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*Research Article*

# Diversity and Abundance of Breeding Birds, Habitat, and Nesting Substrate Selection in Urban Areas: A Relevant Case from the Southern Slope of the Mediterranean

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Urban areas may affect the richness of avian species. The abundance and diversity of urban landscapes offer breeding habitats and nesting resources for urban-adapted species. In our study, we investigated the breeding birds in urban landscapes of Fez's historical city (Morocco). We used line-transects to search for nests of breeding species, populations, and habitats counting breeding sites and predicting factors (foraging, nesting resources, and urbanization). Furthermore, four habitats counting green gardens, old city walls, urban farms, and urban forests were prospected to search for nests of breeding birds. Among 13 breeding species including 12 resident-breeders, and one breeding migrant, a total of 109 nests were documented. Five species counting *Turdus merula*, *Sylvia atricapilla*, *Spilopelia senegalensis*, *Columba livia*, and *Coloeus monedula* were encountered in green gardens; four species counting *Athene noctua*, *Sturnus unicolor*, *Passer domesticus*, and *Tachymarptis melba* were observed in old city walls. *Falco tinnunculus, Fringilla coelebs,* and *Accipiter nisus* occurred in urban forests; and *Streptopelia decaocto* in urban farms. The recorded nests were divided between cavities (50 nests) and trees (59 nests). In green spaces, nests were distributed among *Olea europaea* (17), *Citrus aurantium* (15), *Bambusa vulgaris* (11), and *Eucalyptus globulus* (7). In contrast, *Olea oleaster* and *Cupressus* sp. hosted only tree nests each, while *Populus* sp. and *Washingtonia filifera* hosted only one nest each. Most nests were recorded in habitats rich in nesting trees and close to water sources. On the contrary, the number of nests decreased as the surface and distance of the habitat to the urban center increased. Our data revealed the diversity, habitat use, and nesting substrates of urban breeding bird communities in Morocco and the Southern slope of the Western Palearctic. Future urban plans must integrate measures to provide suitable breeding resources such as cavities of old walls and a high diversity of urban green spaces for birds to enhance their breeding performances, thus promoting the well-being of the population via increasing biodiversity.

## 1. Introduction

In urban areas, impervious landscapes and infrastructures such as roads and buildings replace the majority of natural habitats and vegetation cover [1–3]. The natural structures have undergone significant area and quality losses [4, 5]. Native species of vegetation are frequently obliterated in favor of exotic and introduced species [6, 7]. In addition, more people are involved in maintaining urban landscapes, such as by using pesticides in city parks and gardens [8].

All of these lead to the modification of breeding habitats and the decrease in nesting and foraging resources for bird species [9, 10]. On the contrary, urbanized ecosystems offer suitable habitats for adapted species [11]. Gardens and green spaces offer nesting trees, fruits, and seeds for birds [11], while buildings provide cavities, crevices, and elevated platforms, which may serve as breeding or roosting positions for a wide range of species [12, 13]. For example, it has been shown currently that there is a positive correlation between the occurrence of the vulnerable European turtle dove (Streptopelia turtur), Eurasian collared dove (*Streptopelia decaocto*), and woodpigeon (*Columba palumbus*), and the habitat features of urban landscapes counting green spaces, the extent of urban parks, which offer nesting substrates and foraging resources [14, 15].

In Morocco, most ornithological studies have addressed wetlands [14–18], farmlands [17–21], and forests [22–24] far from human-occupied lands. In contrast, urbanized and humane-made landscapes have received little attention [23, 25–27], despite their intensifying enlargements [28, 29]. These studies revealed important avian populations, principally in Northern cities, such as the globally vulnerable European Turtle doves (*Streptopelia turtur arenicola*) observed in Rabat city, the breeding case of the Glossy Ibis (*Plegadis falcinellus*) in Mohammedia city [30], and the foraging of Maghreb Owl pair (*Strix mauritanica*) in an urban environment of Rabat [31]. These examples also demonstrate the ability of Moroccan urban ecosystems to support avian species, including those whose conservation status is critical. However, little research has been done on breeding communities and how they interact with urban environments [32].

In this study, we aimed at assessing the breeding birds in the historical city of Fez and how they select nesting habitats and nesting trees along the center-periphery gradient. Equally, we analyzed the predicting factors of habitat use. The progression of urban systems in this city has left mixed patches of farmland and natural habitats surrounded by a massive built-up matrix [33–35], which presents a unique opportunity to investigate the effects of urban fragmentation on avian species. This segment is considered to be the missing component of Moroccan diversity [23, 25–27, 31, 36]. Previous investigations have revealed the reduction of bird species in urban habitats compared with nonurbanized ecosystems [37, 38]. The potential results of this study are expected to be useful for urban management in order to protect the breeding and foraging resources for urban-adapted birds.

## 2. Materials and Methods

*2.1. Study Area.* This research was conducted in the Fez-Meknes region located in the central zone of Morocco [39]. The study sites were selected in Fez city located in the plain of Saiss, between the pre-Rif and the Middle Atlas Mountains (Figure 1). The study city is extending over an area of 332.1 $km^2$ and is bounded by the province of Moulay Yacoub in the North, North-West, and North-East, and the province of Sefrou in the South-West. Furthermore, the province of Fez includes five municipalities counting two urban (Fez and Méchouar El Jdid) and three rural (Sidi Harazem, Skhinate, and Oulad Tayeb). The urban municipality of Fez is divided into six districts: Agdal, Saiss, Jnan El Ouard, El Mariniyine, Fez-Medina, and Zouagha.

The city of Fez is the chief urban center of the Fez-Meknes region and ranks the third agglomeration of Morocco after Casablanca and Rabat-Sale, with over 1,150,131 inhabitants [40]. The urbanization of the region is characterized by a high concentration of population and economic activities in the two cities of Fez and Meknes [29, 33]. The road network of the Fez has a total length of 111,500 km for national roads, 20,830 km for regional Roads, and 43,920 km for provincial roads. In terms of railway infrastructure, the region is served by a railway with a length of 200 km. Thus, this network allows the connection of Fez and Meknes to the destinations of Marrakech, Tangier, and Oujda [41]. Equally, the province of Fez includes Fez-Saïss international airport over an area of 223 ha [39]. All cited elements are suspected to affect birds in the city of Fez.

Fez is characterized by a continental climate with extreme variations between the different seasons [42]. The average temperature is around 30°C, while the maximum temperatures can reach above 40°C mainly from July to August, the minimum temperatures during the coldest months reach 3°C mainly in January [42].

Based on preliminary monitoring, conducted from 2017 to 2018 in Fez city, seven urban sites grouped into four habitats were selected and monitored during the breeding season of 2019, namely, public gardens of Jnane Sbil and hay Lmsla; urban farms of Cheraybi and Borj Sud; old city walls of Fes Jedid and Bab Boujloud; and urban forests of Ain Chkef. These habitats present different urban features susceptible to influence the avian species. These habitats were selected from the central zone to the periphery of Fez city.

*2.2. Mapping of Spatial Distribution.* All studied habitats were delimited first based on the master plan of Fez city (1/1500). Furthermore, field visits were recorded using (Geo Tracker-GPS tracker) mobile application, and then we mapped the habitats based on the GPS of habitats and the WGS coordinate system. Recorded visits in the Geo tracker application were exported to KMZ files to be used on Google Earth Pro software and each habitat was delimited based on satellite maps of Landsat, then the geographical coordinates of each site were generated in Excel format with the QGIS software (version 3.20). Furthermore, we created a Shapefile layer of polygons with a WGS coordinate system, which was digitized based on previously imported coordinates. The created polygons were used to calculate automatically the surface of each habitat (we used the measurements button). Similarly, we calculated the distances separating the studied habitat from the center of Fez based on digitized maps. We created Shapefile layers of point type, from the fixed breeding habitat to the fixed point of the urban center, based on the generated satellite map (Landsat). In the end, the recorded nests were displayed on the map of monitored habitats to demonstrate the distribution of breeding species in the city of Fez.

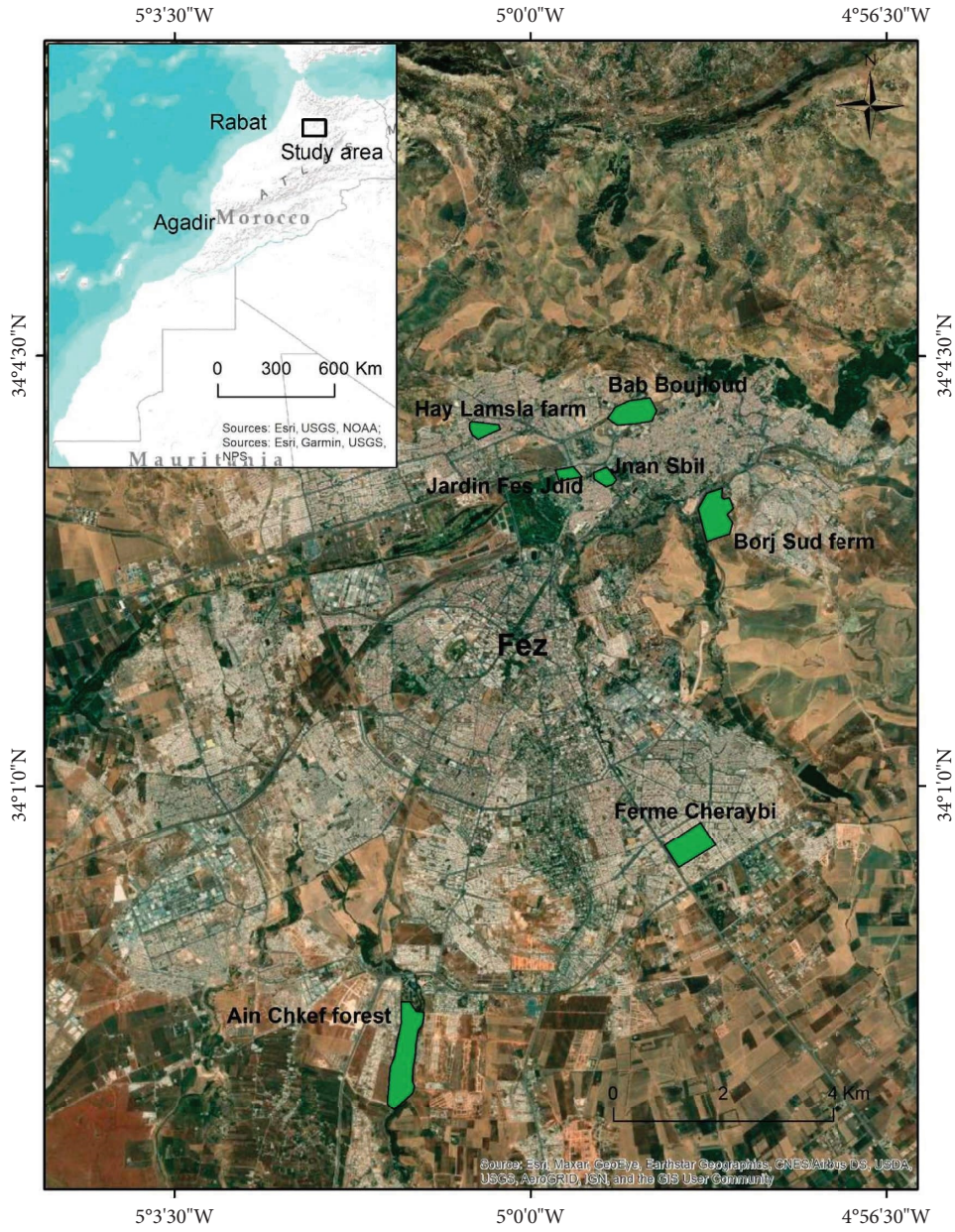



Figure 1: Administrative delimitation of Fez city and studied sites from the center to the periphery.

*2.3. Data Collection.* In each urban habitat, we monitored breeding birds twice monthly during the breeding period from March to August 2019. This period has been chosen based on the breeding chronology of birds in the Saïss plain [43, 44]. In order to search for nests of breeding species, we used line-transects of 1 km based on small surfaces of the investigated ecosystems. Each transect was divided into three to four sampling points and separated by 200 to 300 m to avoid double sampling. Bird pairs were recorded visually or acoustically for 10 to 20 min at each sampling point, and then we searched for nests in the surrounding areas that can be suitable for nesting (trees, cavities, and/or walls). Birds were identified via binoculars and a field guide of birds.

Field transects were conducted from the early hours of the day (06:00 am) to sunset (18:00 pm). In the public gardens, we searched for breeding activities on vegetation cover, ornamental and fruit trees, and flowers. In the old city, we monitored breeding activities on historic walls, monuments, and buildings. After the observation of pairs, we noted only breeding habitats, nests, breeding species, and type of nesting substrate (three categories: cavity, natural tree, and exotic tree), while the nest content was neglected due to the visiting frequency (twice a month) which is not sufficient to monitor eggs, chicks, and their status (predation attacks, disturbance, success, incubation, etc.).

*2.4. Environmental Variables.* To evaluate the factors suspected to explain any potential variation in habitat use and diversity of avian species in urban habitats, we recorded the vegetation diversity, availability of water (distance to the nearest water source), covered area (surfaces of breeding

habitat), and distance to the urban center for all selected habitats. The vegetation diversity (encountered plants) in studied habitats was identified in the field with the assistance of the regional department of water and forestry in Fez and divided into natural and exotic plants. The natural plants were those remaining after the urbanization of the area, while the exotic species were those introduced to the green spaces of Fez city. Distance to the nearest water sources was noted from each breeding site (marked with nests) to the nearest rivers, pools, irrigation canals, springs, etc. The surface of monitored habitats and their distance to the urban center (delimited by the master plan of Fez) were extracted from the previously created satellite map of Fez using QGIS 3.20.

*2.5. Statistics.* Before starting the statistical analysis, recorded species were grouped in orders and families as mentioned by [32, 36, 43]. Equally, the phenological status of breeding species (residents, breeders, migrants, and winterers) was noted based on the current phenology of Moroccan birds [45], while the conservation status of each breeding bird was cited following the latest IUCN Red list update [46]. The number of breeding species and recorded nests were compared among nesting supports, including cavities and trees (exotic and natural plants) and urban breeding habitats via the one-way ANOVA test.

To assess the affinity of recorded birds (13 birds and 105 nests) toward urban breeding habitats and nesting supports, breeding birds ($N = 13$) were considered as response variables (response = 1, at least one nest is recorded for the bird, response = 0 absence of nest of the species), while examined urban habitats ($N = 4$) were considered as explanatory factors (independent variables), and were analyzed with detrended correspondence analysis (DCA) (only eigenvalues >1.0 were selected). Similarly, the selection of nesting supports (eight species of trees and wall cavities) used by breeding bird species (105 nests of 13 species) was evaluated by detrended correspondence analysis (DCA) in the same way as habitat use. This multivariate method is widely used to evaluate the ecological requirements counting habitat use and nesting supports for bird species [19, 47]. All analyses were performed using SPSS 18.

To evaluate the effect of distances (km) separating the breeding sites ($n = 7$ sites) to the nearest water point and urban center of Fez, the surface area of each breeding habitat (ha), and the number of potential nesting supports (tree species and cavities per site) considered as independent variables (predictors) on the breeding density (number of nests per site considered as a dependent variable), we used linear regression (regression coefficients were estimated and significant values were at $p < 0.05$). The correlation between the abundance of nests, the diversity of breeding birds, and the diversity of nesting trees was estimated via simple regression.

## 3. Results

*3.1. Breeding Species.* In total, 13 breeding birds, belonging to 6 orders and 11 families, were documented in the urban landscapes of Fez city (Table 1). The order of Passeriformes was the most abundant with six (6) avian species, followed by Columbiformes with three species. In contrast, Apodiformes, Strigiformes, Falconiformes, and Accipitriformes recorded only one (1) species each. Except for the Columbidae (three species), all families recorded only one (1) bird species. Furthermore, all nesting species were of less concern conservation status. On the other hand, the phenological status of breeding species was variable; 12 species were resident breeders and one migrant breeder.

Breeding species were distributed differently among the urban habitats of Fez (Figure 2). In total, 7 breeding species counting *Passer domesticus* (12 nests), *Turdus merula* (11), *Tachymarptis melba* (9), *Coloeus monedula* (9), *Sylvia atricapilla* (8), *Streptopelia decaocto* (6), and *Columba livia* (6) were located in Jnane Sbil; 4 species counting *Sylvia atricapilla* (1), *Turdus merula* (1), *Streptopelia decaocto* (1), and *Spilopelia senegalensis* (1) in Fes Jedid; 4 species in Bab Boujloud counting *Passer domesticus* (6), *Sturnus unicolor* (3), *Tachymarptis melba* (4), and *Athene noctua* (1); 3 species in Ain Chkef counting *Turdus merula* (3), *Falco tinnunculus* (1), and *Accipiter nisus* (4); 2 species in Cheraybi counting *Turdus merula* (4) and *Streptopelia decaocto* (7); and one species in both Hay Lmsla and Borj Sud which is *Streptopelia decaocto* with 5 and 4 nests, respectively.

*3.2. Affinity to Breeding Habitats.* The selection of nesting sites by breeding birds is presented in Figure 3. Five species, *Turdus merula*, *Sylvia atricapilla*, *Spilopelia senegalensis*, *Columba livia*, and *Coloeus monedula* were related to green gardens, followed by old city walls that hosted *Athene noctua*, *Sturnus unicolor*, *Passer domesticus*, and *Tachymarptis melba*. In contrast, only *Falco tinnunculus* and *Accipiter nisus* were related to the urban forest, while *Streptopelia decaocto* was related to urban farms.

Breeding sites were partitioned between predator, prey, and competitor birds in Fez urban landscapes (Figure 3). Breeding sites of passerines were selected in gardens, farms, and walls far from urban forests colonized by birds of prey counting *Falco tinnunculus* and *Accipiter nisus*. Both breeding Columbidae selected separated nesting sites; *Spilopelia senegalensis* was found in public green gardens, and *Streptopelia decaocto* was concentrated in urban farms, while nests of *Columba livia* were found in the walls of the old city. The other species have shared the breeding habitats.

*3.3. Selection of Nesting Support.* Nesting supports were variables among breeding birds and habitats. In comparison, 50 nests were constructed on walls, 37 on exotic plants, and only 18 on natural plants ($N = 7$ habitats (105 nests) DF = 2, $F = 0.40$, $P = 0.006$). A higher number of nests were recorded in cavities (50 nests), followed by *Olea europaea* (17 nests), *Citrus aurantium* (15 nests), *Bambusa vulgaris* (11 nests), and *Eucalyptus globulus* (7 nests). In contrast, *Olea oleaster* and *Cupressus* sp. hosted only 3 nests each, while *Populus* sp. and *Washingtonia filifera* hosted only one nest each.

Breeding birds selected different nesting substrates (Figure 4). *Columba livia* (Ci), *Sturnus unicolor* (Su), *Passer*

Table 1: Diversity of breeding species (nests) recorded in studied urban habitats of Fez city.

| Order | Family | Species | Nest | Status | Conservation status |
|---|---|---|---|---|---|
| Passeriformes | Sylviidae | *Sylvia atricapilla* | 9 | r/b | LC |
| Passeriformes | Turdidae | *Turdus merula* | 19 | r/b | LC |
| Columbiformes | Columbidae | *Streptopelia decaocto* | 23 | r/b | LC |
| Passeriformes | Corvidae | *Coloeus monedula* | 9 | r/b | LC |
| Apodiformes | Apodidae | *Tachymarptis melba* | 13 | b/m | LC |
| Passeriformes | Passéridae | *Passer domesticus* | 18 | r/b | LC |
| Columbiformes | Columbidae | *Columba livia* | 6 | r/b | LC |
| Strigiformes | Strigidae | *Athene noctua* | 1 | r/b | LC |
| Passeriformes | Sturnidae | *Sturnus unicolor* | 3 | r/b | LC |
| Falconiformes | Falconidae | *Falco tinnunculus* | 1 | r/b | LC |
| Accipitriformes | Accipitridae | *Accipiter nisus* | 4 | r/b | LC |
| Passeriformes | Fringullidae | *Fringilla coelebs* | 2 | r/b | LC |
| Columbiformes | Columbidae | *Spilopelia senegalensis* | 1 | r/b | LC |

*domesticus* (Pd), *Coloeus monedula* (Cm), *Athene noctua* (Ano), and *Tachymarptis melba* (Tm) selected only cavities of walls for nesting, while *Accipiter nisus* (An) and *Falco tinnunculus* (Ft) strictly nested on *Eucalyptus globulus*. In contrast, *Streptopelia decaocto* (Sd), *Fringilla coelebs* (Fc), and *Turdus merula* (Tme) were commonly nested on trees counting *Cupressus* sp. *Olea europaea*, and *Citrus aurantium*, while *Sylvia atricapilla* (Sa) selected alone three species of trees for nesting (*Olea oleaster*, *Populus* sp., and *Bambus vulgaris*).

*3.4. Predicting Factors.* The factors predicting the abundance of nests in studied habitats are summarized in Table 2. The abundance of nests is influenced positively by the presence of water sources and the diversity of nesting trees in the breeding habitat (most nests were recorded in habitats located near water sources and rich in vegetation cover). On the contrary, the number of nests declines with the habitat's increased surface and in sites located near the urban center of Fez. The surface of the habitat does not influence the abundance of nests. The abundance of nests and diversity of the nesting birds are positively correlated to the diversity of plants in each habitat (Figure 5).

## 4. Discussion

To our knowledge, this is the first large-scale investigation of the breeding avian community in urban ecosystems in Morocco [25–27, 30, 31, 36, 48, 49]. Our study highlighted an important breeding population composed of resident and migratory species. Similar results were recorded in Algeria with 28 breeding species in Annaba city [50] and in Tunisia with nearly 40 breeding birds in Gabès coastal city [51]. In the Northern slope of the Mediterranean, our results are very close to those cited in Kavala (Greece) and in Rovaniemi (Finland) with 26 and 15 breeding species, respectively. However, the recorded breeding birds are inferior when compared to other Moroccan ecosystems counting farmlands that host nearly 60 breeding birds [36], forests with 70 breeding species [22, 24, 47], and wetlands with nearly 100 breeding species [14]. The increased urbanization rate is suggested to be behind this lower avian diversity in Fez city. Currently, El Garouani et al. [33] have shown an expansion of residential and industrial areas in places of water bodies, forests, and rangelands which constitute the vital habitats for wild avifaunae as the breeding cases of the vulnerable Turtle doves (*Streptopelia turtur arenicola*), Eurasian Collared dove (*Streptopelia decaocto*), and the Maghreb magpie (*Pica mauritanica*) in the orchards located in the periphery of Fez [17, 18, 23] and the Eurasian coot (*Fulica atra*) recorded in Oued Fez river.

Breeding birds selected different habitats for nesting. Nests of *Turdus merula*, *Sylvia atricapilla*, *Spilopelia senegalensis*, *Columba livia*, and *Coloeus monedula* known as urban-adapted birds [36, 52] were recorded in the green gardens of Fez. Nests of *Athene noctua*, *Sturnus unicolor*, *Passer domesticus*, and *Tachymarptis melba* were documented on old city walls which is in agreement with results cited by [53–55] in the Mediterranean and European cities. In addition, nests of *Streptopelia decaocto* were concentrated in urban farms which confirm the current observations made by Eddajjani et al. [26] in Rabat city (Morocco). Nests of birds of prey *Falco tinnunculus* and *Accipiter nisus* were built separately in urban forests far from the breeding passerines. The segregation of breeding habitats between predators and preys is currently cited among avian species [56, 57] as in the case of olive orchards surrounding Fez city [18] in which the breeding Doves (*Streptopelia decaocto* and *Streptopelia turtur*) nested far from the predatory Maghreb magpie (*Pica mauritanica*) and the case of Oued Bouhellou watershed in which the community of breeding passerines selected nesting sites far from the birds of prey counting *Falco tinnunculus*, *Falco naumanni*, *Buteo rufinus*, *Circus aeruginosus*, *Elanus caeruleus*, *Lanius excubitor*, and *Lanius senator*[47]. In the same way, our study revealed a clear habitat partitioning between *Streptopelia decaocto* that nested in urban farmlands and its competitor *Spilopelia senegalensis* concentrated in green gardens. Generally, we suggest that passerines have segregated nesting sites from birds of prey to protect their nests and broods (i.e., predation attacks) [18], as now observed for the same species in Fez and Midelt (180 km from Fez); the competitive Columbidae have divided their nesting places to prevent competition for nesting supports and foraging supplies, particularly during

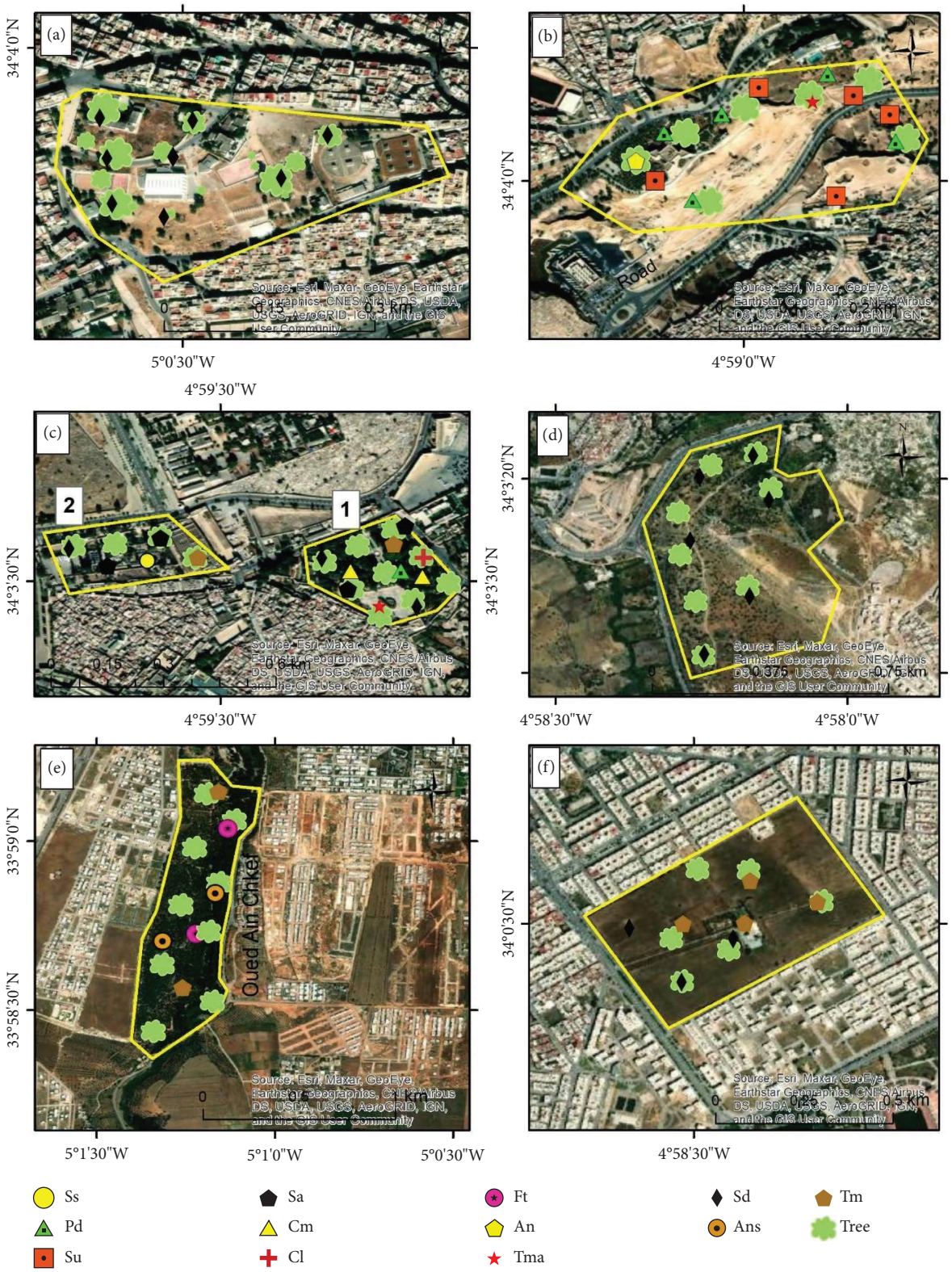



Figure 2: Distribution of nesting species (nests) among the urban habitats of Fes city ((a) Hay Lmsla. (b) Bab Boujloud. (c) 1: Jnane Sbil; 2: Fes Jedid. (d) Borj Sud. (e) Ain Chkef. (f) Cheraybi) (An: *Accipiter nisus*; Ano: *Athene noctua*; Cm: *Coloeus monedula*; Cl: *Columba livia*, Fc: *Fringilla coelebs*, Ft: *Falco tinnunculus*; Pd: *Passer domesticus*; Ss: *Spilopelia senegalensis*; Sd: *Streptopelia decaocto*; Su: *Sturnus unicolor*; Sa: *Sylvia atricapilla*; Tm: *Tachymarptis melba*; Tma: *Turdus merula*).

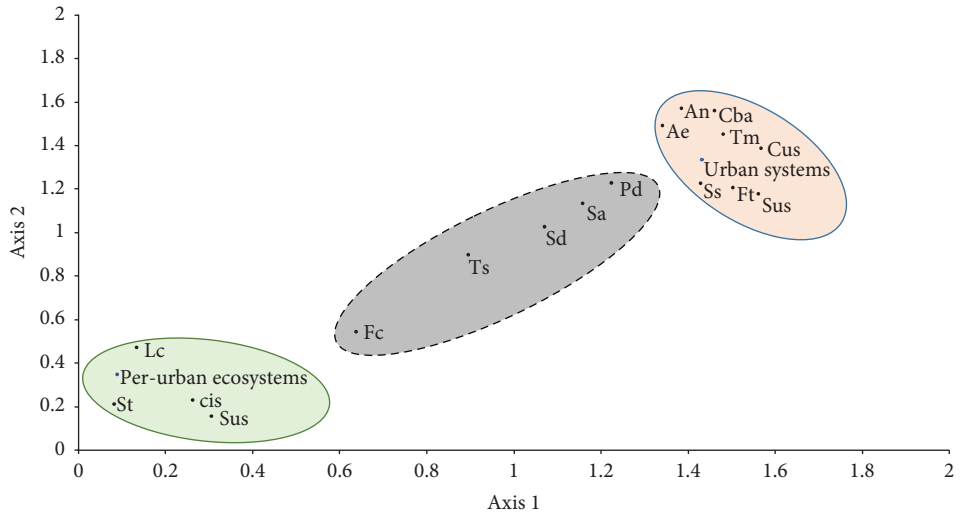



Figure 3: Selected nesting sites in urban habitats of Fez historical city by 13 breeding birds. An: *Accipiter nisus*; Ano: *Athene noctua*; Cm: *Coloeus monedula*; Cl: *Columba livia*, Fc: *Fringilla coelebs*, Ft: *Falco tinnunculus*; Pd: *Passer domesticus*; Ss: *Spilopelia senegalensis*; Sd: *Streptopelia decaocto*; Su: *Sturnus unicolor*; Sa: *Sylvia atricapilla*; Tm: *Tachymarptis melba*; Tme: *Turdus merula.*

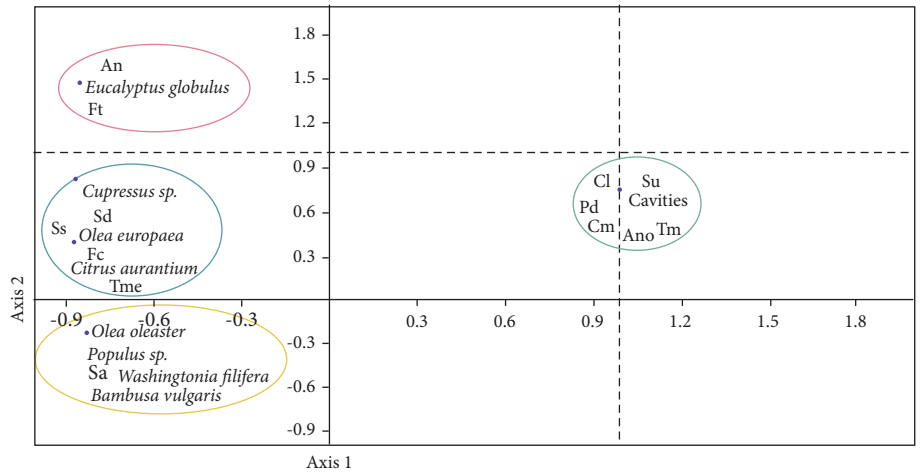



Figure 4: Detrended correspondence analysis (DCA) of nesting tree use among breeding birds of Fez city. (An: *Accipiter nisus*; Ano: *Athene noctua*; Cm: *Coloeus monedula*; Cl: *Columba livia*, Fc: *Fringilla coelebs*, Ft: *Falco tinnunculus*; Pd: *Passer domesticus*; Ss: *Spilopelia senegalensis*; Sd: *Streptopelia decaocto*; Su: *Sturnus unicolor*; Sa: *Sylvia atricapilla*; Tm: *Tachymarptis melba*; Tme: *Turdus merula*).

Table 2: Predictors (area, distance to urban center, distance to nearest water, and nesting trees) of nest abundance in urban habitats of Fez city.

| Models | Unstandardized coefficients | | Standardized coefficients | $t$ | $P$ value |
|---|---|---|---|---|---|
| | B | Std. error | Beta | | |
| (Constant) | 64.115 | 14.115 | | 4.542 | 0.000 |
| Area | −0.131 | 0.332 | −0.146 | −0.396 | 0.695 |
| Distance to urban center | −17.628 | 5.463 | −1.425 | −3.227 | 0.004 |
| Distance to nearest water | 12.012 | 3.934 | 0.566 | 3.053 | 0.006 |
| Nesting trees | 3.907 | 0.639 | 1.711 | 6.117 | 0.000 |

the incubation of their young chicks [17, 18, 58]. The most relevant result of our study is the description of nesting-tree use among the breeding communities; the majority of nests were recorded in cavities of walls (47.61%) and on exotic plants (35.25%), while natural plants hosted only 17.14%. These findings demonstrate the impact of urbanization features known by the expansion of buildings, industrial areas, and the replacement of natural vegetation cover by exotic plant species [59, 60]. Despite the negative impact of urban buildings and exotic plants (in gardens and along

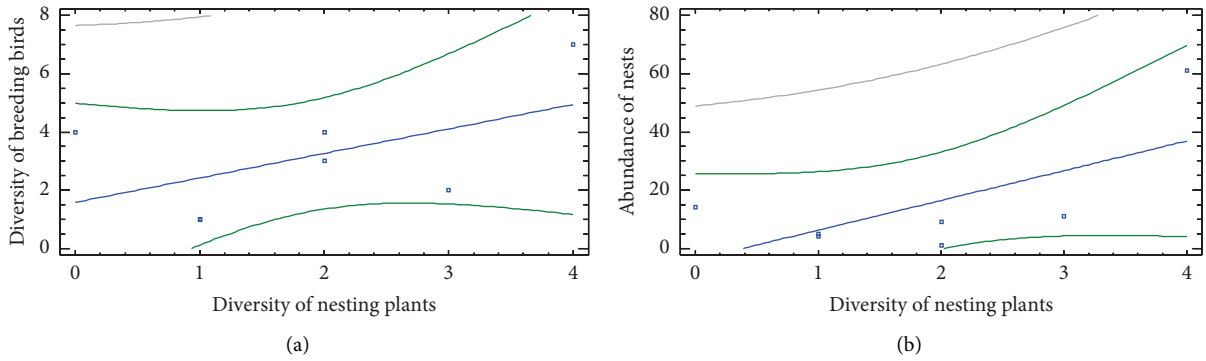



Figure 5: Correlation between the diversity of breeding birds (a), abundance of nests (b), and diversity of nesting plants.

roads) on natural vegetation cover, these infrastructures and introduced plants offer although nesting resources and forage for urban-adapted birds [12, 61, 62]. In our case, the cavities of old walls and exotic plants counting *Citrus aurantium*, *Bambusa vulgaris, Eucalyptus globulus, Washingtonia filifera, Cupressus* sp, and *Populus* sp (recorded in gardens and forests) hosted nearly 83% of nests. Furthermore, the breeding birds selected different nesting supports.

In Fez city, the abundance of nests (the number of nests per site) and the richness of breeding species increase in correlation with the diversity of plants and the presence of water sources in breeding habitats. In contrast, the number of nests declines in habitats close to the central area of the city and when the area of the breeding habitat increases. Similar results were recorded in urban areas of Rabat (Morocco) and in Gabès (Tunisia) in which the diversity of avian species increases in urban gardens rich in plant species, close to water sources, and far from the urban centers [26, 51]. Buildings disrupt birds, but breeding and foraging resources typically draw them to ensure the success of breeding [19, 28, 58].

## 5. Conclusion

This study, to our knowledge, is the first to investigate the diversity of breeding birds in urban ecosystems, taking into account urban habitats, nesting support, vegetation components, urban gradient, and foraging resources as drivers in Morocco and the Southern slope of the western Palearctic. We demonstrated that urban birds select different nesting sites and support far from the urban centers and close to foraging resources. Equally, breeding birds partition nesting sites and support to avoid competition and ensure higher productivity. However, we recommend that additional factors, such as noise, the effects of traffic, crashes, and tourism, ought to be taken into account in future research that evaluates the bird diversity in urban areas. Analyzing how urban noise affects breeding pairs' communication tactics for increasing the transmission range of their courting signals would also be beneficial. Fez city unquestionably provides the ideal frame of reference for developing replies to these questions.

## Data Availability

The data used to support the findings of this study are included in the article.

## Conflicts of Interest

The authors declare they have no conflicts of interest.

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