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# Influence of Mediterranean university campuses on taxonomic, phylogenetic, and functional diversity of urban spiders (Araneae)

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University campuses are well differentiated places from other urban areas because they are usually built to foster an educational environment, support scientific research and nature conservation. However, few studies have tested their potential benefit for urban biodiversity, which could be especially relevant in understudied hot spots, like the Mediterranean region. Spiders, as top urban predators, play a vital role in ecosystem functioning and serve as bioindicators for certain habitat alterations. Here, we investigated whether university campuses in a Mediterranean city hold higher levels of spider diversity than other non-campus urban areas. To do so, we analyzed abundance and the taxonomic, functional and phylogenetic diversity of ground-dwelling and web-weaving spider communities of three university campuses and three other non-campus urban areas in the city of Granada (Spain). Contrary to our expectations, the results suggest that university campuses harbor similar levels of spider diversity to other urban areas. Furthermore, we identified certain urban features that can significantly influence spider assemblages in cities. The presence of native and reduced maintenance along with specific surface types (i.e., herbaceous, campus buildings, pavement and bare soil) were found to enhance the diversity of the urban ground-dwelling spider communities, while web-weaving species are more susceptible to the distance to the outskirts, university campuses management or landscape coverages (i.e., herbaceous or bare soil). These findings suggest that such features should be considered when designing urban areas to promote urban biodiversity.

## KEYWORDS

anthropogenic habitats, biodiversity assessment, green spaces, spider assemblages, urbanization

# 1 Introduction

Recent reports from the United Nations highlight the relentless trajectory of urbanization, with the global human population expected to surge predominantly in urban areas over the next three decades (United Nations, 2019, 2022). However, the expansion of urban areas comes at a cost to biodiversity and ecosystems (Peng et al., 2020; Ren et al., 2022). The transformation of natural habitats into urban landscapes is intricately linked to environmental changes, habitat loss, and fragmentation, all of which pose significant threats to global biodiversity (Groom et al., 2006; Aronson et al., 2014; Ibáñez-Álamo et al., 2017). Moreover, the negative effects of urbanization on biodiversity are expected to intensify in the near future (Seto et al., 2012; Li et al., 2022).

Historically, naturalists and ecologists disregarded urban areas, considering them less valuable than wild or pristine environments, a perspective prevalent in the first half of the twentieth century (Grimm et al., 2008). However, this viewpoint has evolved, recognizing that cultural and biological diversity contribute to resilience and sustainability (Berkes and Ross, 2013; Grimm, 2020). Urbanization brings various environmental effects, not all negative, as human impacts diversify urban landscapes, creating unique habitats (Gaston, 2010). These diverse land uses form the basis for the research field of urban ecology and biodiversity conservation (Breuste et al., 2008; Egerer et al., 2017). In this sense, urban areas can play a crucial role in conservation science, serving as the last refuges for several plant and animal species lost due to habitat destruction (Aronson et al., 2014; Ives et al., 2016; Soanes and Lentini, 2019). Therefore, reconciling urban development with biodiversity conservation emerges as a critical imperative, underscored by its inclusion in the Sustainable Development Goals (goals 11 and 15; United Nations, 2015). However, integrating scientific knowledge into urban policies, governance, and design still remains a challenge (Gaston, 2010; Ikin et al., 2015; Foo et al., 2018).

One of the main questions concerning urbanization is how urban spaces contribute to maintaining biodiversity (Heyman et al., 2017). Some studies have suggested that the presence of species with varying degrees of tolerance to urbanization can lead to biotic homogenization, as only those tolerant would endure (McKinney, 2006; Knop, 2016). This phenomenon increases local biodiversity at the expense of global biodiversity by replacing native taxa with non-native ones (McKinney and Lockwood, 1999), a particularly sensitive situation in regions with a high level of endemic species, such as the Mediterranean area (Cuttelod et al., 2009; Seto et al., 2012). Thus, it is important to identify which species are more tolerant and, for those less tolerant, to study how to minimize the negative impact of urban management to maintain, or even enhance, their presence (Jokimäki et al., 2018). From this perspective, a well-designed urban landscape can serve as a crucial factor in balancing human population growth with biodiversity conservation (Müller et al., 2010; Garrard et al., 2018). Urban species conservation depends on the success of

programs managing green patches and habitat corridors (Vrezec et al., 2021).

Among urban green spaces, university campuses deserve special mention, as their open areas provide users with places for reflection, rest, and socialization, among other functions (Tudorie et al., 2020). These spaces also serve as strategic hubs for promoting sustainability and the development of environmental awareness among citizens, such as strengthening their connection with nature (Colding and Barthel, 2017). Moreover, they provide researchers, students, and staff with the tools to showcase research developments, achievements, and applied improvements in a representative part of the city (Yerokhin et al., 2025). In this way, university campuses can be seen as cornerstones linking nature conservation, research, and the cultivation of environmental awareness among citizens.

Historically, the establishment of university campuses in natural areas has helped preserve patches of original vegetation within their boundaries (Wheeler, 2008). Additionally, because of the aforementioned functions, it is common for campuses to implement improvements in green space management—such as modified mowing practices and the incorporation of wildflower gardens—and to carry out projects to renaturalize wetlands, grow native plant gardens, install insect hotels, create botanical gardens, and establish other living laboratories (Bliss et al., 2021; Kueffer et al., 2025; Yerokhin et al., 2025). These characteristics position university campuses as urban areas composed of a heterogeneous mosaic of habitats that offer breeding and feeding grounds for an important range of species (Wheeler, 2008; Sattler et al., 2010). Internal motivation within universities to improve their green spaces drives changes that enhance biodiversity, as a broad array of taxa can benefit from shifts in vegetation management—such as increased understorey vegetation and higher native plant diversity (Threlfall et al., 2017).

It is important to consider that, in some cases, species richness in university campuses might appear higher simply because survey effort in these areas is higher than in other urban locations, as it has been described for plant diversity—because they serve as home to botanists (Moerman and Estabrook, 2006). Although species richness is important for assessing ecosystem functioning, other biodiversity metrics are also essential (Sattler et al., 2010). We still lack a comprehensive understanding of how urban communities interact with university campuses, and targeted studies are needed to investigate this relationship more concretely. Moreover, most research on university campuses is geographically biased toward certain countries such as China, India, and the USA, as noted by Liu et al. (2021), leaving significant knowledge gaps in the Southern Hemisphere and in key biodiversity hotspots. Given that the Mediterranean region is one of the most sensitive biodiversity hotspots to urbanization (Seto et al., 2012; Carpio et al., 2017), it is crucial to better understand the impacts of different urban land uses—such as university campuses—in this region, and to identify potential solutions or mitigation strategies to minimize those impacts. Previous research on various animal taxa suggests that Mediterranean university campuses may be more biodiverse than other urban areas (Arjona et al., 2023; Sanllorente et al., 2023).

Nevertheless, studies on university campuses often show a taxonomic bias, with plants and vertebrates being the most studied groups (Liu et al., 2021), while much less is known about urban arthropods. Among arthropods, spiders (Arachnida: Araneae) are abundant and dominant predators in urban ecosystems (Meineke et al., 2017; Trigos-Peral et al., 2020). However, their community composition varies depending on urban landscape features and management practices (Lowe et al., 2018; Delgado de la Flor et al., 2020), and some species may serve as indicators of habitat disturbance (Magura et al., 2010; Burkman and Gardiner, 2015). Additionally, studying their traits and functional identities has proven to be an effective approach for predicting changes in ecosystem functioning (Gagic et al., 2015; Schirmel et al., 2016). The main goal of this study is to investigate if university campuses have higher levels of spider diversity than other urban areas as it has been shown for other arthropods (Arjona et al., 2023). To do so, we analyzed several components of diversity (taxonomic, phylogenetic, and functional) of the urban spider communities within a Mediterranean city. By considering different diversity components, our knowledge of the ecological outcomes and patterns improves, helping identify more efficient management strategies (Beninde et al., 2015; Ibáñez-Álamo et al., 2020). Additionally, we explored various urban landscape variables that could influence spider assemblages and help enhance urban

biodiversity through targeted practices (see Argañaraz et al., 2018; Lowe et al., 2018; Delgado de la Flor et al., 2020).

## 2 Materials and methods

### 2.1 Field work

Field work was conducted in the city of Granada (Spain) in the same areas previously analyzed in Arjona et al. (2023): three university campuses (FN, CA, and PTS) and three other (non-campus) urban areas. All study areas were separated by at least 1 km to ensure their independence. For comparison purposes, each university campus was paired with another non-campus urban area, so that both had equal perimeter and size (Figure 1). Within each area, we established six sampling points separated by a minimum distance of 100 meters. There, ground-dwelling spiders were collected with pitfall traps (in spring 2022) while web spiders were surveyed by sight (in spring 2023). Sampling occurred six times at two-week intervals, avoiding rainy or excessively windy days (>4 of Beaufort wind scale). Pitfall traps consisted in plastic containers of 55-mm diameter and 75-mm depth, half-filled with soapy water (Woodcock, 2005; Carpintero and Reyes-López, 2014). The traps were left in place for 48h, after which the collected spiders

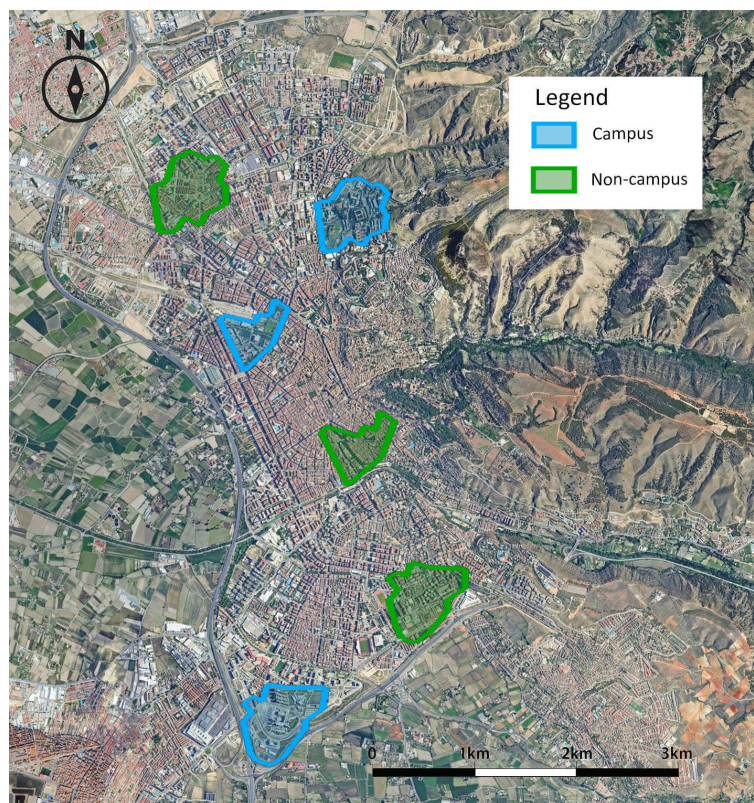


FIGURE 1

Map showing the location and shape of the sampling areas in the city of Granada. University campus areas are shown in blue and non-campus areas in green.



were preserved in ethanol for identification in the laboratory. Web-weaving spiders were sampled using the protocol described by Jiménez-Valverde and Lobo (2005). This involved an active 15-minute search within a 10-meter radius circle centered on each pitfall trap point. Specimens were directly collected, preserved in ethanol, and subsequently identified in the lab using taxonomic keys (Nentwig et al., 2023). Adults were identified to the species level (348 specimens), while juveniles (189 specimens) were identified to the genus level when the species-level identification was not possible. Species and genus names were used in accordance with the World Spider Catalog (2023). We decided to include juveniles in the analyses as several studies have demonstrated their importance for obtaining reliable results on spider diversity assessments (e.g., Jiménez-Valverde and Lobo, 2006; Domènech et al., 2022). However, we also performed the same statistical analyses using only adult specimens to check for potential inconsistencies in the results.

## 2.2 Landscape variables

To investigate the effects of land cover on urban spiders, we selected a 50-m radius to represent local-scale landscape influence, and 100-m and 500-m radii to capture broader landscape effects. These spatial scales were chosen based on previous studies conducted on spider communities (Argañaraz et al., 2018; Cabon et al., 2024). At the 50m local-scale, land cover data for each of the 36 sampling points were retrieved from Arjona et al. (2023). This assessment was performed following the classification of three primary elements: vegetation, impervious surfaces and buildings following Cadenasso et al. (2007). Using this framework, we obtained proportional coverage data of woody vegetation (trees and shrubs), herbaceous vegetation (herbs and grasses), bare soil, pavement, and buildings. To characterize land-cover composition at the 100-m and 500-m scales, we used the Dynamic World dataset (Google Dynamic World V1; Brown et al., 2022), which provides global, near real-time land-cover classifications derived from Sentinel-2 imagery at a 10-m spatial resolution. Using Google Earth Engine (Gorelick et al., 2017), we extracted the annual mean probabilities for the same land-cover classes considered at the local scale (i.e., woody vegetation, herbaceous vegetation, and bare soil) by averaging all available Dynamic World scenes separately for each study year (2022 and 2023). However, at these broader spatial scales, we used the built-land class from the Dynamic World classification, which jointly represents the local-scale classes pavement and buildings.

In addition, vegetation at each sampling point (50-m radius) was classified into five levels of nativeness (0, when all vegetation is non-native; 1, if less than 10% of the vegetation is native; 2, when 11–35% of the vegetation is native; 3, between 36 and 75% of the vegetation is native; and 4, if more than 75% of the vegetation is native) as well as the management intensity (0, for no maintenance; 1, for basic maintenance; 2, if annual weeding; 3, when regular mowing; and 4, if regular mowing and reseeding). Finally, the distance to the urban outskirts was measured, as this factor can

influence urban arthropod diversity (McIntyre, 2000). This was measured as the shortest Euclidean distance to the city edge (defined by the presence of cultivated land or peri-urban vegetation formations) using Google Earth Pro Version 7.3.

## 2.3 Biodiversity estimations

All diversity indices (taxonomic, phylogenetic, and functional) were estimated using the R package *BAT* (Cardoso et al., 2015). Species counts, for adults, and genera counts, for adults and juveniles, were aggregated across the six temporal replicates for these calculations. A phylogenetic dendrogram was constructed by generating a phylogenetic tree based on the Linnean hierarchy, where genera are separated by 0.5 and species by 0.25, using the function *linnean*. For functional diversity, relevant traits were retrieved from databases for spider community characterization (Cardoso et al., 2011; Macías-Hernández et al., 2020). For species for which some data was not available, we used those from the closest species (within the genus otherwise within the family). These traits—including web type, hunting method, trophic specialization, vertical stratification in vegetation, and circadian activity—were chosen for their ecological relevance in structuring spider assemblages, particularly in urban environments, as they reflect key strategies of resource acquisition, habitat preferences, and behavioral adaptation. Traits were standardized using a Multiple Factor Analysis (MFA), which summarizes the main axes of variation in spider resource acquisition strategies. Species/genera  $\times$  traits matrices were subjected to a hierarchical clustering procedure using UPGMA (Unweighted Pair Group Method with Arithmetic Mean) based on the principal components derived from the MFA, calculated with the function *MFA* in the *FactoMineR* package (Béreau-Bertaut and Pagès, 2008). Finally, the *tree.build* function was applied to produce the functional tree. Subsequently, species richness, functional and phylogenetic diversity were calculated using the function *alpha* from the *BAT* package (Cardoso et al., 2015).

## 2.4 Statistical analyses

Spatial autocorrelation was assessed by conducting Mantel tests comparing the geographical distance with the Bray–Curtis dissimilarity between spider assemblages in campus and non-campus areas. Mantel tests were performed using the R package *vegan* (Legendre and Legendre, 2012). These matrices were compared using Spearman's rank correlations and the significance of the tests was revised by permutation with 9,999 randomizations. The Bray–Curtis dissimilarity matrix showed no significant relationship with the geographic distance for both, species (Mantel statistic  $R = -0.03012$ ,  $p\text{-value} = 0.7122$ ) or genera (Mantel statistic  $R = -0.05401$ ,  $p\text{-value} = 0.8373$ ), and thus no spatial autocorrelation was found; therefore, no corrections were implemented in the following analyses. Then, we calculated the accumulation curves of our sampling for both methodologies

(pitfalls and web search) and both taxonomic levels (species and genera) using the R package *iNEXT* (Hsieh et al., 2016).

Then, we analyzed four components of spider diversity (abundance, species richness, phylogenetic and functional diversity) at the species (only adults) and genus (adults and juveniles) level, in two possible habitats (ground and web), and across three spatial scales (50-m, 100-m, and 500-m) by fitting generalized linear models (GLMs). All models were initially fitted including the study area ID (six in total) as a random effect to account for potential non-independence among sampling sites. However, the variance associated with this term was negligible (approaching zero), and likelihood ratio tests did not support its retention. Each model included the following fixed predictors: the proportion of land-cover elements within the corresponding buffer (woody vegetation, herbaceous vegetation, and bare soil at every scale, and pavement and buildings for the local scale, 50-m, or built-land for 100-m and 500-m scales), the level of native flora (0–4), management intensity (0–4), and distance to the city outskirts (km). The type of urban area (Campus vs. Non-campus) was included as a fixed factor and, except at the 500-m scale (as this buffer exceeded the physical extent of the campus area and could therefore yield misleading results), as an interaction term with all previously mentioned predictors to test for potential campus-related effects. Also, for phylogenetic and functional diversity, species richness was included as a covariate to account for its potential influence. Prior to model fitting, we examined pairwise Spearman correlations among all explanatory variables and excluded those showing  $|r| > 0.6$  to avoid multicollinearity (Dormann et al., 2013).

For species richness, we used GLMs with a Poisson error distribution, whereas abundance models showing overdispersion (residual deviance exceeding residual degrees of freedom) were refitted using a negative binomial distribution to obtain reliable estimates of standard errors. For functional and phylogenetic diversity, we applied linear models (LMs) assuming Gaussian errors. Response variables deviating from normality were log-transformed prior to model fitting. Because phylogenetic diversity values for web-weaving spiders at the species level were highly right-skewed and showed very limited variance across sites, we were unable to achieve normality through any standard transformation; consequently, this response variable was not modeled further.

For each spatial scale (50-m, 100-m, and 500-m), we fitted a separate full model including all explanatory variables and their corresponding interactions with type of urban area. Fixed effects corresponded to the landscape variables measured at each scale, while native vegetation and management intensity were included in all models regardless of scale to account for local habitat characteristics. Model selection was then performed independently for each spatial scale using Akaike's Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson, 2004). Conditional model averages were derived from the best-supported candidate models (i.e.,  $\Delta\text{AICc} < 2$ ) to obtain robust estimates of variable effects. All models were run with the R packages *lme4* (Bates et al., 2003) and *lmerTest* (Kuznetsova et al., 2013). The normality of the data was assessed with Shapiro–Wilk

tests and the R package *stats* (Royston, 1995) whereas homoscedasticity and multicollinearity were examined with the R package *car* (Fox et al., 2001). Model selection and averaging were performed using the *MuMIn* package (Bartoń, 2010).

### 3 Results

A total of 537 individuals were collected, of which 280 corresponded to pitfall traps and 257 to webs. 55 genera (adults and juveniles) and 47 species (only adults) were identified, the ground-dwelling habitat hosting more species than the webs (Supplementary Figure S1). *Dictyna arundinacea* (Linnaeus, 1758) was the most abundant species (21% of individuals found) while *Dictyna* corresponded with the most abundant genus (17.7%). The most common families were Linyphiidae (21.1%) and Dictynidae (20.7%; Supplementary Table S1). In total, 13 species and 9 genera were found only in university campus areas, while 8 species and 10 genera were unique to non-campus areas. Campus areas therefore hosted slightly more unique species, although most of them were rare (fewer than three specimens), except for the genus *Holcnemus*, which was represented by 26 detections. The accumulation curves of our sampling showed that coverage was close to 85% for ground-dwelling spiders and 90% for web weavers (Supplementary Figure S2), evidencing the appropriateness of the methodology used and the reliability of our analyses.

The optimal spatial scale varied with habitat and diversity type. For ground-dwelling spiders, best-supported models occurred mostly at 50–100-m, whereas web-building spiders showed broader or less consistent patterns. Richness and abundance responded mainly to local scales, while functional and phylogenetic diversity were more associated with 100-m (see Supplementary Table S2).

According to the final models, there is no general association between any of the four spider diversity components analyzed and the type of urban area (see Supplementary Table S3). However, we found some effects of the local and landscape variables on spider diversity (Table 1): native vegetation has a positive influence on taxonomic diversity on the ground habitat (estimate=0.36,  $p < 0.00$ ). Conversely, maintenance intensity affects negatively to the taxonomic diversity of ground-dwelling spiders (estimate=-0.21,  $p = 0.02$ ) and the distance to the outskirts to the taxonomic diversity of web-weaving spiders (estimate=-0.46,  $p = 0.01$ ). Land coverage was differently associated to diversity, concretely, herbaceous vegetation (estimate=0.34,  $p < 0.00$ ), paved surfaces (estimate=0.24,  $p = 0.01$ ) and buildings (estimate=0.47,  $p = 0.02$ ) were positively associated to taxonomic diversity of ground-dwelling spiders. Bare soil was positively (estimate=0.43,  $p = 0.02$ ) while herbaceous negatively (estimate=-0.78,  $p < 0.00$ ) associated to taxonomic diversity of web weavers. Phylogenetic diversity of ground-dwelling spiders was negatively associated with built-land (estimate=-0.87,  $p = 0.04$ ) and positively with bare soil (estimate=0.73,  $p = 0.05$ ), while for web-weaving spiders we found negative association with pavement coverage (estimate=-0.18,

TABLE 1 Schematic presentation of significant associations (from final models) between values of abundance, taxonomic diversity, functional diversity and phylogenetic diversity and several urban features calculated for spider communities (adults and juveniles) in Granada campus and non-campus areas.

Urban variables		Abundance		Taxonomic diversity		Funtional diversity		Phylogenetic diversity	
		Ground	Web	Ground	Web	Ground	Web	Ground	Web
Native flora				(+)					
Maintenance				(-)					
Distance to the outskirts					(-)				
Coverage	Herbaceous			(+)	(-)				
	Pavement - local			(+)					(-)
	Buildings - local			(+)					
	Built-land							(-)	
	Bare soil				(+)			(+)	
Non-campus*Buildings		(-)		(-)					
Non-campus*Maintenance							(+)		

Positive significant associations are indicated in green (+), while negative ones are highlighted in red (-). Full final models are shown in [Supplementary Table S3](#).

$p=0.04$ ). We found no significant direct association with abundance or functional diversity of these variables.

We also detected some associations between the type of urban area and the landscape variables in relation to the diversity components (Table 1; [Supplementary Table S3](#)). In fact, ground-dwelling spider abundance (estimate=-1.19,  $p<0.00$ ; [Figure 2A](#)) and taxonomic diversity (estimate=-1.01,  $p<0.00$ ; [Figure 2B](#)) were negatively associated to the building cover in non-campus areas compared to campus urban areas. For the functional diversity of web-weaving spiders, maintenance intensity had a positive association in non-campus areas, in comparison with the campus areas (estimate=1.36,  $p=0.02$ ; [Figure 2C](#)). No significant association in interaction with type of urban area was found in phylogenetic diversity models. Nevertheless, the best models at other spatial scales, not selected as the more explicative, detected other significant interactions that are also shown in [Supplementary Table S3](#).

### 4 Discussion

Our study explores for the first time, if Mediterranean university campuses are associated to higher spider diversity than non-campus urban areas. Previous studies in this region have shown that the taxonomic diversity (i.e., species richness) of certain animal groups like birds and butterflies is significantly higher in university campuses than in other nearby urban areas ([Arjona et al., 2023](#); [Sanllorente et al., 2023](#)). However, according to our results, there is not such a direct effect for spider assemblages, although ground-dwelling species seem to be somehow affected by some urban features depending on whether they are in university campuses or other urban areas. Despite similar overall abundance and richness, some species and genera were found exclusively in one type of urban area. *Holocnemus* sp. was found

exclusively in university campuses, building its webs on *Cupressus* sp. trees, which were also present in both campus and non-campus areas. This pattern may be related to differences in management practices, as in non-campus areas the removal of medium-sized spider webs on *Cupressus* sp. seems more common, while smaller webs, such as those of *Dictyna arundinacea* (also linked with *Cupressus* sp.) were abundant in both area types. Therefore, although some spiders could be considered as urban exploiters ([Lowe et al., 2016](#); [Johnson et al., 2020](#)), they are also sensitive to certain local factors that limit their presence.

Our results show that vegetation has a marked influence on certain components of urban spider diversity. This is supported by the positive association between the proportion of native vegetation and ground-dwelling spider taxonomic diversity. Other studies have reported a similar association in urban habitats with different animal groups (e.g., [Samways et al., 1996](#); [Burghardt et al., 2009](#); [Ikin et al., 2013](#); see also a review by [Berthon et al., 2021](#)); however, to our knowledge, no such relationship has been documented for urban spiders, although it has been shown for non-urban environments ([Mgobozi et al., 2008](#); [Smith DiCarlo and DeBano, 2019](#)). The importance of keeping native vegetation in urban habitats seems often overlooked in urban studies despite its known benefits in terms of sustainability ([de la Barrera et al., 2016](#)) or ecosystem services ([Prendergast et al., 2022](#); [Tartaglia and Aronson, 2024](#)), especially in semi-arid environments ([Vásquez-Méndez et al., 2011](#)), like the Mediterranean region, our study area. The fact that native vegetation can hold a higher number of potential preys for spiders (e.g., herbivorous insects; [Mata et al., 2021](#)), may explain this positive association. Furthermore, woody vegetation may also benefit spider richness, as it provides an adequate place to build webs and hold a wide array of potential prey species compared to other coverages, but we did not find that positive relationship in any of our models. For ground-dwelling spiders, the effect of woody vegetation at the landscape level depended on the type of urban area, showing a

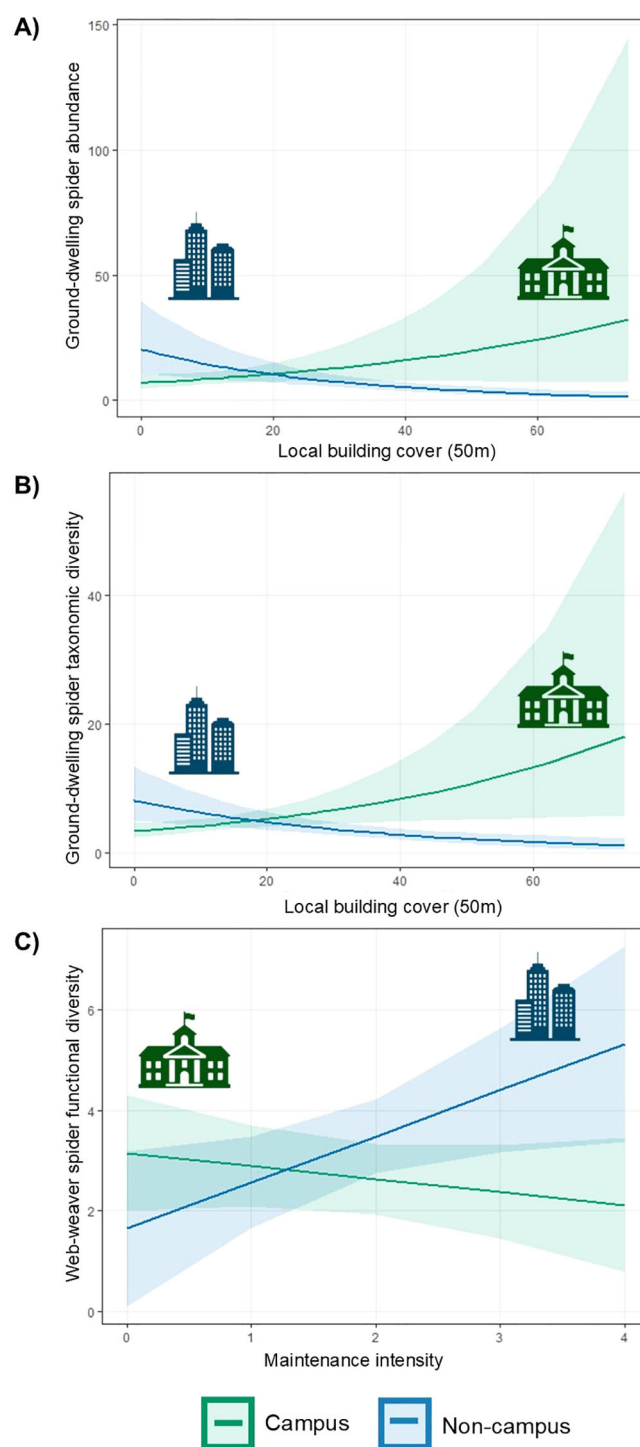


FIGURE 2

Associations in relation to the type of urban area (campus or non-campus) of (A) ground-dwelling spider abundance and the local building cover, (B) ground-dwelling spider genus richness and the local building cover, and (C) genus functional diversity of web-weaver spider and maintenance intensity. For further details see [Supplementary Table S3](#).

stronger negative association with taxonomic diversity in non-campus areas than in campus areas. This contrasting effect should be further explored, but, as several authors have suggested that vegetation complexity seems to be correlated with functional diversity ([Cardoso et al., 2011](#); [Delgado de la Flor et al., 2020](#); [Sharma et al., 2024](#)), our

result would evidence that Mediterranean campuses host less homogeneous vegetation than non-campus areas. Further, herbaceous vegetation at a landscape level seems to favor the taxonomic diversity of ground-dwelling spiders regardless of the type of urban area, a similar effect observed for other urban arthropods like

butterflies or beetles but in a local scale (Arjona et al., 2023), this highlights the different sensitivity of taxa to different urban land configuration scales. The negative effect of the herbaceous vegetation on web-weavers could be due to their more limited dispersal ability (Mcnett and Rypstra, 2000) together with the frequent mowing practices, making the colonization of this vegetation difficult. Finally, and in relation with the previous sentence, the intensity of vegetation management seems to negatively influence taxonomic richness of the ground-dwelling spiders, as reported in other studies (Delgado de la Flor et al., 2020), related to the loss of specialists and the homogenization of species (Sharma et al., 2024) or functional groups (e.g., those with low dispersal abilities; Sattler et al., 2010). Management intensity shows contrasting effects on the functional diversity of web-weaving spiders, being positive in non-campus but negative in campus areas. This pattern may reflect that irregular intense management in urban spaces can increase the functional diversity (Matevski et al., 2025), but a greater continuity in management could imply different outcomes for the functional diversity in the university campuses.

Further, we also detected that some urban features, like the pavement coverage, can enhance the taxonomic diversity of the ground-dwelling spider assemblages. Paved surfaces promote elevated temperatures that can favor the outbreak of several arthropod pests (Meineke et al., 2017), which often constitute the prey of many spiders. In fact, some studies have found a positive relationship between the urban heat island effect and spider voracity (Johnson et al., 2020). Similarly, there is some evidence suggesting that elevated temperatures in urban areas also extend the breeding season of certain species (Lowe et al., 2016). However, other studies also reported a negative effect of temperature on spider diversity (Meineke et al., 2017), so that some regional differences (e.g., humidity; Lövei et al., 2019) or urban features could be influencing the impact of the heat island effect (e.g., vegetation cover or the built-up area; Deilami et al., 2018), this way we detected a negative effect of pavement surfaces on phylogenetic diversity of web-weaver species. Another urban feature with some influence on spider diversity, concretely with abundance, is the building coverage. In this case, university buildings seem to promote the presence of ground-dwelling spiders both in abundance and in taxonomic diversity, in comparison with buildings from other urban areas, a similar result to that found for birds by Sanllorente et al. (2023). Although the ultimate reason for this effect has to be specifically investigated, the way university campuses and their buildings are designed (e.g., in a biophilic concept, see Jones, 2013) could play a key role in enhancing biodiversity. Also, bare soil coverage seems to favor the taxonomic diversity of web-weaving spiders and the phylogenetic diversity of ground-dwelling spiders inhabiting non-campus urban areas. In relation to this, Otoshi et al. (2015) found that bare soil was associated with lower levels of richness and activity density of spiders; the fact that we did not detect an effect on species richness could be explained by differences in species composition between both regions, even though Granada and California share a Mediterranean climate. Otoshi et al. (2015) suggested that the effect of bare soil could be related to lower humidity and higher temperature, which species from Granada might tolerate due to their semi-nocturnal habits, like the Gnaphosidae species (Cardoso et al., 2011; Macías-Hernández et al., 2020). Similarly, Argañaraz et al. (2018) also found a

negative effect of bare soil on spider abundance, but the spider community analyzed there was exclusively associated to vegetation, whereas our study is focused on the ground-dwelling and web-weavers, which may respond differently to this urban feature. Furthermore, most studies on urban spiders are conducted in specific locations within the urban landscape such as urban parks (Otoshi et al., 2015; Peng et al., 2020), gardens (Egerer et al., 2017) or street trees (Meineke et al., 2017), that are somehow similar land covers (green areas). However, our study includes information on several urban locations including green but also paved and built-up areas, that can host a wider array of species and provide different outcomes than if performed in a single type of location (Lowe et al., 2018). Finally, the distance to the outskirts seems to be negatively associated to the taxonomic diversity of web-weaving spiders, but not to the abundance. This would suggest that web-weaving spiders are being filtered towards the city center, with only a few species able to persist there. Such limited species representation and phylogenetic clustering could explain why the phylogenetic diversity for web-weaving species could not be normalized for modelling. Local landscape coverages do not seem to explain web-weaving genus diversity, which is related with the stochasticity of successful colonization of those arthropods (e.g. via ballooning; Delgado de la Flor et al., 2020) or different local habitat suitability among web-weaving guilds (Lowe et al., 2018).

In conclusion, because they are important predators, spiders are key to regulate many insect populations that can turn into pests. The Mediterranean university campuses do not seem to directly favor spider assemblages in comparison with other urban areas. However, our study reveals that certain features, mainly the presence of native vegetation, but also the heterogeneity of the urban habitat (e.g., different vegetation types, bare soil and paved surfaces), together with biophilic buildings, can enhance the diversity of the urban spider communities, especially for the ground-dwelling ones. All these should be taken in consideration by city planners and stakeholders in order to create more biodiverse urban areas.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

## Ethics statement

The manuscript presents research on animals that do not require ethical approval for their study.

## Author contributions

JA: Investigation, Writing – review & editing, Formal analysis, Writing – original draft, Visualization, Methodology. AR-F: Investigation, Conceptualization, Methodology, Writing – review



& editing. EM: Writing – review & editing, Investigation. LN-A: Formal analysis, Visualization, Writing – review & editing. JI-Á: Writing – review & editing, Methodology, Funding acquisition, Conceptualization. OS: Conceptualization, Visualization, Writing – review & editing, Funding acquisition, Supervision, Methodology.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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## Supplementary material

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