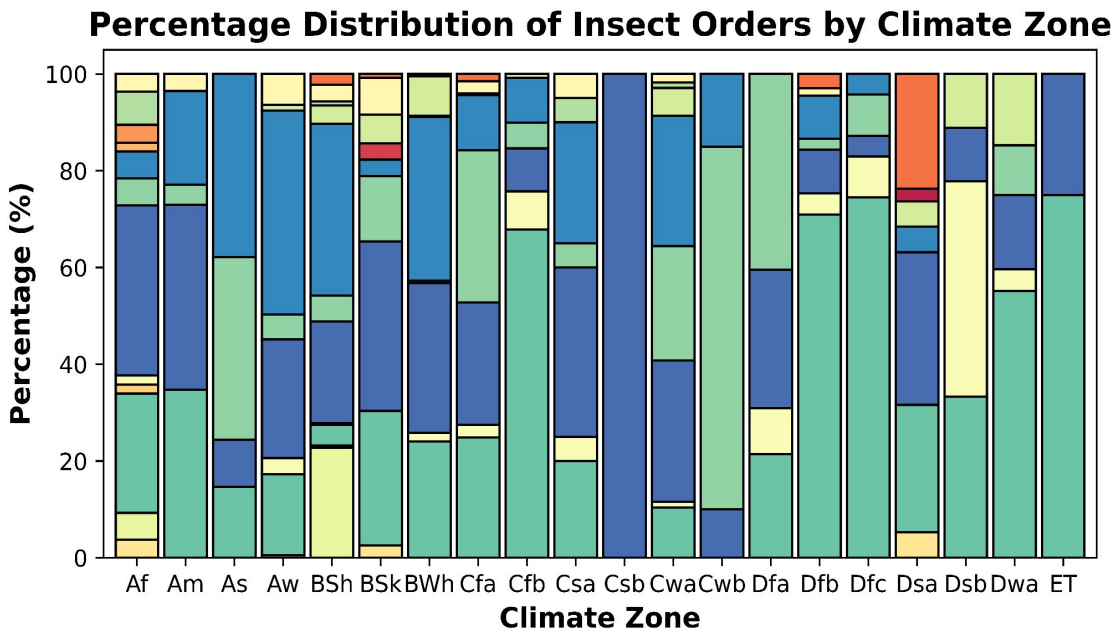


Fig. S3| Percent distribution of insect orders by Köppen-Geiger climate zones.

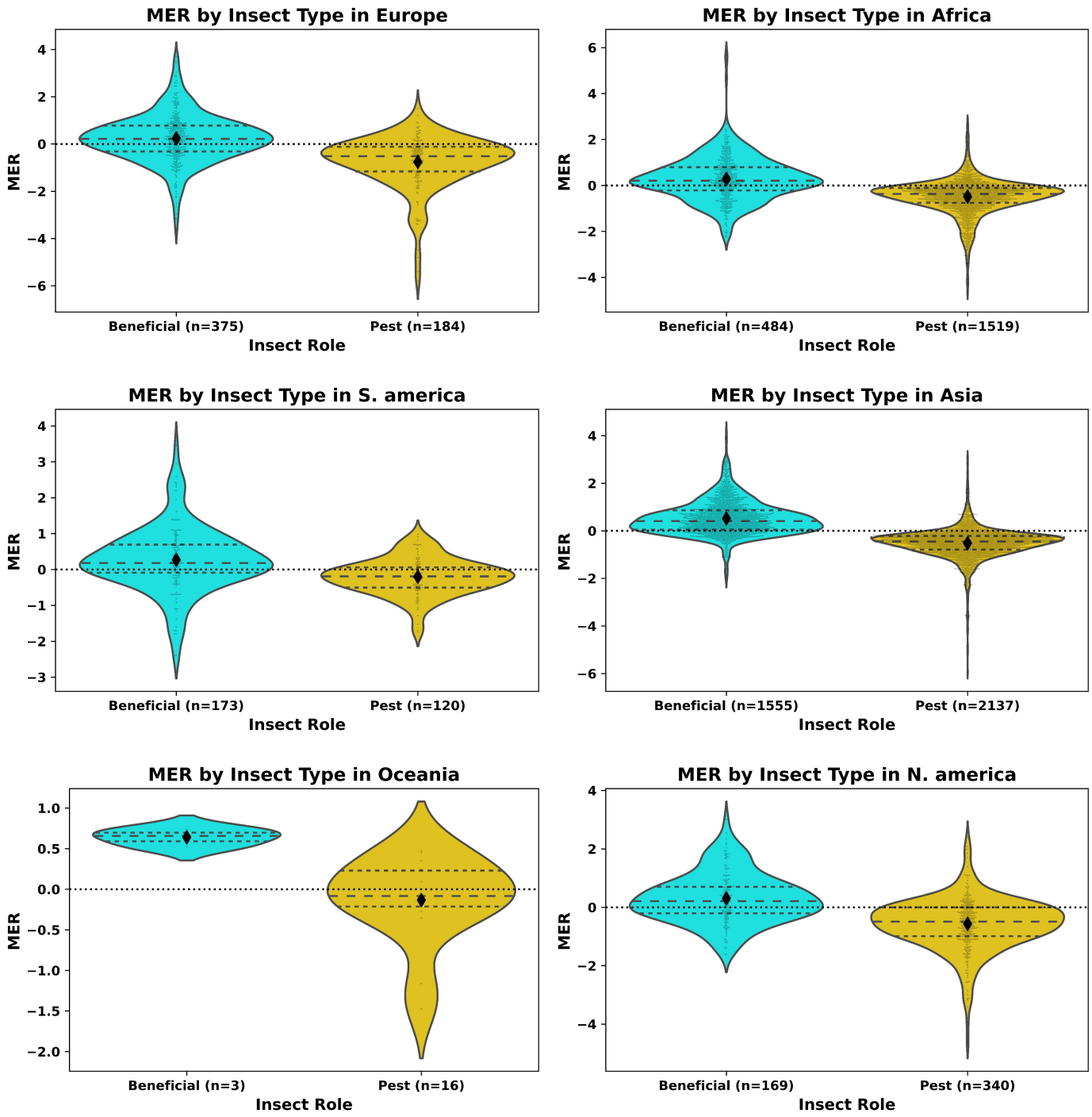
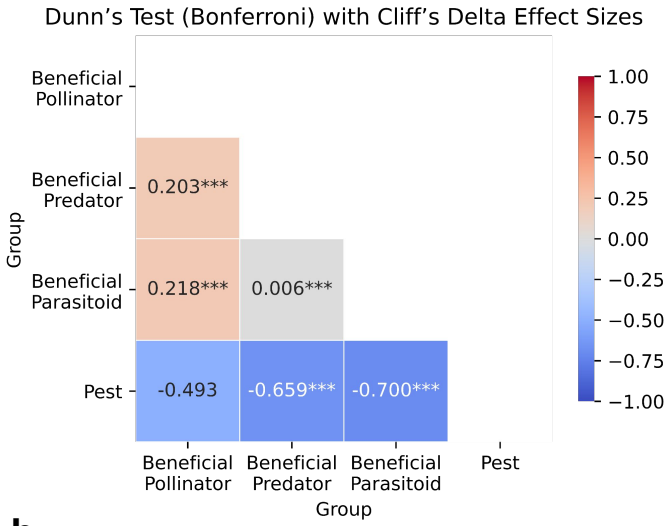


Fig. S4| Effect of intercropping on beneficial insects and pests in different continents. The total number of individual effect sizes is indicated by "n." The diamond symbol illustrates the average effect size.

a



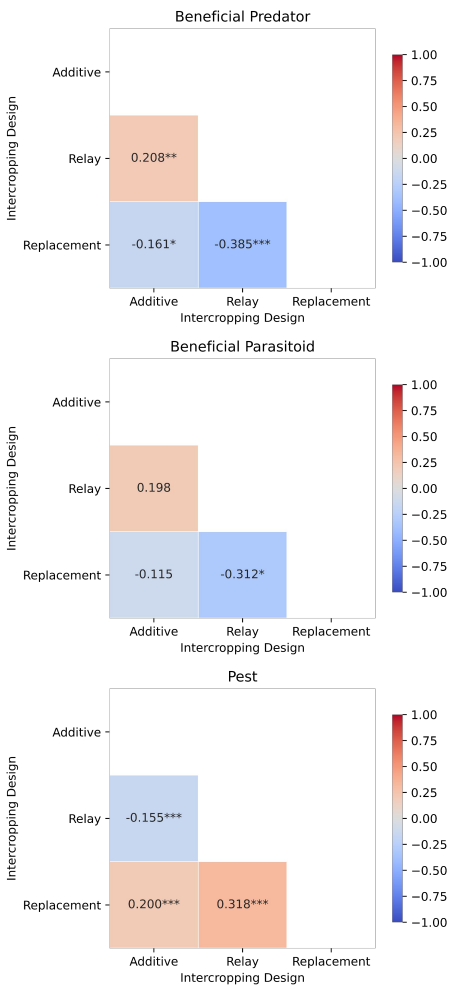
Kruskal-Wallis Test Results:

- Q statistic: 1995.064
- P-value <0.001
- There is significant heterogeneity among groups.

Higgins & Thompson's I^2 Statistic:

- I^2 = 99.85%
- High heterogeneity detected.

b



Beneficial Pollinator:
Only one Intercropping Design present.

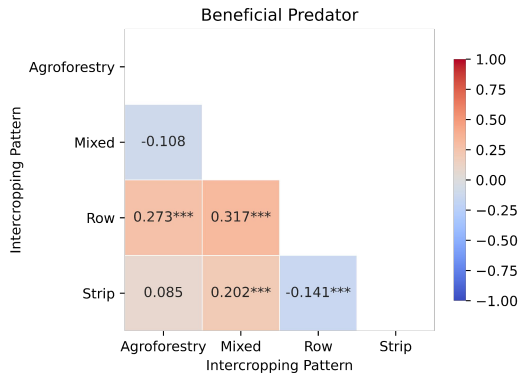
Beneficial Predator:
Kruskal-Wallis test p-value: 8.7716e-04
Effect Size (ε^2) = 0.0080
LOO-CV Mean p-value: 8.8349e-04, Std Dev: 7.8786e-05
LOO-CV Mean Effect Size (ε^2): 0.0080, Std Dev: 0.0001

Beneficial Parasitoid:
Kruskal-Wallis test p-value: 7.0440e-02
Effect Size (ε^2) = 0.0114
LOO-CV Mean p-value: 7.1090e-02, Std Dev: 7.4237e-03
LOO-CV Mean Effect Size (ε^2): 0.0114, Std Dev: 0.0005

Pest:
Kruskal-Wallis test p-value: 3.0699e-06
Effect Size (ε^2) = 0.0063
LOO-CV Mean p-value: 3.0891e-06, Std Dev: 2.5951e-07
LOO-CV Mean Effect Size (ε^2): 0.0063, Std Dev: 0.0000

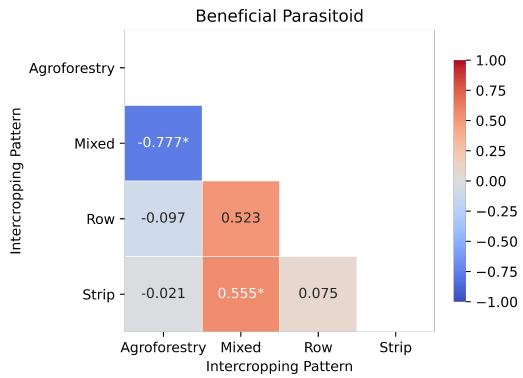
Fig. S5| Statistical analysis of effect of intercropping. a, Statistical analysis of effect of intercropping on pollinators, parasitoids, and predators. **b,** Effect of temporal intercropping arrangements on insect functional groups. Here '*' means 10% significance level, '**' means 5% significance level, '***" means 1% significance level.

a



Beneficial Pollinator:
Kruskal-Wallis test p-value: 3.7302e-01
Effect Size (ε^2) = 0.0297
LOO-CV Mean p-value: 3.7630e-01, Std Dev: 4.9215e-02
LOO-CV Mean Effect Size (ε^2): 0.0300, Std Dev: 0.0036

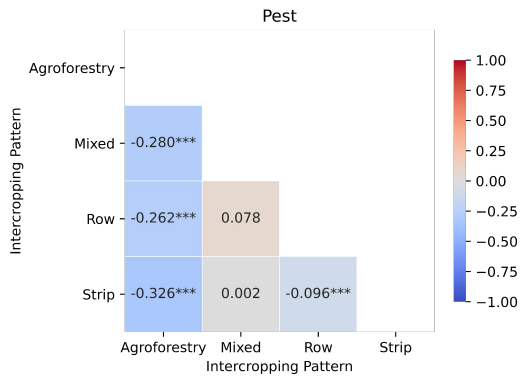
b



Beneficial Predator:
Kruskal-Wallis test p-value: 5.0623e-17
Effect Size (ε^2) = 0.0447
LOO-CV Mean p-value: 5.2768e-17, Std Dev: 1.0547e-17
LOO-CV Mean Effect Size (ε^2): 0.0447, Std Dev: 0.0002

Beneficial Parasitoid:
Kruskal-Wallis test p-value: 4.4995e-02
Effect Size (ε^2) = 0.0173
LOO-CV Mean p-value: 4.5440e-02, Std Dev: 4.6976e-03
LOO-CV Mean Effect Size (ε^2): 0.0174, Std Dev: 0.0004

c



Pest:
Kruskal-Wallis test p-value: 8.1852e-13
Effect Size (ε^2) = 0.0146
LOO-CV Mean p-value: 8.3032e-13, Std Dev: 1.0724e-13
LOO-CV Mean Effect Size (ε^2): 0.0146, Std Dev: 0.0001

Fig. S6| Statistical analysis of effect of spatial intercropping arrangements on insect functional groups. Here '*' means 10% significance level, '**' means 5% significance level, '***" means 1% significance level.

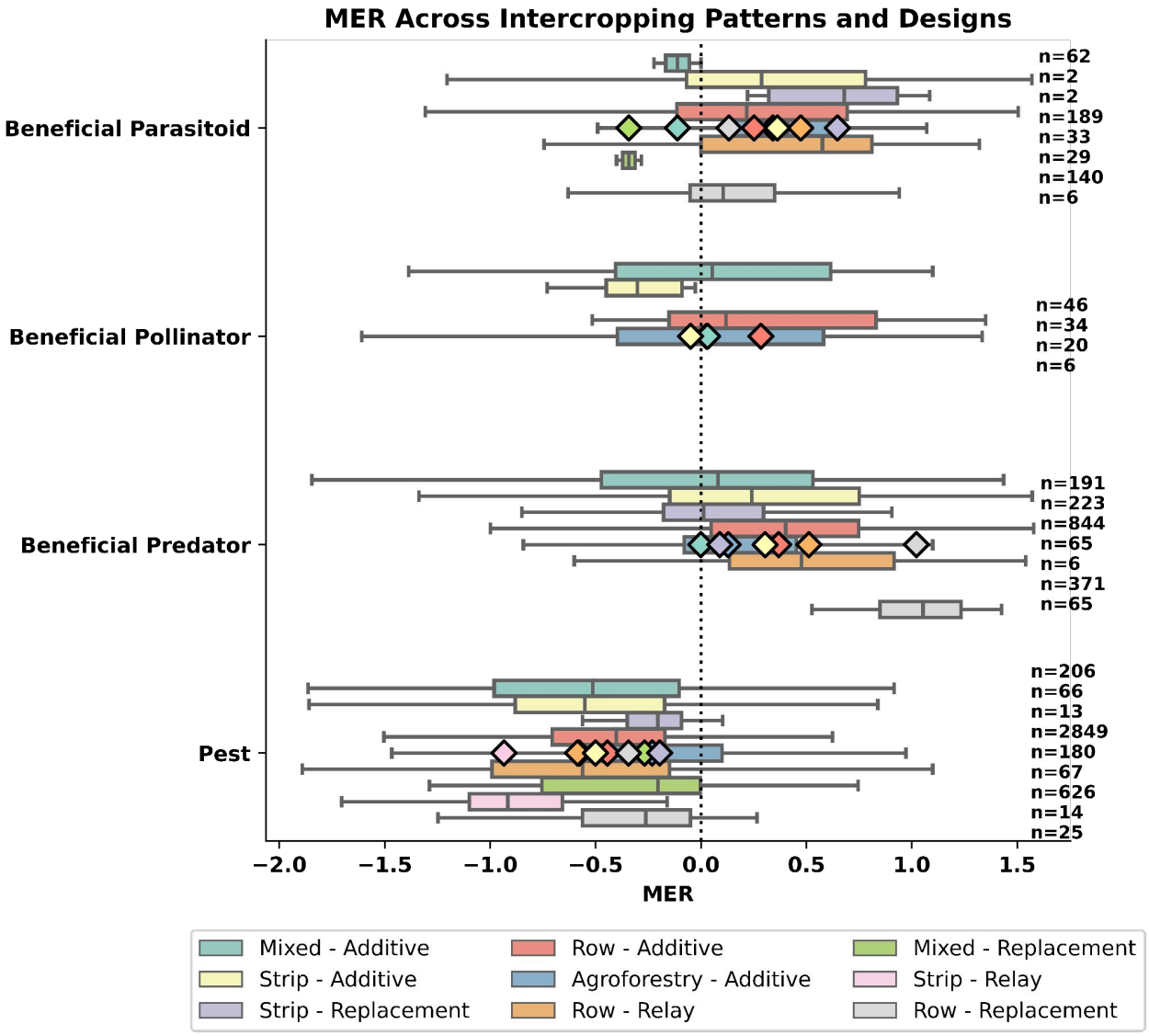
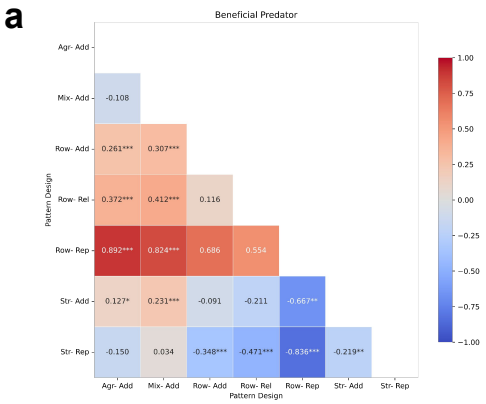
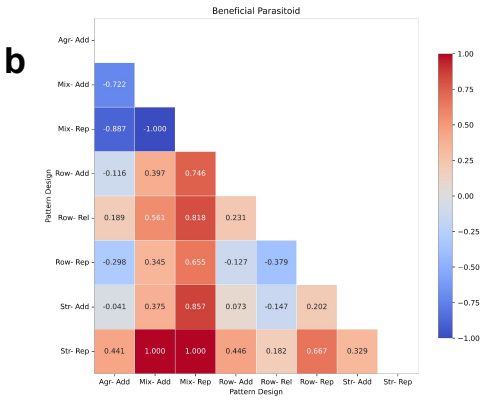


Fig. S7| Effect of spatiotemporal intercropping configurations on different insect functional groups i.e. beneficial parasitoid, beneficial pollinator, beneficial predator and pest.



Beneficial Pollinator:
Kruskal-Wallis test p-value: 3.7302e-01
Effect Size (ε^2) = 0.0297
LOO-CV Mean p-value: 3.7630e-01, Std Dev: 4.9215e-02
LOO-CV Mean Effect Size (ε^2): 0.0300, Std Dev: 0.0036



Beneficial Predator:
Kruskal-Wallis test p-value: 6.5842e-19
Effect Size (ε^2) = 0.0555
LOO-CV Mean p-value: 6.9043e-19, Std Dev: 1.4841e-19
LOO-CV Mean Effect Size (ε^2): 0.0555, Std Dev: 0.0002

Beneficial Parasitoid:
Kruskal-Wallis test p-value: 1.1655e-02
Effect Size (ε^2) = 0.0389
LOO-CV Mean p-value: 1.1872e-02, Std Dev: 1.5241e-03
LOO-CV Mean Effect Size (ε^2): 0.0390, Std Dev: 0.0007

Pest:
Kruskal-Wallis test p-value: 8.2146e-18
Effect Size (ε^2) = 0.0243
LOO-CV Mean p-value: 8.3896e-18, Std Dev: 1.2843e-18
LOO-CV Mean Effect Size (ε^2): 0.0243, Std Dev: 0.0001

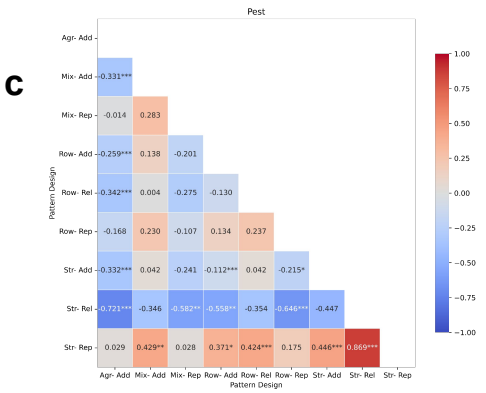
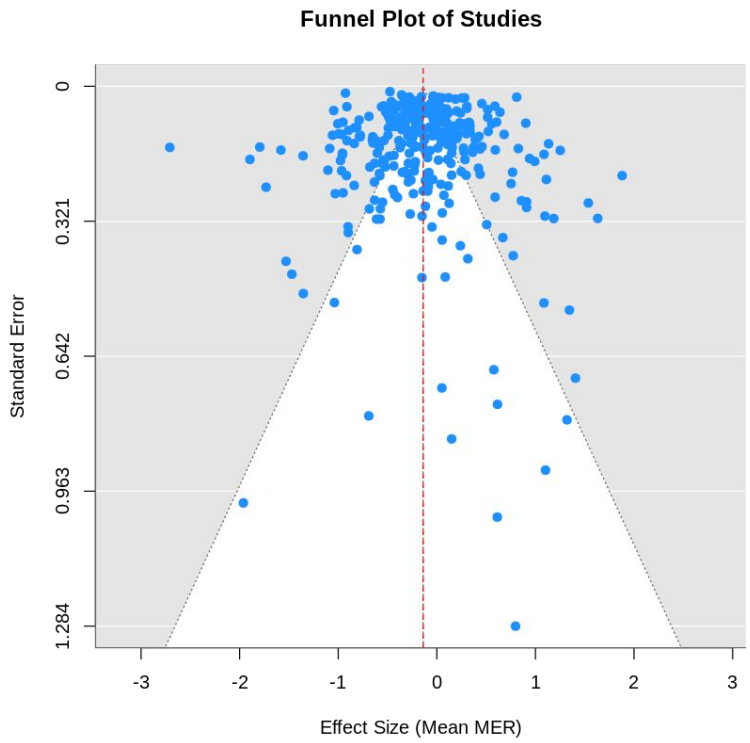


Fig. S8| Statistical analysis of effect of spatiotemporal intercropping configurations on different insect functional groups i.e. beneficial parasitoid, beneficial pollinator, beneficial predator and pest. Here '*' means 10% significance level, '**' means 5% significance level, '***" means 1% significance level.

a



Statistic	Value
logLik	-280.9108
deviance	561.8215
AIC	565.8215
BIC	573.4258
AICc	565.8581

Measure	Value	Interpretation
tau^2	0.2650 (SE = 0.0228)	Estimated variance between studies (heterogeneity)
tau	0.5147	Square root of tau^2 (standard deviation of true effects)
I^2	98.25%	Proportion of total variance due to heterogeneity (very high)
H^2	57.07	Ratio of total variability to sampling variability

Estimate	SE	z-value	p-value	95% CI	Significance
-0.1384	0.0299	-4.625	< .0001	[-0.1970, -0.0797]	*** (highly significant)

Fig. S9| Funnel plot assessing publication bias using Egger's test. Funnel plot displays effect sizes against their standard errors across studies. The dashed vertical line represents the pooled effect estimate.

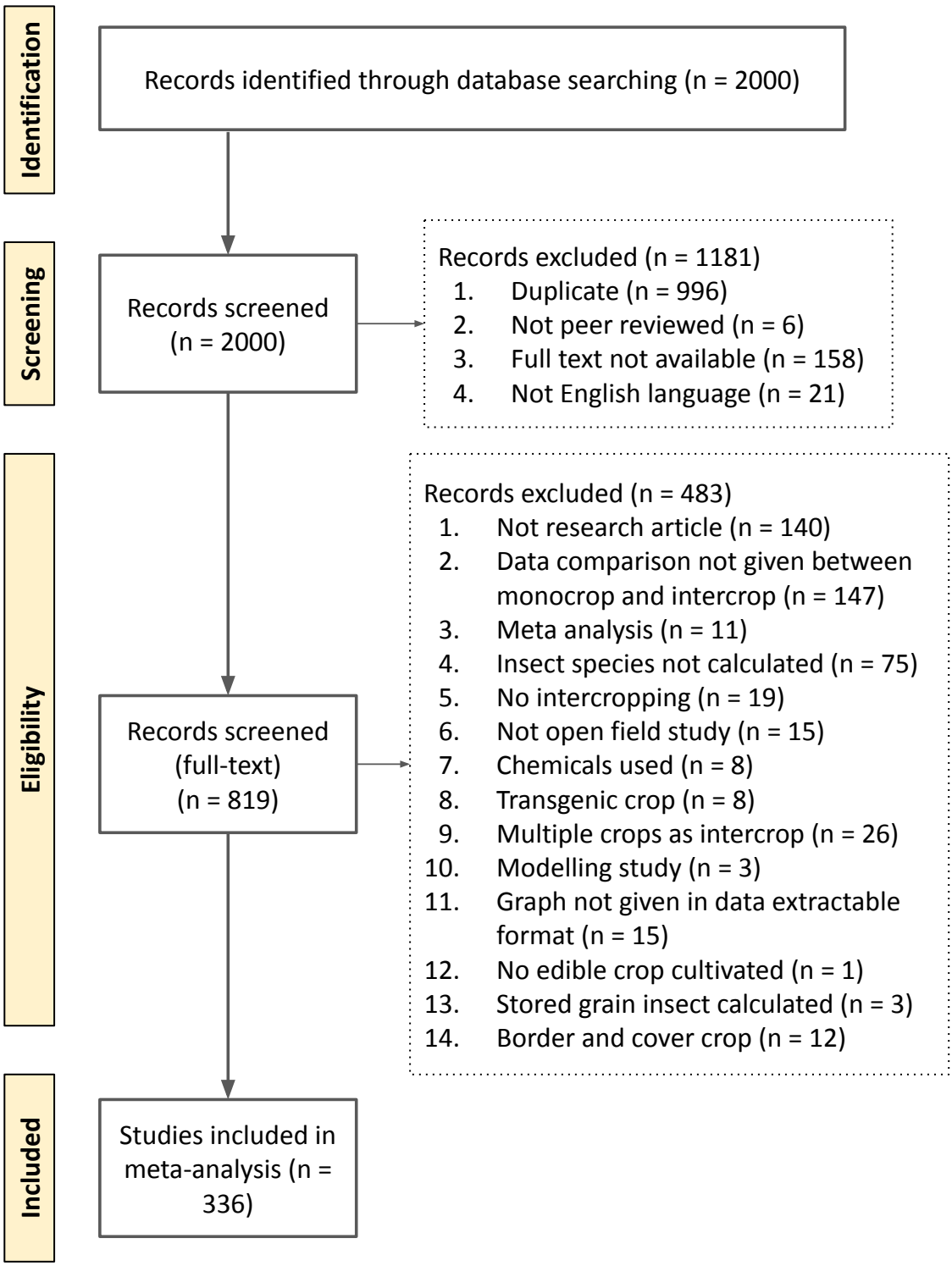


Fig. S10| PRISMA flow diagram of study selection process. Flow diagram outlining the identification, screening, eligibility, and inclusion of studies in accordance with PRISMA guidelines. 'n' is the number of studies excluded or included at each step.

Insect_order	Af	Am	As	Aw	BSh	BSk	BWh	BWk	Cfa	Cfb	Csa	Csb	Cwa	Cwb	Dfa	Dfb	Dfc	Dsa	Dsb	Dwa	ET
Araneae	2.7	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0
Blattodea	4.0	0.0	0.0	0.5	19.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coleoptera	20.4	34.2	14.6	16.3	5.9	28.2	23.4	25.0	21.6	68.6	20.4	0.0	11.7	0.0	21.4	70.9	74.5	24.5	33.3	55.1	75.0
Dermaptera	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diptera	2.2	0.0	0.0	3.3	2.5	0.0	3.0	25.0	2.8	8.1	4.4	0.0	4.1	10.7	9.5	4.5	8.5	0.0	44.4	4.5	0.0
Hemiptera	30.7	36.0	9.8	24.0	20.4	34.9	32.6	25.0	24.8	8.8	30.7	100.0	28.8	26.2	28.6	9.0	4.3	28.3	11.1	15.4	25.0
Hymenoptera	4.9	5.6	37.8	6.1	7.3	12.5	0.5	0.0	37.0	5.1	4.4	0.0	20.0	35.7	40.5	2.2	8.5	9.4	0.0	10.3	0.0
Lepidoptera	22.2	21.1	37.8	41.9	35.3	3.1	32.0	0.0	9.7	8.3	28.5	0.0	25.2	27.4	0.0	9.0	4.3	9.4	0.0	0.0	0.0
Mantodea	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mesostigmata	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Neuroptera	0.0	0.0	0.0	1.3	3.3	7.8	8.0	25.0	0.6	1.1	2.9	0.0	4.5	0.0	0.0	0.0	0.0	5.7	11.1	14.7	0.0
Odonata	2.7	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Opiliones	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0
Orthoptera	4.9	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	4.4	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thysanoptera	2.7	3.1	0.0	6.5	3.0	7.1	0.5	0.0	2.2	0.0	4.4	0.0	1.2	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Trombidiformes	0.0	0.0	0.0	0.0	1.9	0.8	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	17.0	0.0	0.0	0.0

Table S1| Percent distribution of insect orders by Köppen-Geiger climate zones.

Continent	Weighted MER	MER for Beneficial	MER for Pest
Europe	-0.088	0.24	-0.758
Africa	-0.303	0.283	-0.490
S. america	0.078	0.272	-0.291
Asia	-0.081	0.523	-0.52
Oceania	-0.011	0.641	-0.134
N. america	-0.275	0.307	-0.565

Table S2| Continental variation in intercropping effects on insect-mediated services.