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URBAN LANDSCAPES ARE RICHER IN BIRD SPECIES WHEN COMPARED TO FARMING LANDS: EVIDENCE FROM MOROCCO (NORTHWEST AFRICA)

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Abstract. Urban expansion leads to modifications of habitat features, organization, and resources. Bird assemblages are known to respond by escaping destructive changes and adapting to sustainable ones. In this study, we investigated for the first time the avian diversity and its variation following the rural-urban gradient in Beni Mellal (Morocco) from 2018 to 2021. We used the line-transect method and multivariate analysis to demonstrate the selection of breeding habitats. Our result revealed a total of 84 species divided into resident breeders (64.28%), passage migrants (17.85%), breeding migrants (26.19%), winter visitors (32.18%) and accidental visitors (1.19%). Two globally vulnerable species counting the European Turtle Dove *Streptopelia turtur* and the European Goldfinch *Carduelis carduelis* were recorded. Breeding populations were concentrated in green spaces (9 species) located in the urban zone, compared with farmlands (7 species), peri-urban (3 species), and rural areas (3 species). Therefore, these results reverse the hypothesis that rural and farming lands are more species-rich because of a higher population size. This is due to the abundance of breeding and foraging resources in urban green spaces compared to arid lands surrounding cities in this North African area. Furthermore, our study provides a new opportunity for comparative studies of avian diversity in Morocco and Northwest Africa.

INTRODUCTION

In North Africa, the expansion of urbanization can offer a comprehensive experiment to investigate the impacts of human infrastructures on biological and ecological features (Wang et al. 2020). Urbanized lands have received less attention (Chenchouni 2017; Aouissi et al. 2017, 2021) because scientists have conventionally concentrated their interest on more natural ecosystems (Squalli et al. 2020; Mansouri et al. 2021, 2022; Es Salai et al. 2021) and farmlands (Hanane and Besnard 2014; Mansouri et al. 2021, 2022). However, the urban gradient has promised an important opportunity for ecological studies in the northern part of the Mediterranean region (Battisti et al. 2022; Halbac-Cotoara-Zamfir et al. 2022). According to Dadashpoor et al. (2019), urbanization can create a multifaceted ecological gradient that ranges from unaltered natural landscapes to heavily modified urban patches. This can be useful for identifying interactions between environmental heterogeneity and the abundance and diversity of bird species (Kettel et al. 2018; Partridge and Clark 2018). The majority of studies comparing urban and rural avian populations have found that while species abundance generally decreases as cities grow, overall avian biomass or density typically rises as urbanization increases (Callaghan et al. 2020; Mohring et al. 2021).

However, most previous research did not explore avian groups across a wide-range gradient of urbanization, from undisturbed landscapes to highly urbanized ecosystems (Crooks et al. 2004; Minor and Urban 2010; Grade et al. 2021; Roselli et al. 2021). Current studies that did explore avian communities across urban gradients demonstrated that both species richness and total abundance peaked at non-urbanized or moderately urbanized levels (Sanz and Caula 2015; Ciach and Fröhlich 2017; Xu et al. 2018). Though the examination of rural-urban gradients is comparatively novel in Northwest Africa (Hamza et al. 2021; Mansouri et al. 2021), however, the miniature picture is known of the real patterns of species abundance, distribution, and richness along urban gradients (Mansouri et al. 2021; Saâd et al. 2021).

The majority of avian species research in Morocco has focused on aquatic ecosystems far from populated areas (Cherkaoui et al. 2015; Es Salai et al. 2021; Squalli et al. 2021), farmlands (Mansouri et al. 2019), and forests (Cherkaoui et al. 2009; Mansouri et al. 2022). Despite their expanding populations, urban areas have not received considerable attention (Bellout et al. 2021; Mansouri et al. 2021, 2022; Bahi et al. 2016). According to Ofori et al. (2022), urban structures lead to the fragmentation and destruction of natural systems, which threatens avian populations, particularly the highly endemic and endangered species (Aouissi et al. 2021; Saâd et al. 2021). Unlike natural systems dominated by natural habitats (Blitzer et al. 2012), vegetation cover (Ebrahimi et al. 2016), and abundant foraging resources (Whelan 2001), urbanization enlarges novel structural features, such as human constructions (Henderson and Powell 2001), lush ornamental vegetation (Celesti-Grapow and Ricotta 2021), and non-native trees (Čeplová et al. 2017), which are suggested to impact avian species via breeding and/or foraging resources. On the contrary, urban landscapes dominated by green spaces, water canalizations, and landfills are suggested to offer required elements for birds, principally in the arid environments (Partridge and Clark 2018; Arnold et al. 2021), which is the case in Moroccan systems where nesting and feeding elements are rare (El Alaoui El Fels et al. 2022).

In this study, we aimed to assess how avian assemblages varied along a rural-urbanized gradient in the Beni-Mellal region, central Morocco. The evolution of urban expansions in this area has left distinct patches of natural and farmland habitats surrounded by a massive urban matrix (Barakat et al. 2019; El Baghdadi et al. 2019). This creates a highly important study case to investigate the effects of urban fragmentation on bird assemblages, which is the missing component of Moroccan diversity (Bellout et al. 2021; Mansouri et al. 2021, 2022). As compared to non-urbanized ecosystems, there are fewer bird species in

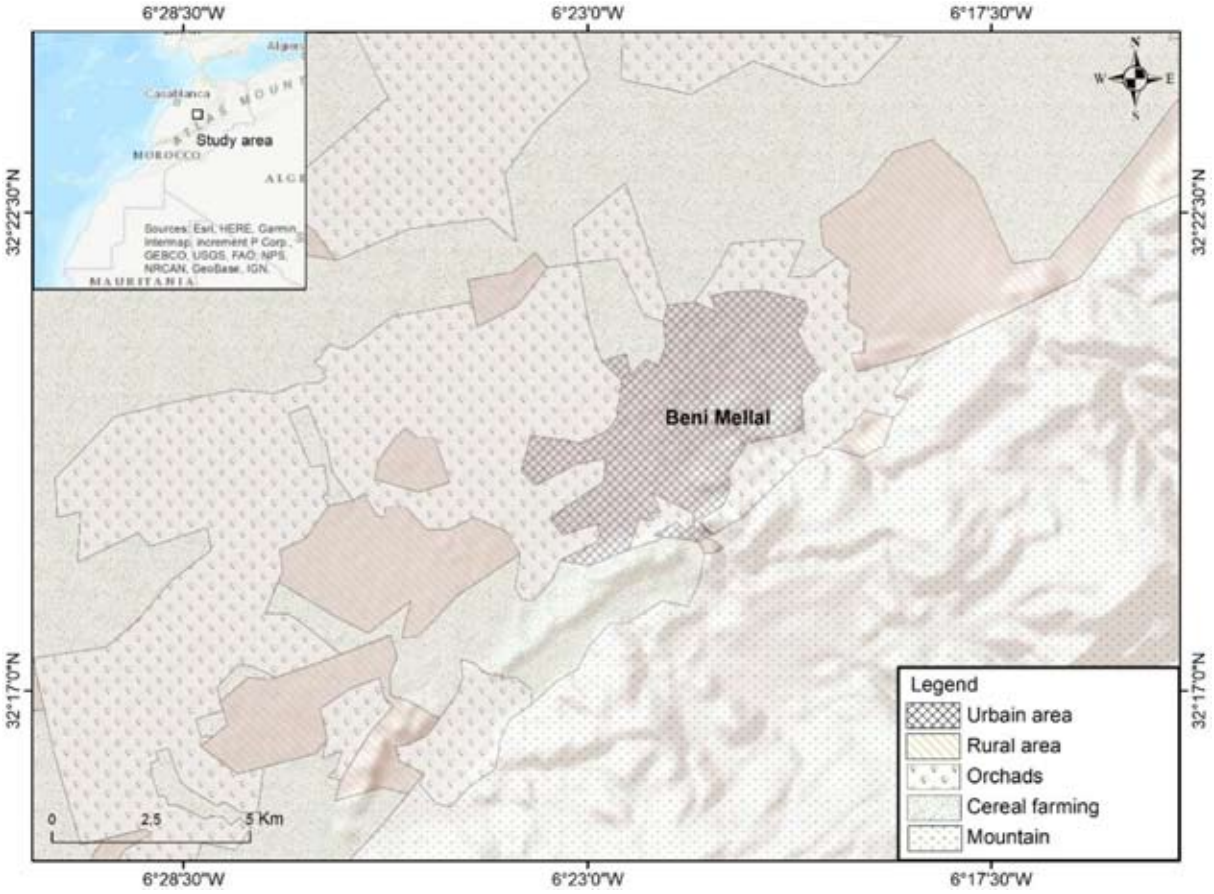

Figure 1. Location of studied area in Morocco and delimitation of studied habitats.

urban habitats, (Sanz and Caula 2015; Ciach and Fröhlich 2017; Xu et al. 2018). We extended on this prior research by monitoring both the abundance and richness of the whole avian communities within urban-rural gradients. Equally, breeding populations were monitored to clarify the affinity of birds toward selected habitats.

MATERIALS AND METHODS

Study area

This study was conducted in the Beni Mellal-Khénifra region located in the central area of Morocco. The study zone was selected around Beni Mellal city located in the plain of Tadla, between the High Atlas and the Middle Atlas (Figure 1). In 2014, the population of the Beni Mellal-Khénifra region was 2,520,776 inhabitants, which represents 7.4% of the total population of Morocco (Barakat et al. 2017). The rural population in the region predominates with 51% of the total population compared to 49.6% nationally. The rate of urbanization in the Beni Mellal-Khénifra region reached 49.1% in 2014 (Barakat et al. 2021). More than 2/3 of the urban population of the region is concentrated in the three provinces of Beni Mellal, Khouribga, and Khénifra which would shelter 75% of the total urban population of the region with rates of successive urbanization of 69.68%, 61.58% and 59.2%, respectively, according to the census of 2014. The Beni Mellal-Khénifra region has a moderately dense road network consisting of 1114.63 km of national roads, 4283.45 km of regional roads, of which 93.525 km are paved, and 2454.79 km of provincial roads, of which 393.38 km are coated. These human-made ecosystems are among the most developed in Morocco and Northwest Africa (Er-rami and Touhami 2022). Equally, the airport infrastructure of the Beni Mellal-Khénifra region consists of a single airport "Beni Mellal airport" of 170 ha located 8 km northwest of the city, with a capacity of 150,000 passengers per year. On the other hand, the region is dominated by rivers counting Oum Er-Rbia, Derna, El Abid, Lakhdar and Tassout (Barakat et al. 2016; Layati et al. 2021), forest potential of 443,500 ha (Barakat et al. 2018), and agricultural fields that cover 948,426 ha (Abouhani 2001). These elements are suggested to influence bird communities in the area.

Due to its location between the plain of Tadla, the High and the Middle Atlas, the study sites were selected between 500 m (city of Beni Mellal) and 1320 m altitude (boundary parts of farmlands and rural areas) (Mansouri et al. 2020; Mounir et al. 2022). The area is characterized by a continental climate, and precipitations vary annually between 450 and 750 mm. Temperatures vary between −6°C (in winter) and 40°C in summer (Kamal et al. 2018; Arroub et al. 2021).

Monitoring of avian species

The study area was divided into three major habitats (Figure 1), counting rural areas (rural zones of forests, steppes, and herbaceous cover following the administrative classification of the region), the farmlands (cereals, orchards, and other farming lands situated between rural zones and urban landscapes), and urban zones (all areas included in the urban perimeter of the region master plan). Due to their complexity, the urban sites were divided into (i) peri-urban areas where buildings were surrounded by natural landscapes counting forests, rivers, and steppes; (ii) urban centres counting the most urbanized sites in the city (roads, buildings, and other infrastructures with the absence of gardens and green sites or trees); and (iii) green spaces counting gardens, ornamental trees, river vegetation, and fragmented forests in the city of Beni Mellal.

In each habitat, birds were investigated twice monthly and monitored during both breeding and wintering periods from January 2018 to December 2020. In rural areas and farmlands, bird species were assessed by means of a line-transect of 2 km divided into 6 to 7 points of counts of 10 to 15 minutes (Bibby et al. 2000). Birds were surveyed in urban habitats along roads (following the linear transect, as in the case of farmlands), in gardens (with central "Point-counts" of 10 to 15 minutes of sampling), and in river vegetation along the river from the entrance to the outer boundary of the city (Mansouri et al. 2021). The same techniques were used for breeding species in each habitat, but they were enhanced with breeding parameters counting mating behaviour (breeding pairs, acoustic or visual mating), nests (construction and transportation of nesting twigs), and chicks (nestlings and sub-adults), which are suggested to prove the breeding activity for each species in the studied sites (Mansouri et al. 2021), as well as the affinity to each habitat. Transects were conducted during the early hours of the day. Otherwise, between 06:00 to 18:00, the number of heard or observed birds was counted for each species during the period of each point. Equally, the breeding species were noted for each habitat and season. In total, 20 transects with 120 sampling points were released in each habitat (farmlands, rural and urban areas).

Foraging and breeding resources

Counting the number of tree and building cavities (number of species), cereal varieties (number of varieties), fruit trees (number of species), food debris (rest of crops on field, human food in trash on roads, streets, and markets), landfills, and flowers (species) enables us to identify the potential breeding resources in each habitat. The potential difference in habitat selection is suggested to be explained by these factors.

Data analyses

The recorded species (total observed individuals for each species during the study period) were grouped in orders and families with percentages. The number of breeding, migrants, wintering, and resident species were calculated based on the phenological status of each. The conservation status of each bird was cited following the latest UICN Red List update. Equally, the number of species, families, and abundance were calculated for the study period and transect. The number of recorded species and their abundance were compared among studied habitats with the Kruskal Wallis test.

To evaluate the affinity of recorded species (breeding and non-breeding species) toward studied habitats, documented species (N = 84 for total species and N = 37 for breeding species) were considered response variables (response = 1, presence of birds (breeding or non-breeding); response = 0, absence), while monitored habitats (N = 5) were considered explanatory variables and were analysed with Detrended correspondence analysis (DCA) (only eigenvalues >1.0 were selected). Equally, to evaluate the principal elements controlling the selection of habitats for breeding species, potential nesting resources (number of cavities in buildings and trees (species)), and foraging elements (cereals (8 varieties), lucerne (4 varieties), fruit trees (14), food debris (rest of crops on field, human food in rubbish on roads, streets, and Markets) landfills, and flowers (34 species) were considered factors (explanatory variables), while habitats (n = 5) were considered response variables and were analysed with principal component analysis (PCA) (only eigenvalues >1.0 and components with % of variance >50% were selected). These methods are widely used to evaluate the ecological requirements of habitats for plant and animal species counting birds (Dudáš et al. 2021; Bowles and Kleinsasser 2022). All analyses were performed using SPSS 18 for Windows and results were reported at a significance threshold of 0.05.

RESULTS

Diversity of birds

Table S1 lists the avian diversity of the prospected zone. A total of 84 bird species were spotted, including 65 species of passerines, 4 species of aquatic birds, and 12 species of raptors. The species that have been found fall under 33 families and 13 orders. Passeriformes, Accipitriformes, and Columbiformes were the most numerous orders, accounting for 59.13 %, 7.40%, and 4.93% of all birds, respectively. Cuculiformes, Caprimulgiformes, Ciconiiformes, and Caprimulgiformes were the least numerous orders, each having only one species. Similar to this, the most numerous families included Sylviidae (5.88% of species), Accipitridae (7.05% of species), Columbidae (5.88% of species), and Muscicapidae (12.94% of species). Additionally, the most frequently observed (abundance) birds were *Turdus merula*, *Passer domesticus*, and *Pycnonotus barbatus*, while *Motacilla alba, Circus aeruginosus*, *Anas platyrhynchos*, *Strixaluco mauritanica*, *Caprimulgus europaeus*, *Sylvia cantillans*, *Merops apiaster*, *Delichon urbicum*, *Oriolus oriolus*, and *Periparus ater* were less abundant avian species.

For the phenological status, 64.28% of birds were resident breeders, 17.85% were passage migrants, 26.19% were breeding migrants, 32.18% were winter visitors and 1.19% were accidental visitors. On the other hand, the majority of species (97.53%) were categorized in the list of least-concern species, while only two species (2.47%) were globally endangered counting the Vulnerable European Turtle Dove *Streptopelia turtur* and the Near Threatened Meadow Pipit *Anthus pratensis*.

There were more species observed overall in rural areas (60), farmlands (51), green spaces (46), and peri-urban areas (45), compared to urban areas (27 species) (Table 1). The observed species' abundance (counted birds for each species over the course of the entire study period) and mean abundance per transect were comparable among the examined habitats.

Habitat richness and affinity

Green spaces hosted an important diversity with 62 bird species (Figure 2). Rural areas hosted 11 birds, followed by farmlands and peri-urban zones with 7 and 6 bird species, respectively. The urban centres hosted only two birds. On the other hand, 37 bird species were documented as breeders via their nests, juveniles, and breeding pairs. Most breeders (14 species) were not related to a specific habitat, while 23 species were found in the unique breeding sites (Figure 3). In urban green spaces, 9 breeding birds were documented counting *Columba livia*, *Chloris chloris*, *Sylvia atricapilla*, *Sturnus unicolor*, *Parus major*, *Troglodytes troglodytes*, *Phoenicurus ochruros*, *Motacilla cinerea*, and *Elanus*

Table 1. Comparison with Kruskal-Wallis test of bird species and their abundance among studied habitats.

Habitats	Farmlands	Rural areas	Green spaces	Peri-urban areas	Urban centre	*p*-value
Species	51	60	46	45	27	–
Abundance	36.31 ± 8.44	38.5 ± 8.49	44.76 ± 9.95	24.93 ± 5.57	35.51 ± 10.12	0.386
Abundance/ transect	2.69 ± 0.40	2.67 ± 0.29	3 ± 0.24	4.19 ± 1.23	3.28 ± 0.71	0.554

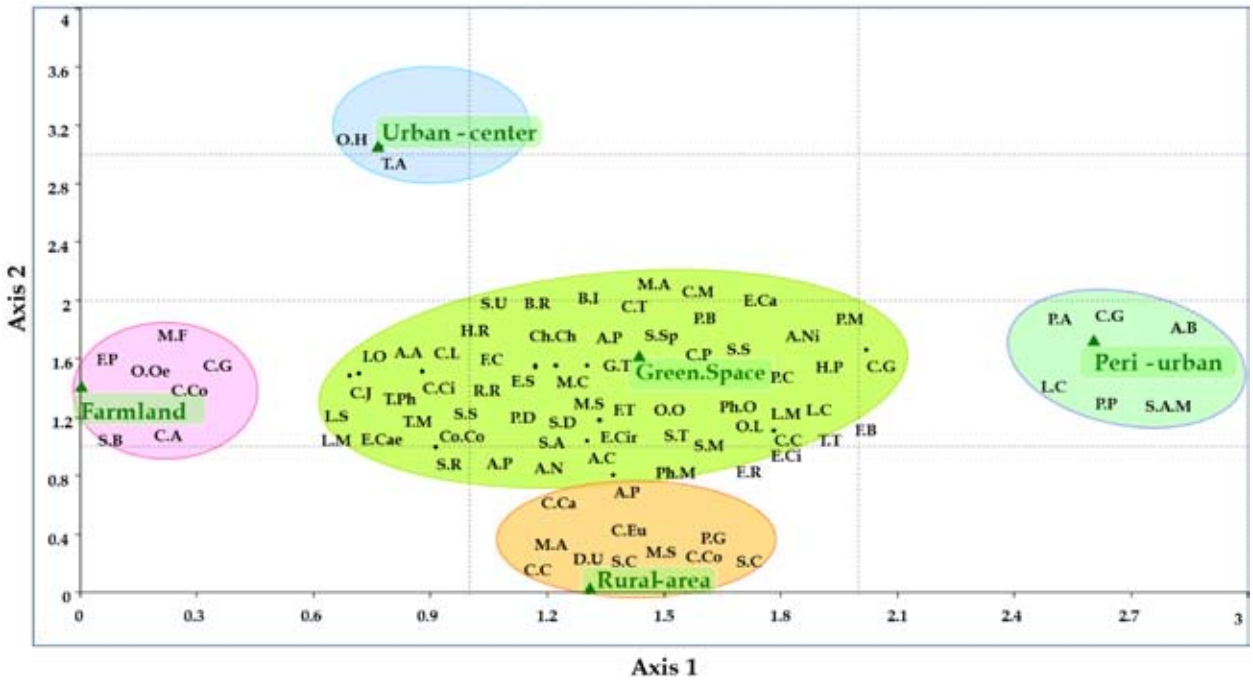

Figure 2. Distribution and affinity of avian species in studied habitats of Beni Mellal (**C.G**: *Cercotrichas galactotes,* **H.P**: *Hieraaetus pennatus,* **L.C***: Loxia curvirostra,* **M.F:** *Motacilla flava,* **M.A:** *Motacilla alba,* **C.C:** *Cettia cetti,* **E.S:** *Emberiza sahari,* **E.Ci:** *Emberiza cia,* **E.Ca:** *Emberiza calandra,* **E.Cir:** *Emberiza cirlus,* **P.B:** *Pycnonotus barbatus,* **C.A:** *Circus aeruginosus,* **B.R:** *Buteo rufinus,* **C.Co:** *Coturnix coturnix,* **A.P:** *Anas platyrhynchos,* **C.Ca:** *Carduelis carduelis,* **A.N:** *Athene noctua,* **C.M:** *Corvus monedula,* **S.A.M:** *Strix aluco mauritanica,* **C.Ci:** *Ciconia ciconia,* **C.G:** *Circaetus gallicus,* **C.J:** *Cisticola juncidis,* **G.T:** *Galerida theklae;* **C.C:** *Cuculus canorus,* **T.A:** *Tyto alba,* **E.Cae:** *Elanus caeruleus,* **C.Eu:** *Caprimulgus europaeus,* **A.Ni:** *Accipiter nisus,* **S.U:** *Sturnus unicolor,* **F.T:** *Falco tinnunculus,* **F.B:** *Falco biarmicus,* **F.P:** *Falco peregrinus,* **S.A:** *Sylvia atricapilla,* **S.B:** *Sylvia borin,* **S.C***: Sylvia communis,* **S.M:** *Sylvia melanocephala,* **S.C:** *Sylvia cantillans,* **M.S:** *Muscicapa striata,* **C.Co:** *Corvus corax,* **T.Ph:** *Turdus philomelos,* **Co.Co:** *Coccothraustes coccothraustes,* **M.A:** *Merops apiaster,* **A.C:** *Ardea cinerea,* **B.I***: Bubulcus ibis,* **D.U:** *Delichon urbicum,* **R.R:** *Ripa ria riparia,* **H.R:** *Hirundo rustica,* **I.O:** *Iduna opaca,* **L.C:** *Linaria cannabina,* **O.O:** *Oriolus oriolus,* **A.A:** *Apus apus,* **A.P:** *Apus pallidus,* **T.M:** *Turdus merula,* **P.M:** *Parus major,* **P.A:** *Perip arusater,* **C.T:** *Cyanistes teneriffae,* **P.D:** *Passer domesticus,* **M.S:** *Monticola solitarius,* **A.B:** *Alectoris barbara,* **P.P:** *Pica pica,* **L.S:** *Lanius senator,* **L.M:** *Lanius meridionalis,* **C.L:** *Columba livia,* **C.P:** *Columba palumbus,* **F.C:** *Fringilla coelebs,* **A.P:** *Anthus pratensis,* **P.C:** *Phylloscopus collybita,* **C.G:** *Coracias garrulus*, **L.M:** *Luscinia megarhynchos,* **E.R:** *Erithacus rubecula,* **Ph.M:** *Phoenicurus moussieri,* **Ph.O:** *Phoenicurus ochruros,* **S.S:** *Serinus serinus,* **S.R:** *Saxicola rubicola,* **S.Sp:** *Spinus spinus,* **S.T***:Streptopelia turtur,* **S.S:** *Spilopelia senegalensis,* **S.D:** *Streptopelia decaocto,* **O.Oe***: Oenanthe oenanthe,* **O.H:** *Oenanthe hispanica,* **O.L:** *Oenanthe leucura,* **T.T:** *Troglodytes troglodytes,* **Ch.Ch:** *Chloris chloris.*

caeruleus. In farmlands, 6 breeding species were confirmed counting *Lanius senator*, *Saxicola rubicola*, *Galerida theklae,* and *Carduelis carduelis*, followed by rural ecosystems with 3 species: *Serinus serinus*, *Emberiza cia*, and *Emberiza cirlus*. Only 3 breeding species were observed in peri-urban zones and two in urban centres.

Foraging and breeding resources

The principal component analysis of potential breeding and foraging resources recorded in each habitat is presented in Figure 4 and Table S2. The green spaces are principally rich in foraging elements counting flowers, debris, and water resources, as well as nesting potentials from cavities and ornamental trees. Farmlands and rural habitats are rich in cereals, lucernes, and fruit trees, while urban and peri-urban habitats are close to landfills only.

DISCUSSION

Based on extensive literature research, our study represents the first and unique exploration of the avian diversity in the rural-urban gradient in Morocco (Lahrouz et al. 2013; Greig-Smith 2020; Rihane et al. 2020; Bellout et al. 2021; Cherkaoui et al. 2021; Mansouri et al. 2022). Our main objective was to offer the first data on the avian diversity following the rural-urban gradient and the similarity of communities to the urban and natural landscapes. We acquired new and valued data describing the variation of bird diversity and their affinity toward natural and urbanized habitats. These findings are the first and only delivered information related to avian abundance in the rural-urban gradient in Morocco and the entire Northwest African region, which is of importance for carrying out a future monitoring and long-term

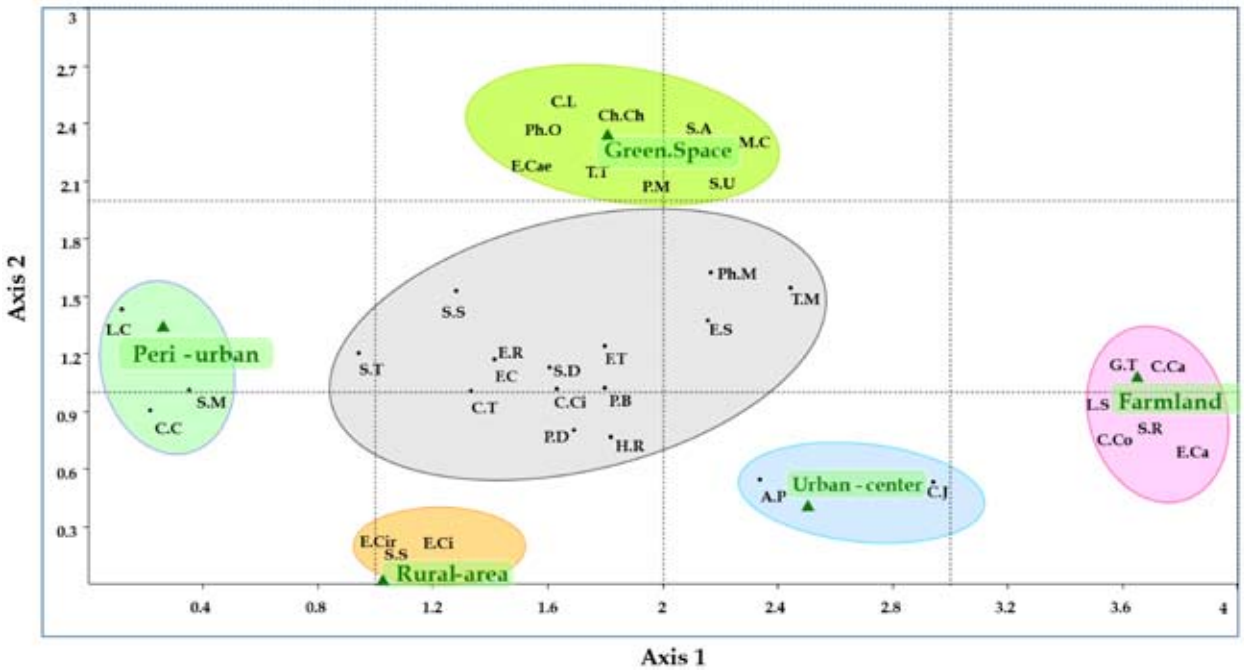

Figure 3. Distribution and similarity of breeding birds in studied habitats of Beni Mellal (**L.C:** *Linaria cannabina,* **S.M:** *Sylvia melanocephala,* **C.C:** *Cettiacetti,* **A.P***: Anas platyrhynchos,* **C.J:** *Cisticola juncidis,* **E.Cir:** *Emberiza cirlus,* **E.Ci:** *Emberiza cia,* **S.S:** *Serinus serinus,* **G.T:** *Galerida theklae,* **C.Ca:** *Carduelis carduelis,* **L.S:** *Lanius senator,* **S.R:** *Saxicola rubicola,* **C.Co:** *Coturnix coturnix,* **E.Ca:** *Emberiza calandra,* **Ch.Ch:** *Chloris chloris,* **C.L:** *Columba livia,* **S.A:** *Sylvia atricapilla,* **M.C:** *Motacilla cinerea,* **Ph.O:** *Phoenicurus ochruros,* **T.T:** *Troglodytes troglodytes,* **S.U:** *Sturnus unicolor,* **P.M:** *Parus major,* **E.Cae:** *Elanus caeruleus,* **S.T:** *Streptopelia turtur,* **E.S:** *Emberiza sahari,* **F.C:** *Fringilla coelebs,* **E.R:** *Erithacus rubecula,* **F.T:** *Falco tinnunculus,* **H.R:** *Hirundo rustica,* **Ph.M:** *Phoenicurus moussieri,* **T.M:** *Turdus merula,* **S.D:** *Streptopelia decaocto,* **P.D:** *Passer domesticus,* **P.B:** *Pycnonotus barbatus,* **C.Ci:** *Ciconia ciconia.*

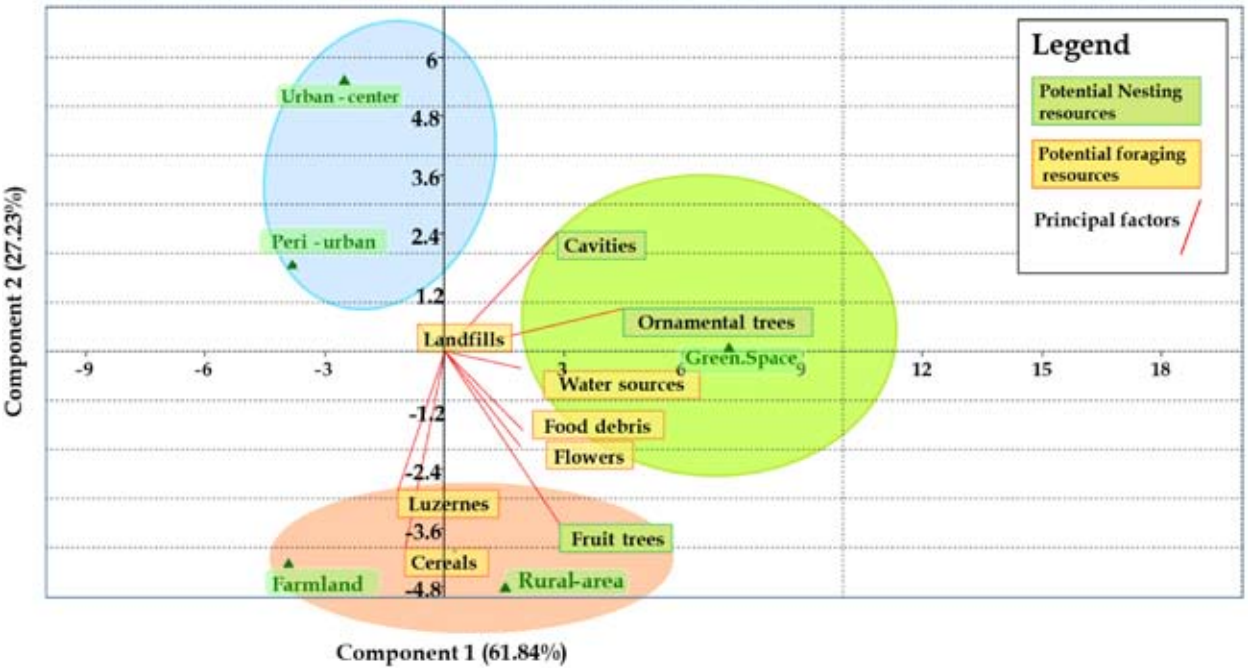

Figure 4. Principal foraging and breeding resources characterizing selected habitats for breeding species analysed with PCA.

conservation actions at least for the endangered avian populations.

This study highlighted an important avian diversity in Beni Mellal areas, observed in different ecosystems. Accipitridae, Muscicapidae, and Alaudidae represent 34% of recorded species, while Upupidae, Ciconiidae, and Oriolidae represent only 3% of recorded birds. Equally, orders of Passeriformes and Gruiformes were the most

observed in the area. This is completely identical to the results revealed in Midelt which is a city located only 160 km from Beni Mellal. This diversity of birds is supported by the diversity of habitats rich in foraging and nesting elements as confirmed recently for the globally threatened Turtle Dove *Streptopelia turtur* (Lormee et al. 2016; Mansouri et al. 2022) and previously for the Scottish Ringed Plover *Charadrius morinellus* (Whitfield et al. 1996). Moreover, the heterogeneity of ecosystems counting rural areas, farmlands, and urban infrastructures offer suitable breeding and feeding requirements of farmland, urban, and other affinity birds. On the other hand, two species of conservation concern, including the vulnerable European Turtle Dove and the European Goldfinch (Calderon et al. 2016) have been observed regularly in the studied area, and this requires an important and urgent research attention to characterize their habitats and ecological requirements for effective conservation measures (Clergeau et al. 2001; Lepczyk et al. 2017).

In terms of habitat richness and similarity, rural areas were the most diverse habitats with birds, followed by farmlands and peri-urban zones, while the urban centres hosted only two birds. This confirms the hypothesis that rural zones are richer in species because of low population size and intact habitats (Sengupta et al. 2014; Di Pietro et al. 2021). On the other hand, breeding species have revealed variable affinities toward studied habitats. The majority of species were indifferent and nested in all habitats from rural to urban. Equally, the majority of breeding birds were not related to specific habitats. Contrary to recent findings from the Northern slope of the Mediterranean basin (Murgui 2009; Calegaro-Marques & Amato 2014; Di Pietro et al. 2021), breeding birds were more abundant in rural than urban areas. The minority were concentrated in green spaces, followed by farmlands and rural ecosystems. This is in contradiction with current results sited in the Northern slope of the Mediterranean basin (Murgui 2009; Calegaro-Marques & Amato 2014; Di Pietro et al. 2021), in which breeding birds were abundant in rural areas more than cities. In the context of our study, the abundance of nesting is supported by counting ornamental trees, gardens (public and domestic), and riparian vegetation crossing the city, as well as foraging requirements counting landfills, flowers and seeds of planted trees (gardens and domestics), rubbishes, broken canals. All these factors must be taken into consideration in order to attract nesting species to urban areas more than to rural habitats of Beni Mellal, which are impacted by aridity leading to a reduction of wild and planted seeds, deforestation via wood consumption and incendiaries which lead to the elimination of potential nesting resources.

In summary, this study highlights the avifauna diversity and its variation in the rural-urban gradient and filled a lack of data on this topic in Morocco. This research offers the first detailed study on the variation of avian species richness, abundance, and affinity in the rural-urban gradient in Morocco and the whole Northwest African region. Unlike previous studies in other Mediterranean zones, this investigation showed an important richness in green spaces surrounded by urban landscapes compared to rural and farmland areas where human impact is low.

Conflict of interests

The authors declare they have no competing interests.

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Data Availability

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

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Table S1. Abundance, phenological status (PM: Passage Migrant, RB: Resident Breeder, BM: Breeding Migrant, WV: Winter visitor, AV: Accidental Visitor) and UICN conservation status (LC: Least Concern, E: Endangered, VU: Vulnerable, NT: Near Threatened) of recorded species in Beni Mellal region.

Order	Family	Species	Status	Conservation status	Abundance observed and heard	Mean
Passeriformes	Muscicapidae	*Cercotrichas galactotes*	PM	LC	3	3
		Muscicapa striata	BM	LC	114	10.36
		Monticola solitarius	RB, WV	LC	2	2
		Luscinia megarhynchos	BM	LC	15	3
		Erithacus rubecula	RB, WV	LC	11	1.22
		Phoenicurus moussieri	RB	LC	18	1.8
		Phoenicurus ochruros	RB, WV	LC	39	3.9
		Saxicola rubicola	RB, WV	LC	24	6.75
		Oenanthe oenanthe	PM	LC	4	4
		Oenanthe hispanica	BM	LC	6	2
		Oenanthe leucura	RB	LC	7	1.4
	Fringullidae	*Loxia curvirostra*	RB, WV	LC	9	4.5
		Carduelis carduelis	RB, WV	LC	9	1.8
		Coccothraustes coccothraustes	RB, WV	LC	79	6.07
		Linaria cannabina	RB, WV	LC	212	16.3
		Fringilla coelebs	RB, WV	LC	589	29.45
		Serinus serinus	RB, WV	LC	418	19.9
		Spinus spinus	WV	LC	2	2
		Chloris chloris	RB, WV	LC	366	18.3
	Motacillidae	*Motacilla flava*	BM	LC	1	1
		Motacilla cinerea	RB, WV	LC	56	4.66
		Motacilla alba	RB, WV	LC	134	11.16
		Anthus pratensis	BM, PM	NT	18	3
	Emberizidae	*Emberiza sahari*	RB	LC	178	16.18
		Emberiza cia	RB, WV	LC	9	1.8
		Emberiza calandra	RB, WV	LC	58	14.5
		Emberiza cirlus	RB	LC	53	4.81
	Sylviidae	*Sylvia atricapilla*	RB, WV	LC	295	22.69
		Sylvia borin	PM	LC	3	1
		Sylvia communis	BM	LC	2	1
		Sylvia melanocephala	RB	LC	368	17.52
		Sylvia cantillans	BM	LC	1	1
	Hirundinidae	*Delichon urbicum*	BM	LC	1	1
		Riparia riparia	PM	LC	2	1
		Hirundo rustica	BM	LC	367	30.58
	Paridae	*Parus major*	RB	LC	49	6.12
		Periparus ater	RB	LC	1	1
		Cyanistes teneriffae	RB	LC	150	11.54
	Laniidae	*Lanius senator*	BM	LC	30	15
		Lanius meridionalis	PAV		18	4.5
	Corvidae	*Pyrrhocorax graculus*	RB	LC	3	3
		Coloeus monedula	RB	LC	316	105.3
		Pica pica	RB	LC	84	41
		Corvus corax	RB	LC	6	6
	Cettiidae	*Cettia cetti*	RB	LC	43	4.3
	Pycnonotidae	*Pycnonotus barbatus*	RB	LC	845	40.24
	Cisticolidae	*Cisticola juncidis*	RB, WV	LC	45	9
	Alaudidae	*Galerida theklae*	RB	LC	198	22
	Sturnidae	*Sturnus unicolor*	RB, WV	LC	136	34
	Cettiidae	*Cettia cetti*	RB	LC	43	4.3
	Turdidae	*Turdus philomelos*	WV	LC	17	8.5
	Acrocephalidae	*Iduna opaca*	BM	LC	12	6

Order	Family	Species	Status	Conservation status	Abundance observed and heard	Mean
	Oriolidae	*Oriolus oriolus*	BM	LC	1	1
	Turdidae	*Turdus merula*	RB	LC	426	21.3
	Passéridae	*Passer domesticus*	RB	LC	1224	58.28
	Phylloscopidae	*Phylloscopus collybita*	WV, PM	LC	57	4.75
	Troglodytidae	*Troglodytes troglodytes*	RB	LC	28	3.5
Falconiformes	Falconidae	*Falco tinnunculus*	RB, WV, PM	LC	152	8.44
		Falco biarmicus	RB, PM	LC	2	1
		Falco peregrinus	RB, WV	LC	2	1
Columbiformes	Columbidae	*Columba livia*	RB	LC	283	21.7
		Columba palumbus	RB	LC	17	4.25
		Streptopelia turtur	BM, PM	VU	72	18
		Spilopelia senegalensis	RB	LC	35	5
		Streptopelia decaocto	RB	LC	410	19.52
Accipitriformes	Accipitridae	*Hieraaetus pennatus*	BM	LC	14	2
		Circus aeruginosus	RB, PM	LC	1	1
		Buteo rufinus	RB	LC	6	1.5
		Circaetus gallicus	BM, PM	LC	12	6
		Elanus caeruleus	RB	LC	10	5
		Accipiter nisus	RB	LC	23	2.55
Pelecaniformes	Ardéidae	*Ardea cinerea*	WV, PM	LC	3	1
		Bubulcus ibis	RB, PM, WV	LC	165	12.69
Apodiformes	Apodidae	*Apus apus*	BM	LC	251	35.85
		Apus pallidus	RB	LC	121	40.33
Strigiformes	Strigidae	*Athene noctua*	RB	LC	32	3.2
		Strix aluco mauritanica	RB	LC	1	1
Anseriformes	Anatidae	*Anas platyrhynchos*	RB, WV	LC	1	1
Ciconiiformes	Ciconiidae	*Ciconia ciconia*	BM	LC	49	3.77
Cuculiformes	Cuculidae	*Cuculus canorus*	BM, PM	LC	2	2
Caprimulgiformes	Caprimulgidae	*Caprimulgus europaeus*	BM	LC	1	1
Galliformes	Phasianidae	*Coturnix coturnix*	RB, BM, WV	LC	5	5
		Alectoris barbara	RB	LC	9	3
Coraciiformes	Coraciidae	*Coracias garrulus*	BM, PM	LC	2	2
	Meropidae	*Merops apiaster*	BM, PM	LC	1	1

Table S2. Most common foraging and breeding resources (natural and fruits, seeds, trees and other nesting supports) in the studied habitats.

Habitats	Farmlands	Rural areas	Green spaces	Peri-urban areas	Urban centre
Foraging and breeding resources	Fig orchards, olive orchards, cereal fields, reeds, lucerne fields, jujube and acacia steppes, castor, and corn fields	Olive tree, Rossoliere, cypresses, eucalyptus, Euphorbia plants, fig tree, resinifers, Aleppo pine, Canarisus pine, cereal cultivation, carob tree, almond and mulberry tree, poplar, and pomegranate tree	Poplar, fig, reeds, olive tree, Atlas cypress, almond tree, Aleppo pine, carob tree, orange tree, pistacia, common freina, and palm tree	Oleaster, Aleppo pine, euphorbia, carob tree, pistacia tree, Urginea, plum cultivation, and dwarf palm	Orange tree, buildings, old houses, vegetables in the public, markets