Supplementary Materials

Article Title: Effects of soil management practices on the diversity and functionality of agroecosystems: evidence from ground-dwelling spiders' responses in vineyards

Document S1: Field Sampling, Laboratory Analysis, and Classification of Soil-Dwelling Spiders

Field Sampling

Sampling of soil-surface spider communities—which live and move on the soil surface or within the leaf litter—was conducted in plots representing different soil management practices across four vineyard sites: Site A (2018), Site B (plots a and b, 2010,2018), Site C (2010), and Site D (2010, 2013, 2018). In some locations, sampling plots were also established in the peripheries or boundary zones of the vineyards.

The dataset resulted from the integration of several research projects and sampling campaigns conducted between 2010 and 2018, predominantly from April to October. Although the different campaigns shared the general objective of evaluating the ecological effects of soil management practices on soil arthropod biodiversity, the duration of pitfall-trap exposure varied among sites and sampling periods, resulting in differences in sampling effort. The surveyed plots were managed under different soil management regimes, classified according to a gradient of soil disturbance, from less to more disturbed:

- **NCH (Non-Crop Habitat; 63 samples):** Adjacent natural or semi-natural vegetation areas used as a less-disturbed reference habitat, where the soil was either left undisturbed or the vegetation was subject to occasional mowing.

- **CCT (Full Ground Cover; 48 samples):** Vineyard plots with vegetation cover both in the inter-rows and under the vine rows, with vegetation mown once or twice per year.

- **CCH (Inter-row vegetation cover with herbicide application under rows; 165 samples):** Vineyard plots with vegetation cover maintained in the inter-rows, mown once or twice per year, while herbicides were applied under the vine rows.

- **BS (Bare Soil due to tillage and herbicide application; 22 samples):** Vineyard plots with completely exposed soil resulting from tillage and/or herbicide application.

Spiders were sampled during spring, summer, and autumn using pitfall traps (16 cm deep and 9 cm in diameter) filled with approximately 150 ml of a water–propylene glycol solution (3:1, v/v). To accommodate farm management constraints, the duration of trap exposure varied among sites and sampling periods, ranging from 24 to 96 h per sampling campaign. The baseline sampling design consisted of three pitfall traps (replicates) per site and soil management regime in each sampling campaign. At each site and on each sampling date, sampling was conducted simultaneously across all evaluated treatments within the same farm, thereby ensuring temporal consistency among treatments within each location. Traps that were accidentally lost during a campaign (e.g., due to agricultural machinery, adverse weather conditions, or animal activity) were excluded from the calculation of the number of valid samples for the respective farm and sampling campaign.

Laboratory Analysis and Classification

Following field collection, the captured specimens were immediately transferred to and preserved in 70% ethanol until laboratory sorting. All individuals were counted and initially separated into morphospecies. Final taxonomic identification was conducted by specialists to the lowest possible taxonomic level, following the taxonomic nomenclature adopted by the World Spider Catalog [1] and Spiders of Europe [2]. When species-level identification was not possible, specimens were assigned unique alphanumeric codes as morphospecies to avoid losing biological information and to prevent bias in subsequent analyses. This approach allows morphologically similar or cryptic taxa, which may occupy distinct ecological niches, to be retained as separate operational units.

Spiders were subsequently categorized into eight ecological guilds according to their foraging strategies, based on web architecture and hunting methods, following the framework proposed by Cardoso et al. [3]:

- (a) Sensing web weavers
- (b) Sheet web weavers
- (c) Space web weavers
- (d) Orb web weavers
- (e) Specialists
- (f) Ambush hunters
- (g) Ground hunters

- (h) Other hunters

References

1. World Spider Catalog. World Spider Catalog, version 27.5; Natural History Museum Bern: Bern, Switzerland, 2026. Available online: nmbe.ch.
2. Nentwig, W.; Blick, T.; Bosmans, R.; Kropf, C.; Stäubli, A. Spiders of Europe, version 09.2026. Available online: nmbe.ch.
3. Cardoso, P.; Pekár, S.; Jocqué, R.; Coddington, J.A. Global Patterns of Guild Composition and Functional Diversity of Spiders. *PLoS ONE* **2011**, *6*, e21710.

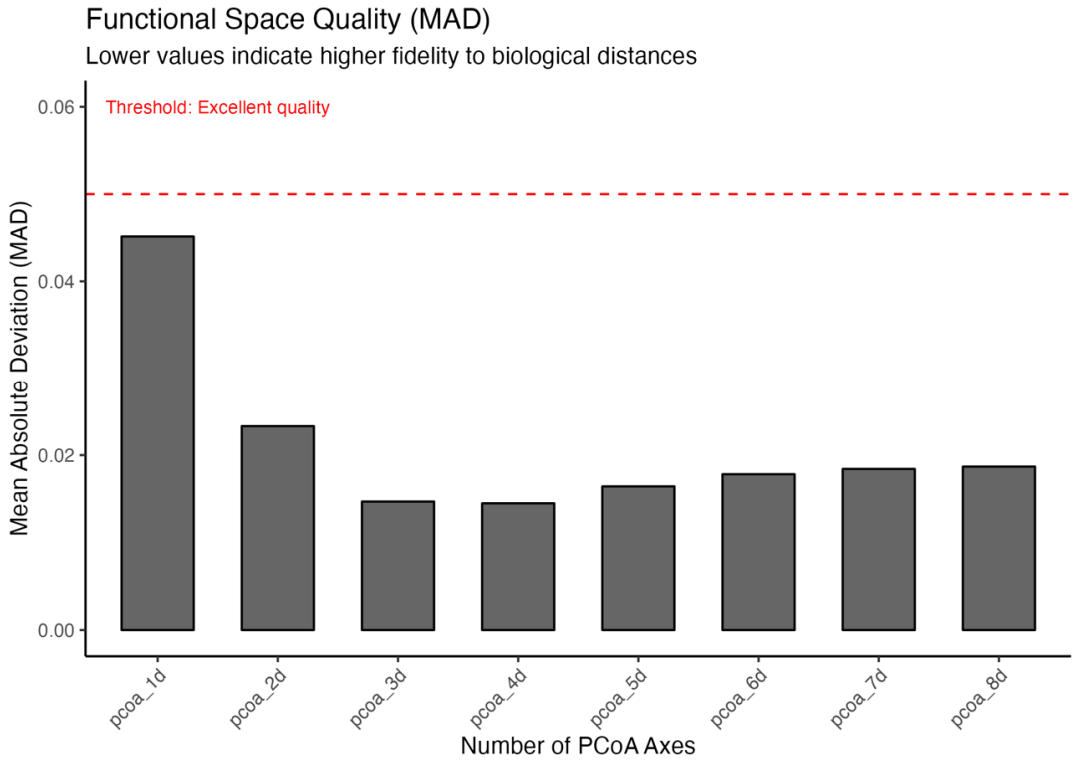


Figure S1. Functional space quality optimization for spider communities (2 to 8 PCoA axes). Lower values of Mean Absolute Deviation (MAD) indicate higher fidelity of the functional space to the original trait-based distances. Axis labels: (X) number of PCoA axes; (Y) Mean Absolute Deviation (MAD).

Table S1 Summary of sampling effort across studied farms and habitats in the Douro viticultural region. **NCH** – non-crop habitat; **CCT** – full ground cover; **CCH** – inter-row vegetation cover with herbicide application within rows; **BS** – bare soil due to tillage and herbicide application.

Locations	Year	Sampling Effort	Habitats according to Production Mode (n. º of samples)

		(hours)	CCH	BS	CCT	NCH
A	2018	96	6	6	30	6
B	2010	24	27	-	-	9
	2018	96	29	12	6	6
C	2010	24	27	-	-	9
D	2010	24	27	-	-	27
	2013	72	27	-	-	-
	2018	96	22	4	12	6
Total			**165**	**22**	**48**	**63**

Note: The totals displayed represent the baseline fieldwork design (298 traps). While all 298 units were utilized in univariate modeling (GLMMs/LMMs), a filtered subset of 200 active traps was deployed in downstream multivariate ordinations and functional space analysis following the exclusion of 98 empty row vectors due to mathematical zero-variance constraints.

Table S2. Full-dataset sensitivity analysis (N = 298 traps, including 98 zero-catch units) evaluating **(a)** pairwise PERMANOVA using zero-adjusted Bray–Curtis dissimilarity (dummy species pseudocount = 0.01) and (**b)**significant indicator taxa (IndVal.g, $P < 0.05$) compared against the active-trap baseline (N = 200).

a) Pairwise PERMANOVA (Zero-adjusted Bray–Curtis, N = 298)

Pairs	F	R^2	p-value	P(adj)	Sig.
NCH vs CCH	3.367	0.015	0.001	0.006	*
NCH vs CCT	5.945	0.052	0.001	0.006	*
NCH vs BS	2.018	0.023	0.053	0.318	
CCH vs CCT	3.613	0.017	0.001	0.006	*
CCH vs BS	1.159	0.006	0.241	1.000	
CCT vs BS	1.364	0.020	0.132	0.792	

Note: Habitat abbreviations: NCH – Non-crop habitat; CCT – Full ground cover; CCH – Inter-row vegetation cover with herbicide application under rows; BS – Bare soil. *P*(adj) indicates *P*-values adjusted for multiple comparisons using the Bonferroni correction; Sig. indicates statistical significance codes: '*' *P*(adj) < 0.05.

b) Significant indicator taxa (IndVal.g, *P* < 0.05) detected in the full-dataset sensitivity analysis (N = 298 traps, including 98 zero-catch units), compared against the active-trap baseline (N = 200).

Habitat Association	Code	Taxonomic Identity	Functional Guild	IndVal (N = 298)	*P*-value	Status vs. Active Baseline (N = 200)
BS	Sp223	*Pardosa* sp.	Cursorial ground hunter	0.333	0.005	**Retained** (0.378**, BS)
BS	Sp178	*Arctosa* sp.	Cursorial ground hunter	0.302	0.008	**Retained** (0.354**, BS)
BS	Sp219	*Pardosa* sp.	Cursorial ground hunter	0.292	0.013	**Retained** (0.341**, BS)
CCT	Sp154	*Gnaphosidae* sp.	Nocturnal ground hunter	0.391	0.009	**Emerged** (Dominant in CCT)
CCT	Sp116	*Nomisia* sp.	Nocturnal ground hunter	0.292	0.006	**Retained** (0.320*, CCT)
CCT	Sp98	*Leptodrassus albidus*	Nocturnal ground hunter	0.253	0.026	**Retained** (0.277*, CCT)
CCT	Sp259	*Pellenes* sp.	Diurnal visual hunter	0.206	0.033	**Emerged** (New in N = 298)
NCH	Sp45	*Linyphiidae* sp.	Sheet-web weaver	0.331	0.006	**Retained** (0.454***, NCH)
NCH	Sp8	*Tegenaria* sp.	Funnel-web weaver	0.250	0.023	**Retained** (0.343**, NCH)
BS + CCT	Sp344	*Zodarion* sp.	Ant-eating specialist	0.439	0.001	**Retained** (0.490**, BS+CCT)
BS + CCT	Sp342	*Zodarion* sp.	Ant-eating specialist	0.293	0.010	**Retained** (0.328*, BS+CCT)
BS + CCT	Sp54	*Dictyna* cf. *civica*	Cribellate canopy weaver	0.269	0.019	**Retained** (0.302*, BS+CCT)
BS + CCT	Sp64	*Castianeira badia*	Ant-mimicking diurnal hunter	0.269	0.010	**Retained** (0.302*, BS+CCT)
BS + CCT	Sp15	*Tegenaria* sp.	Funnel-web weaver	0.209	0.032	**Retained** (0.234*, BS+CCT)
BS + CCT	Sp273	*Neaetha* sp.	Diurnal visual hunter	0.209	0.035	**Retained** (0.234*, BS+CCT)
BS + CCT	Sp63	*Titanoeca* sp.	Cribellate web weaver	0.209	0.035	**Emerged** (New in N = 298)

Note: Habitat abbreviations: NCH – Non-crop habitat; CCT – Full ground cover; CCH – Inter-row vegetation cover with herbicide application under rows; BS – Bare soil. IndVal (*N* = 298) reports the indicator value statistic (IndVal.g) calculated across all 298 traps (999 permutations). In the final column (*Status vs. Active*

Baseline),"Retained" denotes indicator taxa that remained statistically significant across both datasets (with baseline IndVal.g values and associated habitats shown in parentheses), whereas "**Emerged**" denotes taxa that reached statistical significance ($P < 0.05$) only in the full dataset ($N = 298$). Asterisks indicate significance levels in the active-trap baseline ($N = 200$): **'*' $P < 0.05$; '**' $P < 0.01$; '***' $P < 0.001$**.

Table S3. Summary of spider data collected by pitfall traps in the Douro viticultural region (Portugal). Data represent the cumulative normalized spider activity density categorized by functional hunting guilds across different soil management treatments. **NCH**– non-crop habitat; **CCH** – inter-row vegetation cover with herbicide application within rows; **CCT** – full ground cover; **BS** – bare soil due to tillage and herbicide application.

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Ground hunters (Gh.)	Corinnidae	*Castianeira*	*Castianeira badia*	0	0	0.33	0	0.33
Ground hunters (Gh.)	Gnaphosidae	*Leptodrassex*	*Leptodrassex simoni*	0	0	1	0	1
Ground hunters (Gh.)	Gnaphosidae	*Micaria*	*Micaria sp.1*	0	0	1	0	1
Ground hunters (Gh.)	Gnaphosidae	*Micaria*	*Micaria sp.3*	0	0	1.33	0	1.33
Ground hunters (Gh.)	Gnaphosidae	*Zelotes*	*Zelotes egregioides*	0	0.25	1.5	0	1.75
Ground hunters (Gh.)	Gnaphosidae	*Zelotes*	*Zelotes fulvopilosus*	0.25	1.25	2	0	3.5
Ground hunters (Gh.)	Gnaphosidae	*Zelotes*	*Zelotes fuzeta*	0.25	0	0	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Zelotes*	*Zelotes semirufus*	0	0	4	0	4
Ground hunters (Gh.)	Gnaphosidae	*Zelotes*	*Zelotes sp.*	0	0	0	0.25	0.25
Ground hunters (Gh.)	Gnaphosidae	*Drassodes*	*Drassodes sp.5*	0	0.25	0.25	0	0.5
Ground hunters (Gh.)	Gnaphosidae	*Drassodes*	*Drassodes sp.6*	0	0	0	0.25	0.25
Ground hunters (Gh.)	Gnaphosidae	*Haplodrassus*	*Haplodrassus dalmatensis*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Haplodrassus*	*Haplodrassus sp.*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Phaeocedus*	*Phaeocedus sp.5*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Setaphis*	*Setaphis carmeli*	0	1	3	0	4
Ground hunters (Gh.)	Gnaphosidae	*Setaphis*	*Setaphis sp.*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Synaphosus*	*Synaphosus sauvagei*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Callilepis*	*Callilepis sp.*	0	1.25	1.25	0	2.5
Ground hunters (Gh.)	Gnaphosidae	*Callilepis*	*Callilepis sp.1*	0	0	2	0	2

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Ground hunters (Gh.)	Gnaphosidae	*Callilepis*	*Callilepis concolor*	0	1.75	7.08	0	8.83
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosa*	*Gnaphosa alacris*	0	0	2	0	2
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.7*	0	0	2	0	2
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.8*	2	0.75	0	0	2.75
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.9*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.10*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.11*	0	0.25	0.25	0	0.5
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.12*	0	0.75	0.25	0	1
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.13*	0	1	0.25	0	1.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.14*	0	1.25	0.5	0	1.75
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.15*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.16*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.17*	0	0	1	0.25	1.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.18*	0	0	0.5	0	0.5
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.19*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Gnaphosidae	*Gnaphosidae indet.*	*Gnaphosidae sp.20*	0	0	0.5	0	0.5
Ground hunters (Gh.)	Gnaphosidae	*Nomisia*	*Nomisia sp.*	0	1	0	0	1
Ground hunters (Gh.)	Gnaphosidae	*Nomisia*	*Nomisia sp.2*	1	0	4	0	5
Ground hunters (Gh.)	Gnaphosidae	*Nomisia*	*Nomisia sp.5*	0	0	0.67	0	0.67
Ground hunters (Gh.)	Gnaphosidae	*Nomisia*	*Nomisia sp.16*	0	0.75	0	0	0.75
Ground hunters (Gh.)	Lycosidae	*Alopecosa*	*Alopecosa albofasciata*	0.5	7.75	12.83	0.25	21.33
Ground hunters (Gh.)	Lycosidae	*Alopecosa*	*Alopecosa sp.*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Lycosidae	*Arctosa*	*Arctosa sp.31*	0	0.25	0.25	0	0.5
Ground hunters (Gh.)	Lycosidae	*Arctosa*	*Arctosa sp.32*	0	0	0.5	0	0.5
Ground hunters (Gh.)	Lycosidae	*Arctosa*	*Arctosa sp.33*	0.25	0	0.75	0	1
Ground hunters (Gh.)	Lycosidae	*Arctosa*	*Arctosa sp.34*	0.5	0	0	0.25	0.75
Ground hunters (Gh.)	Lycosidae	*Arctosa*	*Arctosa sp.35*	1	0.5	0.25	0	1.75

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Ground hunters (Gh.)	Lycosidae	*Hogna*	*Hogna radiata*	19.75	0	0	0.25	20
Ground hunters (Gh.)	Lycosidae	*Pardosa*	*Pardosa proxima*	0	0	0.33	0	0.33
Ground hunters (Gh.)	Lycosidae	*Pardosa*	*Pardosa sp.30*	0	0	0.75	0	0.75
Ground hunters (Gh.)	Lycosidae	*Pardosa*	*Pardosa sp.31*	0	0	0.75	0	0.75
Ground hunters (Gh.)	Lycosidae	*Trochosa*	*Trochosa sp.3*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Lycosidae	*Trochosa*	*Trochosa sp.4*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Lycosidae	*Trochosa*	*Trochosa sp.5*	0	0	0.25	0.5	0.75
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.8*	1	0	2	0	3
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.9*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.10*	0	0.25	0	0.25	0.5
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.11*	0	0.25	0	0	0.25
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.12*	19.75	1.25	0	0	21
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.13*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.14*	0	0	2	0	2
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.15*	0	7.25	8	0.25	15.5
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.16*	0	0	0.5	0.25	0.75
Ground hunters (Gh.)	Lycosidae	*Lycosidae indet.*	*Lycosidae sp.17*	0	0	0	5.5	5.5
Ground hunters (Gh.)	Linyphiidae	*Agyneta*	*Agyneta sp.3*	0.5	0	0	8.25	8.75
Ground hunters (Gh.)	Linyphiidae	*Parapelecopsis*	*Parapelecopsis sp.*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Linyphiidae	*Pelecopsis*	*Pelecopsis bucephala*	0	0.25	0.5	0	0.75
Ground hunters (Gh.)	Linyphiidae	*Prinerigone*	*Prinerigone vagans*	0	0	1	0	1
Ground hunters (Gh.)	Linyphiidae	*Typhochrestus*	*Typhochrestus bogarti*	0	0	1	0	1
Ground hunters (Gh.)	Linyphiidae	*Linyphiidae indet.*	*Linyphiidae sp.5*	3	0	1	0	4
Ground hunters (Gh.)	Linyphiidae	*Linyphiidae indet.*	*Linyphiidae sp.6*	0	0	0.25	0	0.25
Ground hunters (Gh.)	Linyphiidae	*Linyphiidae indet.*	*Linyphiidae sp.7*	0	1	0	0	1
Ground hunters (Gh.)	Linyphiidae	*Linyphiidae indet.*	*Linyphiidae sp.8*	0	0	0.5	0	0.5
Ground hunters (Gh.)	Oecobiidae	*Oecobius*	*Oecobius machadoi*	0	0	1.67	0	1.67

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion alacre*	0	2	1.83	0.25	4.08
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion styliferum*	0.5	0.75	14.17	0	15.42
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.*	0	2.25	0.25	0.25	2.75
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.1*	1	0	8	0	9
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.34*	0	1.25	6.5	0.25	8
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.35*	0	0.75	0	0	0.75
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.36*	0	6.5	4.5	3	14
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.37*	0	0.25	0	0	0.25
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.38*	0	0	0.75	0	0.75
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.39*	0	0	0.5	0	0.5
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.40*	0	0.25	0	0	0.25
Specialists (Spe.)	Zodariidae	*Zodarion*	*Zodarion sp.41*	0	0.25	0.25	0	0.5
Specialists (Spe.)	Zodariidae	*Selamia*	*Selamia reticulata*	0	0.25	0	0	0.25
Specialists (Spe.)	Dysderidae	*Dysdera*	*Dysdera sp.*	0.5	0.25	0	0	0.75
Sheet web weavers (Sh.w.w.)	Agelenidae	*Malthonica*	*Malthonica sp.1*	5	0	0	0	5
Sheet web weavers (Sh.w.w.)	Agelenidae	*Malthonica*	*Malthonica lusitanica*	12	0	0	0	12
Sheet web weavers (Sh.w.w.)	Agelenidae	*Eratigena*	*Eratigena feminea*	0.25	0.25	0	0.5	1
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria bucculenta*	0	0	1	0	1
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria feminea*	0	0	0.67	0	0.67
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria ramblae*	0	0	0.33	0	0.33
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.4*	1	0	3	0	4
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.24*	0	0.5	0.25	0	0.75
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.25*	0	0	0.25	0	0.25
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.26*	0.5	0	0	0	0.5
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.27*	0	0	0.5	0	0.5
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.28*	0	0.25	0	0	0.25
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.29*	0.5	0	2.25	0	2.75

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.30*	0	0.25	0	0	0.25
Sheet web weavers (Sh.w.w.)	Agelenidae	*Tegenaria*	*Tegenaria sp.31*	0	0.5	0	0	0.5
Sheet web weavers (Sh.w.w.)	Hahniidae	*Hahnia*	*Hahnia sp.1*	0	0	1	0	1
Sheet web weavers (Sh.w.w.)	Hahniidae	*Hahnia*	*Hahnia nava*	0	0	7	0	7
Other hunters (Oh.)	Oxyopidae	*Oxyopes*	*Oxyopes sp.1*	0	0	0.33	0	0.33
Other hunters (Oh.)	Philodromidae	*Thanatus*	*Thanatus sp.1*	0	0	0.33	0	0.33
Other hunters (Oh.)	Salticidae	*Aelurillus*	*Aelurillus luctuosus*	0	0	1	0	1
Other hunters (Oh.)	Salticidae	*Chalcoscirtus*	*Chalcoscirtus infimus*	0	0.25	0.67	0	0.92
Other hunters (Oh.)	Salticidae	*Cyrba*	*Cyrba algerina*	0	0	0.33	0	0.33
Other hunters (Oh.)	Salticidae	*Euophrys*	*Euophrys bulbo*	0	0	0.33	0	0.33
Other hunters (Oh.)	Salticidae	*Euophrys*	*Euophrys rufibarbis*	2	0.25	0	0	2.25
Other hunters (Oh.)	Salticidae	*Heliophanus*	*Heliophanus sp.*	0	0	0.33	0	0.33
Other hunters (Oh.)	Salticidae	*Myrmarachne*	*Myrmarachne sp.2*	0	0	0.33	0	0.33
Other hunters (Oh.)	Salticidae	*Neaetha*	*Neaetha sp.1*	0	0	1	0	1
Other hunters (Oh.)	Salticidae	*Phlegra*	*Phlegra sp.8*	0	0	0.5	0	0.5
Other hunters (Oh.)	Salticidae	*Phlegra*	*Phlegra sp.9*	0	0.5	0	0	0.5
Other hunters (Oh.)	Salticidae	*Salticidae indet.*	*Salticidae sp.3*	0	0	0.25	0	0.25
Other hunters (Oh.)	Scytodidae	*Scytodes*	*Scytodes velutina*	4	0	2	0	6
Ambush hunters (Am.h.)	Thomisidae	*Bassaniodes*	*Bassaniodes bliteus*	0	0.5	0.25	0	0.75
Ambush hunters (Am.h.)	Thomisidae	*Bassaniodes*	*Bassaniodes sp.3*	0	0.75	0	0	0.75
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila cf. pauxilla*	0	0.25	0.25	0.25	0.75
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila sp.5*	0	0	0.33	0	0.33
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila sp.12*	0	0.25	0	0.33	0.58
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila sp.13*	0	0	0.5	0	0.5
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila sp.14*	0	0	0.75	0	0.75
Ambush hunters (Am.h.)	Thomisidae	*Ozyptila*	*Ozyptila sp.15*	0	0	0.25	0	0.25
Ambush hunters (Am.h.)	Thomisidae	*Xysticus*	*Xysticus bufo*	0	0	3.67	0	3.67

Guilds	Family	Genus	Species	NCH	CCT	CCH	BS	Total
Ambush hunters (Am.h.)	Thomisidae	*Xysticus*	*Xysticus kochi*	0	5.75	1	0	6.75
Ambush hunters (Am.h.)	Thomisidae	*Thomisidae indet.*	*Thomisidae sp.4*	0	0	0.25	0	0.25
Ambush hunters (Am.h.)	Thomisidae	*Thomisidae indet.*	*Thomisidae sp.5*	0	0	0.75	0	0.75
Ambush hunters (Am.h.)	Sicariidae	*Loxosceles*	*Loxosceles rufescens*	0	0	0	0.25	0.25
Space web weavers (Sp.w.w.)	Theridiidae	*Euryopis*	*Euryopis episinoides*	0	0	1.25	0	1.25
Space web weavers (Sp.w.w.)	Theridiidae	*Steatoda*	*Steatoda incomposita*	0	0	1	0	1
Space web weavers (Sp.w.w.)	Theridiidae	*Episinus*	*Episinus sp.1*	3	0	1	0	4
Space web weavers (Sp.w.w.)	Theridiidae	*Theridiidae indet.*	*Theridiidae sp.2*	1	0	1	0	2
Space web weavers (Sp.w.w.)	Titanoecidae	*Titanoeca*	*Titanoeca sp.*	1	0	0	0	1
Space web weavers (Sp.w.w.)	Dictynidae	*Marilynia*	*Marilynia bicolor*	0	0.5	1.25	0	1.75
Sensing web weavers (Se.w.w.)	Nemesiidae	*Iberesia*	*Iberesia sp.3*	0.25	0	0	0	0.25
Sensing web weavers (Se.w.w.)	Nemesiidae	*Nemesiidae indet.*	*Nemesiidae sp.1*	0.5	0	0	0.75	1.25
Sensing web weavers (Se.w.w.)	Nemesiidae	*Nemesiidae indet.*	*Nemesiidae sp.2*	1.25	0	0	2	3.25
Sensing web weavers (Se.w.w.)	Nemesiidae	*Nemesiidae indet.*	*Nemesiidae sp.3*	0	0.25	0	0	0.25

Note: Spider abundance represents cumulative normalized values of individuals per trap per day. This normalization was performed to account for unbalanced sampling effort.

* Guild names follow the classification by Cardoso *et al.* (2011).

Table S4. Species richness and sampling coverage of spiders in Douro vineyard management habitats

Habitat	Active Traps	S. Obs	Chao² *	SE	Lower 95% C	SC (%)
BS	16	32	111.22	63.90	32.00	36.31%
CCH	111	97	158.37	22.04	115.16	78.55%
CCT	39	55	100.36	22.18	56.87	72.18%
NCH	34	29	49.04	39.13	29.00	67.48%

Note: Habitat abbreviations: NCH – non-crop habitat; CCT – full ground cover; CCH – inter-row vegetation cover with herbicide application under rows; BS – bare soil due to tillage and herbicide application. Active Trap – number of traps with positive spider captures (N = 200); S_{obs} – observed species richness; Chao2* – asymptotic species richness calculated using the Chao2 incidence-based estimator; SE – standard error of the Chao2 estimate; Lower 95% CI – lower bound of the 95% confidence interval (truncated at S_{obs}); SC (%) – estimated sample coverage

Table S5. Estimated Marginal Means (EMMs) for spider taxonomic diversity metrics across the evaluated habitat types.

Metric & Global Statistics	Habitat	EMM	CI (95%)
Activity-density (ind/trap-day) [2]			
Global Test [1]*:*	NCH (Ref.)	1.29	(0.72 – 2.33)
(χ^2) = 3.497, *df* = 3, *P* = 0.321 [3]	BS	0.81	(0.38 – 1.71)
Model Fit: AIC = 1201.5 [4]	CCH	0.91	(0.54 – 1.53)
	CCT	0.83	(0.44 – 1.57)
Species Richness (spp/trap-day) [2]			
Global Test [1]*:*	NCH (Ref.)	0.45	(0.32 – 0.63)
(χ^2) = 3.969, *df* = 3, *P* = 0.265 [3]	BS	0.49	(0.33 – 0.72)
Model Fit: AIC = 903.0 [4]	CCH	0.58	(0.47 – 0.72)
	CCT (.)	0.63	(0.48 – 0.84)
Shannon Diversity (H') [2]			
Global Type II Wald Test [1]:	NCH (Ref.)	1.08	(1.02 – 1.29)
(χ^2) = 2.111, *df* = 3, *P* = 0.550 [3]	BS	1.06	(1.01 – 1.37)
Model Fit: *REML* = 1519.4 [4]	CCH	1.14	(1.05 – 1.43)
	CCT	1.09	(1.02 – 1.43)
Simpson Diversity (D) [2]			
Global Type II Wald Test [1]:	NCH (Ref.)	1.97	(1.85 – 2.10)
(χ^2) = 8.702, *df* = 3, ***P* = 0.034** [3]	BS	2.17	(1.98 – 2.43)
Model Fit: *REML* = 88.4 [4]	CCH	2.08	(1.98 – 2.20)
	CCT *	**2.24**	**(2.07 – 2.45)**

Note: NCH - Non-crop habitat (baseline reference category); CCT – Full ground cover; CCH – Inter-row vegetation cover with herbicide application under rows; BS – Bare soil due to tillage and herbicide application; df – degrees of freedom; AIC – Akaike Information Criterion; REML – Restricted Maximum Likelihood; EMM – Estimated Marginal Means; CI – Confidence Interval. Bold values indicate statistically significant differences ($P < 0.05$; asterisk denotes significant pairwise difference from NCH at $P = 0.005$); dot (.) denotes a statistically non-significant directional trend at $P = 0.083$)

[1] Global model significance and fit metrics. Linear models (LMM) were fitted using REML with trap_days as a continuous fixed covariate, whereas generalized linear models (GLMM) utilized maximum likelihood

estimation with a Negative Binomial (nbinom2) distribution and a log(trap_days) offset to account for count data properties. All models were validated for overdispersion and zero-inflation using the DHARMa package.

[2] EMMs and 95% Confidence Intervals were back-transformed from the log-scale to the original scale via the ggeffects package (conditioned on trap_days = 1 for count metrics, and via exp(EMM) - 0.001 at mean sampling effort for log-transformed diversity indices).

[3] Overall habitat type effect significance derived from Type II Wald chi-square tests.

[4] Variance components and standard deviations for spatial (farm) and temporal (season, year) random effects, as well as model residuals, are detailed in Table 1 of the main text.

Table S6. Pairwise PERMANOVA comparisons of spider communities across vineyard management habitats in the Douro region, based on (a) taxonomic and (b) functional diversity.

a) Taxonomic diversity

Pairs	*F*	R^2	*p*-value	*P* (adj)	Sig.
NCH vs CCH	3.628	0.025	0.001	0.006	*
NCH vs CCT	4.184	0.056	0.001	0.006	*
NCH vs BS	1.836	0.037	0.008	0.048	*
CCH vs CCT	3.367	0.022	0.001	0.006	*
CCH vs BS	1.555	0.012	0.036	0.216	
CCT vs BS	1.421	0.026	0.112	0.672	

b) Functional diversity

Pairs	*F*	R^2	*p*-value	*P* (adj)	Sig.
NCH vs CCH	2.197	0.015	0.031	0.186	
NCH vs CCT	5.722	0.075	0.002	0.012	*
NCH vs BS	2.947	0.058	0.010	0.060	.
CCH vs CCT	2.985	0.020	0.008	0.048	*
CCH vs BS	1.348	0.011	0.188	1.000	
CCT vs BS	1.389	0.026	0.199	1.000	

Note: Habitat abbreviations: NCH – non-crop habitat; CCT – full ground cover; CCH – inter-row vegetation cover with herbicide application under rows; BS – bare soil.
For panels (a) and (b), *P*(adj) indicates the p-values adjusted for multiple comparisons using the Bonferroni correction method; Sig. indicates statistical significance codes: '*' *P*(adj) < 0.05; '.' *P*(adj) < 0.1 (marginally significant).

Table S7. Taxonomic and functional multi-site beta-diversity partitioning (Sørensen index) for spider communities across a soil management gradient in vineyards of the Douro region, evaluated at (a) the macroscale regional landscape pool (*N* = 200 active traps) and (b) the local intra-habitat scale using sample-size-corrected iterative rarefaction (*N* = 16 traps per habitat).

a) Global regional landscape pool (among-habitat multi-site partitioning, *N* = 200)

Dimension	β_{SOR}	β_{SIM}	β_{NES}
Taxonomic	0.74	0.60 (81%)	0.14 (19%)
Functional	0.52	0.05 (9%)	0.47 (91%)

b) Intra-habitat multi-site beta-diversity partitioning (Permuted Means, N = 16)

Habitat	Dimension	βSOR	βSIM	βNES
NCH	Taxonomic	0.963	0.949	0.014
NCH	Functional	0.154	0.142	0.012
CCT	Taxonomic	0.954	0.931	0.023
CCT	Functional	0.159	0.140	0.019
CCH	Taxonomic	0.968	0.952	0.015
CCH	Functional	0.156	0.142	0.014
BS	Taxonomic	0.973	0.960	0.012
BS	Functional	0.154	0.144	0.010

Note: β_{SOR} – Total Sørensen beta-diversity; β_{SIM} – Simpson dissimilarity component (representing spatial turnover or species and trait replacement); β_{NES} – Nestedness-resultant fraction. In panel **(a)**, percentages in parentheses indicate the relative contribution of the turnover and nestedness components to total beta-diversity across the aggregated regional pool. In panel **(b)**, habitat abbreviations denote: NCH – non-crop habitat; CCT – full ground cover; CCH – inter-row vegetation cover with herbicide application under rows; BS – bare soil (tillage and herbicide); values represent permuted multi-site means derived from sample-size-corrected iterative rarefaction (999 permutations) standardized to the minimum replication threshold (N = 16 independent traps per habitat). All beta-diversity partitioning analyses were performed using the betapart package in R.

Table S8. Summary of spider Functional Entities (FEs), species richness across the evaluated habitat types, and functional trait profiles with highlighted indicator taxa along the soil disturbance gradient in Douro vineyards.

FE_ID	BS	CCH	CCT	NCH	Traits	Key associated bioindicator species
FE_1	13**	40	22*	16	No web, active hunter, euryphagous, ground, diurnal, nocturnal	Sp178 ** (Arctosa sp.), Sp223 ** (Pardosa sp.) Sp219 **(Pardosa sp.), Sp116 * (Nomisia sp.)
FE_2	4	13	8	2	No web, ambush hunter, euryphagous, ground, vegetation, diurnal, nocturnal	—
FE_3	4*	10	7*	1***	Capture web, tube web, sheet web, euryphagous, ground, vegetation, nocturnal	Sp45 *** (Linyphiidae sp.), Sp8 ** (Tegenaria Sp28 * (Tegenaria sp.), Sp15 * (Tegenaria sp.)
FE_4	2*	12	2*	2	No web, active hunter, euryphagous, ground, vegetation, diurnal	Sp64 * (Castianeira badia), Sp273 * (Neaetha
FE_5	3**; *	7*	8**; *	3	No web, ambush hunter, active hunter, stenophagous, ground, diurnal, nocturnal	Sp344 ** (Zodarion sp.), Sp342 * (Zodarion s Sp355 * (Zodarion sp.)
FE_6	1	4	3	1*	Capture web, sheet web, space web, euryphagous, ground, vegetation, nocturnal	Sp47 * (Prinerigone vagans)
FE_7	3*	3	2*	2	Capture web, space web, euryphagous, ground, vegetation, diurnal, nocturnal	Sp54 * (Dictyna cf. civica)
FE_8	1	3	2*	1	No web, active hunter, euryphagous, ground, vegetation, diurnal, nocturnal	Sp98 * (Leptodrassus albidus)
FE_9	0	2	0	0	Capture web, sheet web, euryphagous, ground, diurnal, nocturnal	—
FE_10	0	1	0	0	Sensing web, sheet web, ambush hunter, euryphagous, ground, nocturnal	—
FE_11	0	1	0	0	No web, ambush hunter, euryphagous, ground, nocturnal	—
FE_12	0	0	1	0	Sensing web, tube web, euryphagous, ground, nocturnal	—
FE_13	1*	0	0	1*	No web, active hunter, euryphagous, vegetation, diurnal, nocturnal	Sp225 * (Pardosa sp.)
FE_14	0	1	0	0	No web, active hunter, stenophagous, ground, nocturnal	—

Note: Values under habitat type columns (BS, CCH, CCT, NCH) represent the specific species richness contributing to each Functional Entity (FE). Genus names and specific epithets are italicized according to standard taxonomic rules. Habitat type abbreviations: NCH – Non-crop habitat; CCT – full ground cover; CCH – inter-row vegetation cover with herbicide application in rows; BS – bare soil due to tillage and herbicide application. Asterisks within the habitat type columns indicate the presence of statistically significant indicator species (IndVal; listed in the rightmost column) associated with that habitat or habitat combination: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. Multiple asterisks separated by semicolons (e.g., 3**; * or 8**; *) denote different significance levels across distinct indicator species or habitat combinations evaluated within that FE.

Table S9. Functional trait contribution and significance to the first two axes of the principal coordinate analysis (PCoA).

Functional Trait	PC1 (R^2)	*P*-value (PC1)	PC2 (R^2)	*P*-value (PC2)
No Web	0.817	< 0.001	0.044	0.011
Capture Web	0.816	< 0.001	0.000	—
Sheet Web	0.688	< 0.001	0.054	0.005
Active hunter	0.635	< 0.001	0.138	< 0.001
Vegetation	0.428	< 0.001	0.110	< 0.001
Tube Web	0.413	< 0.001	0.000	—
Space Web	0.283	< 0.001	0.000	—
Stenophagous	0.247	< 0.001	0.134	< 0.001
Euryphagous	0.247	< 0.001	0.134	< 0.001
Ambush hunter	0.085	< 0.001	0.298	< 0.001
Nocturnal	0.000	—	0.485	< 0.001
Sensing Web	0.000	—	0.217	< 0.001
Diurnal	0.000	—	0.217	< 0.001

Note: Values represent the strength of association (R^2). Significant effects are indicated by ($P < 0.05$). Dashes (—) and zero entries (0.000) indicate traits that were not included in the top 10 contribution list for that specific axis.