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A study of composition and diversity variation of avifauna along with different types of agroforestry system in Kibet town, Southern Ethiopia

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Abstract

Background: Agroforestry is an integrated land-use system that plays a great role in the conservation of landscape biodiversity. The study aimed to assess the composition and diversity of avian species along with different habitat types of agroforestry in Kibet Town, Southern Ethiopia.

Methods: Four habitat types of agroforestry system which are home gardens, live fences, parkland, and eucalyptus woodlot were identified. Line transects were used for bird surveys. The Shannon diversity index (H′) and species evenness index (E) were used to compare diversity among habitat types. A similarity percentages (SIMPER) test was carried out to identify the main species and feeding guild that typified each habitat type. The overall significance was assessed with the ANOSIM test using PAST (version 4.03).

Results: A total of 50 bird species belonging to 28 families and 10 orders were recorded. Order Passeriformes (67.3%) had the highest number of species. Bird community composition differed among habitat types. The dissimilarity was mainly due to White-browed robin-chat (*Cossypha heuglini*), Streaky seed-eater (*Serinus striolatus),* Village Weaver (*Ploceus cucullatus*), African Paradise-Flycatcher (*Terpsiphone viridis*), and Black-Headed Paradise Flycatcher (*T. rufiventer*). The finding also revealed that insectivore was the dominant feeding guild.

Conclusions: The present study shows evidence that more insectivore bird species use different types of agroforestry as habitat and foraging sites. So, any concerned bodies who have engaged in avian conservation should give special consideration to this modified landscape.

Keywords: Agroforestry, Avifauna, Feeding guilds, Insectivores, Kibet Town, Land-use

Introduction

Agriculture is a major manipulator of biodiversity but also has the potential to contribute to the protection of biodiversity [18]. To advance conservation and production goals, agricultural practices should be compatible with biodiversity [31]. The negative effect of agricultural systems on biodiversity has been reached to a large extent in this century due to the use of unsound technologies, inadequate zoning and farming practices and, mechanization, and deforestation [2]. Agroforests and other agricultural habitats rich in tree cover are essential for connecting isolated protected areas and their metapopulations [33]. Agroforestry is the most possible land-use system to raise tree cover and help conservation [9]. It is recognized as a possible partial solution for biodiversity conservation and improvement [41]. It improves

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biodiversity as it provides more habitats and food for birds, small mammals, reptiles, earthworms, and insects, which in turn lead to an increase in species diversity as a whole [1].

Agroforestry is recognized as an integrated land-use that can directly enhance agro-biodiversity and contribute to the conservation of landscape biodiversity, while at the same time increasing, diversifying, and sustaining rural incomes [24, 39]. It is a production system characterized by the combination of forestry and agriculture [42]. Many landowners view wildlife as an important by-product of their land management activities, particularly wood production [43]. The role of agroforestry practices on the provision of environmental services, particularly their contribution towards biodiversity conservation, recently attracted wider attention among field scientists [25].

In Ethiopia, agroforestry adoption like cash trees among small farms helps farmers to improve and recover the rural farmland management system and to maximize the farm productivity and income [11, 21]. It is an alternative and probably cheaper option for agricultural intensification and sustainability in the country. Different agroforestry practices are identified in the country as per their suitability to the different agro-ecology [7, 10, 26].

In Ethiopia, bird diversity and abundance in protected areas and natural forests have been studied by many national and international researchers, but the role of agroforestry for the conservation of wildlife in general and avian diversity, in particular, is still not studied in many parts of the country. Furthermore, nowadays to assess the response of species to emergent landscape characteristics is very crucial. Hence, this study was aimed to assess the composition and diversity of avian species along with the different types of agroforestry in case Kibet Town, Southern Ethiopia.

Methods and materials

Study area and site selection

The study was conducted in Southern Ethiopia, Silte zone, Kibet town agroforestry system (Fig. 1). The town is located 148 km from Addis Ababa on the road between Butajira to Arabaminch. It is 173 km far from Hawassa and 26 km from Werabe the capital towns of the Region and Zone, respectively. Its geographical location is approximately at 07°56′ N and 38°14′ E. Its mean annual temperature is 18.8 °C and its annual rainfall pattern is 1200.5 mm which is the climatic data of the closest town of Butajira since there is no available data for the district [15].

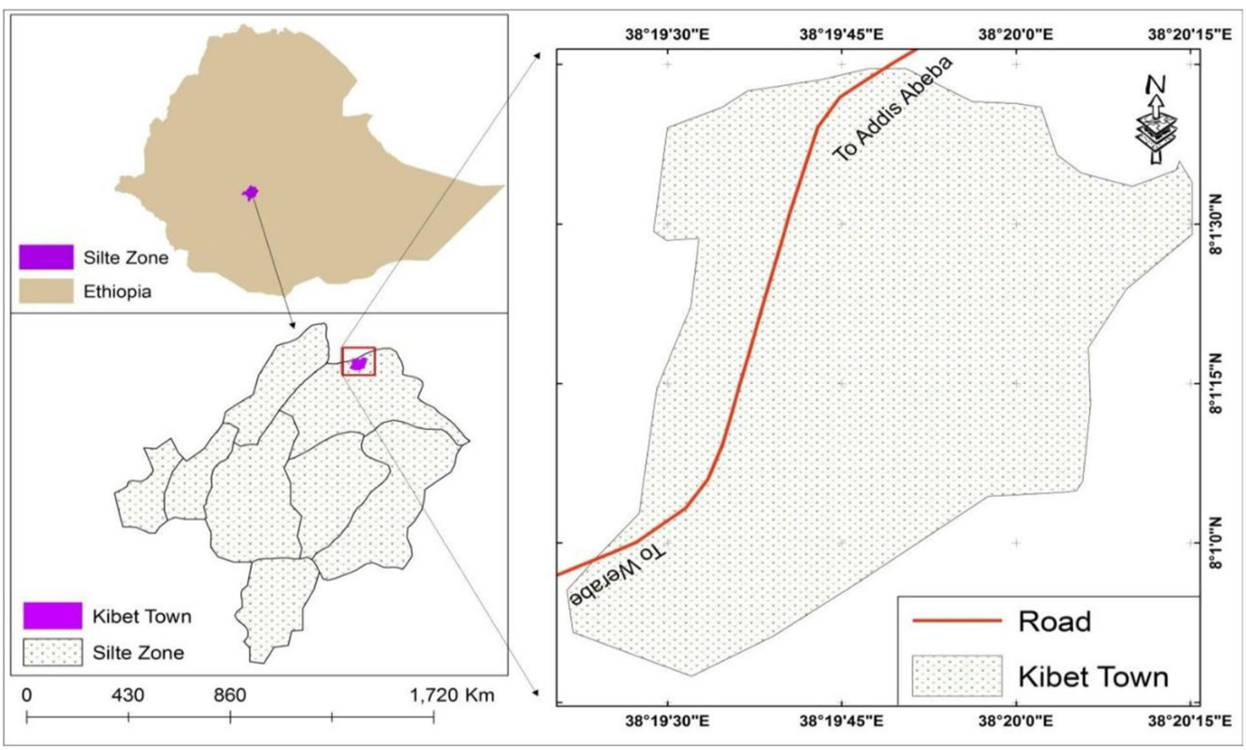

Fig. 1 Map of the study area

The agroforestry system in the study area mainly consists of the chat (*Catha edulis*), coffee (*Coffea arabica* L.), and Enset (*Ensete ventricosum).* Fruit trees such as Sweet orange (*Citrus sinensis L.),* Lime (*Citrus aurantifolia*), Avocado (*Persea Americana Mill*), Mango (*Mangifera indica L.*), and Banana (*Musa paradisiacal L*) are common. Unlike chat and coffee, fruits and vegetables are produced for consumption and local market. There are also several multipurpose tree varieties such as Tid (*Juniperus procera*), Zigba (*Podocarpus gracillor*), Weira (*Olea Africana*), Sholla (*Fiscus gur*), Bisana (*Croton macrostachyus*), Wanza (*Cordia africana*), and different Acacia spp. provide various services including fuelwood.

The vegetation cover of the field within the survey area was mapped during the bird survey. Fields were classified into four categories in terms of their field vegetation cover. These are home gardens, live fences, parkland, and fast-growing eucalyptus woodlots.

Home gardens (Hg) are composed of a high diversity of plants and an important source of household subsistence and cash needs which are characterized by being near the residence. The dominant components of the home gardens are coffee, enset, pepper, various annual crops, and numerous kinds of vegetables.

Live fences (Lf) are barriers of closely spaced trees or shrubs to protect crops or structures against livestock and human interference. It may be established all around the farm, but it is commonly established around the homesteads and gardens. Plant species like Koshim (*Dovyalis abyssinica*) are common native tree species to be promoted for this purpose other such as Qentaffa (*Pterollobium stellatum*), Quelqwal (*Euphorbia abyssinia*), and Acacia spp.

Eucalyptus woodlot (Ew) where woody perennial is planted and managed over time to produce fuelwood, and poles. The most common eucalyptus is the *Eucalyptus globulus.*

Parkland (Pl) involves the growth of individual trees and shrubs in wide spaces in croplands. Some good examples of this practice are *Cordia africana* and *Acacia albida* intercropping with maize.

Study design

The study was conducted from December 2019 to early October 2020 encompassing both wet and dry seasons. We assigned four study sites that reflected the impact of changing agroforestry type on bird diversity in the Kibet town agricultural landscapes. Fifteen sampling sites were established encompassing four study sites (habitat types): Home gardens (Hg, $n=5$), Live fences (Lf $n=4$), Eucalyptus woodlot (Ew, $n=3$), and Parkland (Pl $n=3$). We established a line transect in each sampling site with 500-700 m in length [8]. Each line transect was 100 m far away from the roadside to avoid edge effect and 300 m far away from each other to avoid double counting of the same individual of a species following the work of [6].

Feeding guilds were classified based on direct observations and available literature on feed bioecology [16].

Sampling method

Data were collected from December 2019 to April for the dry season and from late May to early October 2020 for the wet season. Four field visits (two visits in dry season and two visits in wet season) were conducted to observe the composition and diversity of bird species. Line transects were surveyed in each sampling site and pooled the data for analysis. The transect line was walked at a constant pace for approximately 30 min. Species observation mostly took place through vision and also through acoustic.

Bird survey

In all transects walk at a steady pace (30 min) between 7:00 am and 9:00 am in the morning and 4:30 pm to 6:00 pm in the late afternoon when most birds are active [6]. In the home garden area footpaths were used. To minimize disturbance during the count, a waiting period of 3 to 5 min before counting was applied [40]. No count was conducted in the presence of passing vehicles [28]. Species observation mostly took place through vision by using 8×17 binoculars and eyes, but also through sound. Overflying species were not included in the count.

Identification was visual except in some rare cases when the voice will be used if the bird cannot be seen. Identification and categorization of birds to their respective taxonomic groups' done following field guide books [4, 46, 47]. By considering all the recorded species during the study period, a baseline of bird checklist (database) was prepared.

Data analysis

Different samples of each habitat were pooled before analysis. Data were analyzed using the Shannon-Weaver Index to determine the species diversity and evenness in the study area [35]. A similarity analysis (SIMPER) was carried out to calculate the percentage contribution of each bird species to different study sites (i.e., species that are characteristic of each habitat type) along with the agroforestry system. But only the three most contributing species were considered for dissimilarity comparison. Differences in feeding guilds (in terms of feeding functional group) similarity between habitat types were also described by SIMPER and a one-Way Analysis of Similarity (ANOSIM). ANOSIM is a non-parametric permutation test that uses similarity matrices or, in this case, the Bray-Curtis index [13]. When there are no group differences global R is centered at zero, or $R \leq 0$, whereas if there are high group differences $R = 1$ [37]. Additionally, differences in species composition among sites were analyzed by a non-metric multidimensional scaling (NMDS), using the Bray-Curtis index. The species data can be collapsed into two dimensions using this ordination technique [30]. A plot of NMDS was applied as a visual aid to interpreting how species composition differed among habitat types [23]. The ANOSIM and SIMPER test was carried out with PAST 4.03 [20].

Results

A total of 50 bird species were recorded in the study area under 10 orders and 28 families. Order Passeriformes (67.3%) had the highest number of species followed by order Columbiformes (8.16%) while the lowest number of species was recorded under the order Bucerotiformes, Psittaciformes, and Coliiformes each represented with one species (Fig. 2). Out of the total recorded of avian species, 36% ($n = 18$) were residents, 34% ($n = 17$) wet season visitors, and 30% ($n = 15$) were dry season visitors (see Additional file 1). Two endemic bird species of Ethiopia namely Wattled Ibis (*Bostrychia carunculata*) and Black-winged Lovebird (*Agapornis taranta)* were identified from the study area.

Species diversity and evenness indices showed a nearly similar value for each corresponding index among different habitat types. The value of the Shannon-Weiner diversity index (H′) of these four habitat types (viz. Lf, Ew, Hg, and Pl) was greater than 1 (H′ =1.098, 1.093, 1.092, and 1.035, respectively). There was an even dispersal and distribution of species among sampling habitats viz. Lf, Hg, Ew, and Pl (J = 0.999, 0.994, 0.995, and 0.942, respectively) based on Pielou's evenness index (J) value (Fig. 3).

Habitat wise bird species dissimilarity

Regarding bird species similarity among habitat types, the result of similarity percentages (SIMPER) analysis and analyses of similarity (ANOSIM) are shown in Table 1. The dissimilarity between Hg and Lf was mainly linked to White-browed robin-chat (*Cossypha heuglini*) and Streaky seed-eater (*Serinus striolatus)* with a 60.45% dissimilarity level. For the dissimilarities of the two pairs: Hg vs Ew and Hg vs Pl, four main species were contributing more to the average dissimilarity. In particular, the presence of Village Weaver (*Ploceus cucullatus*) and Red-cheeked Cordonbleu (*Uraeginthus bengalus*) in Hg contributed more than 30% to the average dissimilarity. In group pairs, Lf vs Ew and Lf vs Pl, White-browed Robin-Chat (*Cossypha heuglini*), Streaky seed-eater (*Serinus striolatus*), and Village Weaver (*Ploceus cucullatus*) contributed most to the dissimilarity between the two group pairs. In the cases of group Ew vs Pl, the main species contributing to the dissimilarity include African Paradise-Flycatcher (*Terpsiphone viridis*), Black-Headed Paradise Flycatcher (*Terpsiphone rufiventer*), and Village Weaver (*Ploceus cucullatus*) contributed most to the dissimilarity (more than 40%) (Table 1).

As the one–way ANOSIM result shows that the global *R*-value for most group pairs is 1. This suggests that there is group separation between these group pairs. In the cases of groups Hg vs Lf, the global *R*-value is 0.5. The highest group separation with global $R = 1$, occurring among the corresponding group pairs: Hg vs Ew, Hg vs Pl, Lf **vs** Ew,

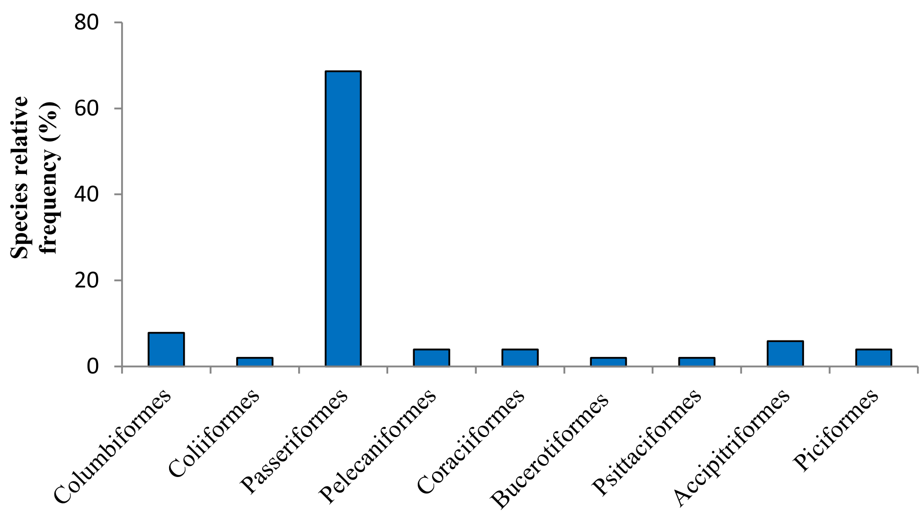

Fig. 2 Species composition of birds in their respective orders

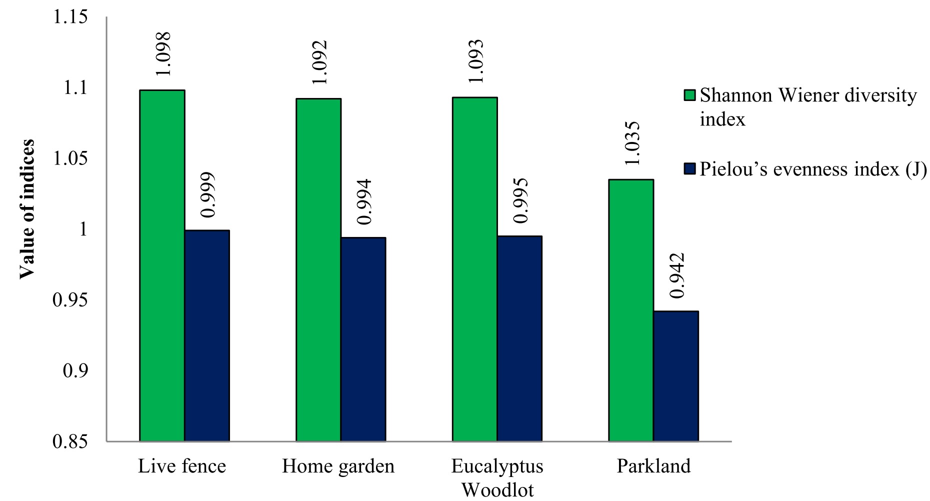

Fig. 3 Variation of Shannon's diversity index and Pielou's evenness index (J) along with different habitats type of the study area

Table 1 SIMPER and ANOSIM results for the pooled data of bird community composition between habitat pairs among the four habitat types (viz. Hg, Lf, Ew, and Pl) are presented

Habitat types	SIMPER				ANOSIM	
	Most discriminating species	**Contrib (%)**	**Cum (%)**	**Over. Av. Dissimilarity**	***R***	***p***
Hg vs Lf	White-browed Robin-Chat	19.5	19.5	60.45	0.5	0.6634
	Streaky seed-eater	12.24	31.75			
	White-rumped Babbler	8.155	39.9			
Hg vs Ew	Village Weaver	19.1	19.1	86.62	1	0.3302
	Red-cheeked Cordonbleu	15.45	34.55			
	Yellow spotted Petronia	7.516	42.07			
Hg **vs** Pl	Village Weaver	17.49	17.49	89.85	1	0.3333
	Red-cheeked Cordonbleu	14.14	31.63			
	Yellow spotted Petronia	6.841	38.47			
Lf **vs** Ew	White-browed Robin-Chat	17.11	17.11	89.59	1	0.3277
	Streaky seed-eater	10.7	27.81			
	Village Weaver	8.009	35.82			
Lf **vs** Pl	White-browed Robin-Chat	15.82	15.82	93.3	1	0.3344
	Streaky seed-eater	9.901	25.72			
	Village Weaver	6.905				
Ew **vs** Pl	African Paradise-Flycatcher	16.54	16.54	49.79	−0.25	0.668
	Black-Headed Paradise Flycatcher	13.01	29.55			
	Village Weaver	12.73	42.28			

Only three species that contributed the most to the dissimilarity are shown. The average dissimilarity is the contribution of each species to the dissimilarity between the two groups according to Bray-Curtis similarity. Contribution % indicated the contribution of each species to the group pair dissimilarity in percentage values. Cumulative % indicates the cumulative value of the contribution of each species to the dissimilarity

Contrib % Percentage contribution, Cum% Cumulative contribution, *Over. Av* Overall average dissimilarity, *R* Global *R*-value, *P*-value Significant value < 0.05

and Lf **vs** Pl. However, in all cases at *p*-value >0.05 the separation is not significant (Table 1). In support of this test, the Non-metric multidimensional scaling (NMDS) ordination technique also showed close clustering of study sites (Hg, Lf, Ew, and Pl) based on species presence–absence among study sites with a 0.09 stress (Fig. 4).

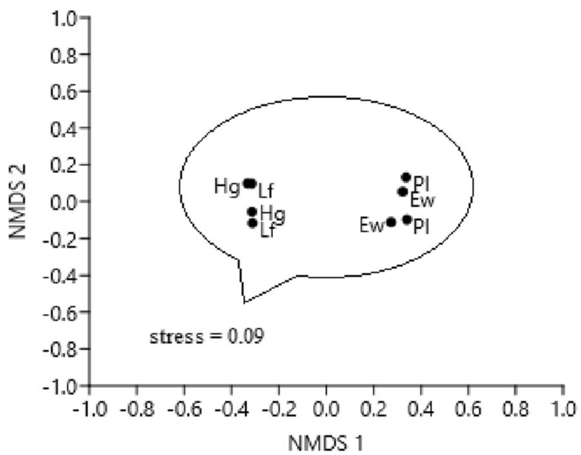

Fig. 4 Non-Metric Multidimensional Scaling (NMDS) representing clustering of habitat types (viz. Hg, Lf, Ew, Pl) based on species presence – absence among study sites (Bray-Curtis index, 95% ellipses) in study area

Bird functional feeding group along with different habitat types

Out of 50 species recorded in this study, the highest 40% were insectivorous, followed by granivorous (18%), nectarivorous (9%), omnivorous (8%) carnivores (3%), and frugivorous (2%). Regarding birds' feeding guild dissimilarity among habitat types, the result of similarity percentages (SIMPER) analysis and analyses of similarity (ANOSIM) are shown in Table 2. The dissimilarity between Hg and Lf was mainly linked to insectivores, granivores, and nectarivores with dissimilarity contributions of 58.06, 20.8, and 10.84%, respectively. For the dissimilarities of the two pairs: Hg vs Ew and Hg vs Pl, three main feeding guilds were contributing to the highest average dissimilarity. These are granivores, insectivores, and nectarivores. In particular, the presence of granivores in Hg contributed 52.18% for group pair of Hg vs Ew and 48.86% for group pair of Hg vs Pl. In group pairs of Lf vs Ew and Lf vs Pl, insectivores and granivores contributed more to the dissimilarity for the group pairs. In the cases of group Ew vs Pl, four feeding guilds contributed more

Table 2 SIMPER and ANOSIM results for the pooled data of bird feeding functional group between habitat pairs among the four habitat types (viz. Hg, Lf, Ew, and Pl) are presented

Habitat types	SIMPER				ANOSIM	
	Most discriminating feeding guild	Contrib (%)	Cum (%)	Over. Av. Dissimilarity	*R*	*p*
Hg vs Lf	Insectivores	58.06	58.06	43.64	0	0.6702
	Granivores	20.4	78.46			
	Nectarivores	10.84	89.31			
Hg vs Ew	Granivores	52.18	52.18	62.72	1	0.3298
	Insectivores	20.78	72.96			
	Nectarivores	11.38	84.34			
	Frugivores	10.27	94.61			
Hg **vs** Pl	Granivores	48.86	48.86	75.04	1	0.3314
	Carnivores	15.97	64.84			
	Insectivores	12.65	77.48			
	Nectarivores	10.71	88.2			
Lf **vs** Ew	Insectivores	50.49	50.49	56.25	0.5	0.3442
	Granivores	35.65	86.14			
Lf **vs** Pl	Insectivores	47.19	47.19	79.06	1	0.3319
	Granivores	28.4	75.59			
	Carnivores	11.08	86.67			
Ew **vs** Pl	Insectivores	28.92	28.92	68.54	0.75	0.3412
	Carnivores	26.53	55.45			
	Frugivores	21.84	77.29			
	Omnivores	11.77	88.06			

Dissimilarities between pairs of groups and bird feeding guild contributions are indicated. The average dissimilarity is the contribution of each feeding guild to the dissimilarity between the two groups according to Bray-Curtis similarity. Contribution % indicated the contribution of each feeding guild to the group pair dissimilarity in percentage values. Cumulative % indicates the cumulative value of the contribution of each feeding guild to the dissimilarity. Only functional feeding groups that contributed the most (> 10%) to the dissimilarity are shown

Contrib% Percentage contribution, Cum% Cumulative contribution, *Over. Av* Overall average dissimilarity, *R* Global *R*-value, *P-value* Significant value < 0.05

to the group dissimilarity including insectivores (28.92%), carnivores (26.53%), frugivores (21.84%), and omnivores (11.77%). From the one–way ANOSIM results, the global *R*- for group pairs suggests that there was group separation between all corresponding pairs except group Hg vs Lf with a global *R*-value is 0, which indicates that no separation between these two groups. In the case of group Lf vs Ew and Ew vs Pl, the global *R*-value is 0.5 and 0.75, respectively. For three groups: Hg vs Ew, Hg vs Pl, and Lf vs Pl, the global *R*-value is 1. This indicates there is group separation between the corresponding group pairs even if in all cases p-value > 0.05 (Table 2).

Discussion

In this study, order Passeriformes (67.3%) had the highest number of species from a total of 50 bird species recorded. The result was similar to Shiferaw and Yazezew [34] who surveyed avifauna at Ansas Dam and the surrounding farmland at Debre Berhan Town, Ethiopia. They found a total of 45 bird species belonging to nine orders likewise Passeriformes (37.8%) was represented the highest number. Species spillover into agricultural matrices is facilitated mainly by land-use type [12].

As found from SIMPER analysis, particular bird species contribute more to the dissimilarities of some groups (sampling habitat) unlike others, for example, White-browed Robin-Chat (*Cossypha heuglini*), Streaky seed-eater (*Serinus striolatus*), and Village Weaver (*Ploceus cucullatus*) contributed most to the dissimilarity of the Lf **vs** Ew and Lf **vs** Pl group pairs. Other species like African Paradise-Flycatcher *(Terpsiphone viridis),* Black-Headed Paradise Flycatcher (*Terpsiphone rufiventer*), and Village Weaver (*Ploceus cucullatus*) were contributed most to the dissimilarity of Ew **vs** Pl group pair (more than 40%). Species occurrence depends on not only a landscape composition but also a patch size [38]. So, habitat heterogeneity is an important environmental determinant of variation in species richness [14].

As ANOSIM significance test shows that there is no significant difference between all group pairs. Additionally, the ordination of non-metric multidimensional scaling (NMDS) was also visually represented a close distance among study sites based on species presence-absence among study sites (Fig. 4). The lack of significant differences in avian diversity among the study sites might be due to the small surveying area. According to Myers [29] to get data with more statistically significant, the number of study sites and the distance between each, and the sample size (sampling efforts) should be increased. The landscape like linear strips of vegetation fences (live fences) crossing the pastures provides some connectivity to bird populations [17]. This might make homogenous bird species composition along with different adjacent agroforestry habitats types.

In this finding, the insectivores feeding guild had the largest number of species (40%). This might be due to the best adapter of this feeding guild to the human-modified agricultural area. The ability of understory insectivorous birds to disperse through deforested countryside help them to persist in small fragments habitats [32] As stated by De Bonilla et al. [14] small landscape fragment has as potential key refuges for the most diverse and specialize feeding guilds, such as granivores and insectivores. According to Muñoz-Sáez et al. [27], an important driver of biotic homogenization of the community may be competition exclusion by agricultural adapters. A high abundance of granivores bird species in the Hg and Lf habitat might partly be associated with diverse seed-producing annual crop species that provided various food types for these birds. Seasonal variations in food sources where farmers plow farmland and annual crop species bloom during the wet and short rain season could be the reason for the relatively higher density of granivores feeding guild. This is similar to Waltert et al. [45] granivorous birds showed the highest species numbers in annual cultures and were significantly fewer species-rich in other habitat types.

As found from SIMPER analysis, some bird feeding functional group contributes more to the dissimilarities of sampling habitats unlike others, for example, In the cases of Ew **vs** Pl group pair, four feeding guilds contributed more to the group dissimilarity these are insectivores (28.92%), carnivores (26.53%), frugivores (21.84%), and omnivores (11.77%) whereas the dissimilarity of Hg vs Lf group pair was mainly linked to insectivores (58.06%), granivores (20.8%) and nectarivores (10.84%). Based on their preference mainly mediated by their choice of food, different functional feeding groups behaved differently [36]. Feeding guild among study sites also not significantly varies. The lack of significant differences might be due to the flight ability of birds along close proximate study sites makes species composition almost homogeneous. A similar previous study suggested that due to their mobile nature, all species of bird supposedly had an equal chance to access all corners of a small area landscape [19]. Several bird species are wide-ranging, and individuals can move from one study site to another within a short period across a landscape [3].

Our observations and interviews with the gardener of the study area showed that very few of the birds detected in the agroforestry habitats feed on the economically important fruits and the lost cause to the crops by these avian species is insignificant. Instead, as most feeding guilds are insectivores, they seem to feed on insects living in the arboreal structures and on the ground. So, it is likely that birds may contribute in important ways to the regulation of insect populations that are the major damaging agents (pests) of the plant.

Conclusion

In Ethiopia, particularly in the study area, the conservation value of agroforestry for avifauna has not been well documented. Most studies are limited to the national parks and other protected areas. In this study, a total of 50 bird species were recorded in the Kibet town agroforestry system comprising resident species (36%), wet season visitors (34%), and dry season visitors (30%). Order Passeriformes (67.3%) had the highest number of species followed by order Columbiformes (8.16%). Two species namely Wattled Ibis (*Bostrychia carunculata*) and Black-winged Lovebird (*Agapornis taranta*) were identified as endemic to Ethiopia. Regarding the feeding guilds, the majority of birds' feeding guilds were categorized as insectivores followed by granivores. Generally, one of the main findings of this study is showing the evidence that more insectivore bird species use different types of agroforestry as habitat and foraging sites.

Recommendations

- ➢ Our finding provides strong evidence that human-modified landscape is successful at attracting more insect-eating birds that might serve as biological control of pests;
- ➢ Mosaic of agricultural areas with a large multi-purpose tree might sustain a considerable proportion of the bird fauna;
- ➢ The Government should give support to simplify the access of tree seed and germplasm to the gardener.

Supplementary Information

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Additional file 1. Bird species recorded in the study area during wet and dry seasons.

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Authors' contributions
All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Hussein Yasin and Wondimagegnehu Tekalign. The first draft of the manuscript was written by Hussein Yasin. The draft manuscript was commented on and approved by Wondimagegnehu Tekalign. The author(s) read and approved the final manuscript.

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Availability of data and materials
Data sharing is not applicable to this manuscript as no datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the declaration of Helsinki that provides guidance for the researcher to protect research subjects. The study was approved by the Institutional Research Review Board (IRB) of Wolaita Sodo University. The consent to participate is not applicable to this research.

Consent for publication
All authors agreed to the public this original research work.

Competing interests
The authors declare that they have no competing interests.

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