

## Research Article

# Influence of Land-Use Type on Forest Bird Community Composition in Mount Kenya Forest

Samuel N. Mahiga <sup>1</sup>, Paul Webala,<sup>2</sup> Mugo J. Mware,<sup>1</sup> and Paul K. Ndang'ang'a<sup>3</sup>

<sup>1</sup>Department of Natural Resources and Environmental Management, Karatina University, P.O. Box 1957-10101, Karatina, Kenya

<sup>2</sup>Department of Forestry and Wildlife Management, Maasai Mara University, P.O. Box 1957-1010, Narok, Kenya

<sup>3</sup>Africa Partnership Secretariat, Birdlife International, P.O. Box 3502-00100, Nairobi, Kenya

Correspondence should be addressed to Samuel N. Mahiga; mahiga.sn@gmail.com

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Few studies have explored how human land uses influence and support persistence of forest biodiversity in central Kenya. In the case of the Mount Kenya ecosystem, farmlands and plantation forests are significant land-use types. Using point counts, we assessed bird communities in natural forests, plantation forests, and farmlands in the Nanyuki Forest Block, Western Mount Kenya. Bird point counts were undertaken during two sampling periods (wet and dry season). Compared to farmlands and plantation forest, natural forest had the highest overall avian species richness and relative species richness of all except one forest-dependent foraging guild (granivores) and nonforest species, which occurred frequently only on farmlands. Plantation forest had the lowest relative richness of all avian habitat and foraging guilds. Conversely, specialist forest-dependent species mainly occurred in the structurally complex remnant natural forest. Our study underscores the importance of remnant natural forests for the persistence and conservation of forest biodiversity and risks posed by replacing them with plantation forests and farmlands.

## 1. Introduction

Global forest loss has increased dramatically in the last few decades [1]. Most deforestation has happened in biodiversity-rich tropical forests [2, 3]; these areas are expected to face even more pressures in the future, largely due to agricultural expansion [4, 5]. The conversion of natural habitats, especially intact old-growth forest [6], to agricultural and pastoral lands is among the greatest threats to biodiversity [4, 7].

Kenya is endowed with a wide range of forest ecosystems ranging from montane rainforests, savannah woodlands, dry forests, coastal forests, and mangroves [8]. Forests play critical ecological, social, cultural and economic functions [9]. They are crucial in providing basic human needs and habitat for wildlife, biodiversity, soil conservation, regulating water flows and sequestering carbon dioxide [10]. Sustainable forest management is at the very core of Kenya's social and economic wellbeing as most of the country's economic sectors rely on environment based resources for their sustenance

[9]. Further, the forest sector is estimated to contribute about 7 billion Kenya Shillings to the economy and employ over 50,000 people directly and another 300,000 indirectly [8]. According to KFS (2012) [8], Kenya Forest Service raised a total of Kenya shillings 858,409,407.05 from 3367.62 hectares of plantation forest in the year 2012, hence making Kenya shillings 254,900.9113 (2,549 USD) per hectare of plantation forest.

The conversion of natural forests to croplands is often accompanied by expansion in monocultures of plantation forests to meet the growing demands for timber and associated wood products [9]. The resulting landscapes comprise different mosaics of anthropogenically modified habitats, including farmlands, agroforests, old growth remnants, logged forests, secondary forests, and tree plantations [11]. The new agroecosystems are often fundamentally different from indigenous natural forests in composition and structure, leading to different ecological and functional processes [12, 13].

It is important to understand anthropogenic impacts on the occurrence of avian functional groups because they determine ecosystem functioning [14]. In addition, birds play pivotal ecological roles both in forest and farmland ecosystems, notably pollination, seed dispersal, and pest control [14–16]. Birds also act as mobile links that transfer energy both within and among ecosystems [17, 18] that are crucial for maintaining ecosystem function and resilience [18].

Mount Kenya forest is an Important Bird Area (IBA) recognised as a priority site for biodiversity conservation [19]. It has a rich Afro-montane bird fauna [20]. The forest is also one of the largest and commercially important forest areas in Kenya and is considered to be among the highest priority forests for national conservation [21]. However, like many other forests in the country, Mount Kenya forest is facing enormous pressure from anthropogenic activities [22]. Situated in an agricultural and densely populated area in central Kenya, the forest ecosystem is under great pressure, mainly due to human activities [22, 23]. Previous studies have identified the main threats facing Mount Kenya forest ecosystem as illegal logging, wildlife poaching, shamba (shifting cultivation) systems, fire, and human-wildlife conflict [24, 25]. Consequently, many sections of the forest have been converted to open woodlands and farmlands.

Commercial plantation forests were introduced in Mount Kenya Forest in early 1900, the main purpose of supplying commercial forest products to the forest industries located within the forest adjacent areas [26]. These plantations make 6.6% of the 277,118 ha covered by all the main vegetation types of Mount Kenya Forest [26]. Human-modified landscapes serve dual purposes of maintaining biodiversity and sustaining local community livelihoods [27].

Mammals respond to human-habitat modification by modifying their life style and behaviours [28], change in breeding period [29], and dietary change [29, 30]. Nonetheless, few studies have evaluated the suitability of human-modified landscapes in sustaining biodiversity [11]. Such information is important for understanding the roles of natural and human modified habitats on biodiversity and in particular birds. Some studies [31–33] have demonstrated that the diversity of birds is negatively correlated with percentage of land used for intensive human activity and levels of homogeneity within agroecosystems at both local habitat and regional landscape scales. It is important to have clear understanding of how birds respond to habitat modification at local level for effective conservation strategies in Kenya.

Therefore, this study investigated the influence of land-use type on avian feeding and forest-dependent guilds in the western part of Mount Kenya Forest. Specifically, this study determined the influence of land-use type (natural forest versus farmland and plantation forest) on occurrence of avian foraging and forest-dependent guilds. This information is important as a scientific basis for managing human-modified land-cover types for the purpose of retention and persistence of forest biodiversity [34]. It also provides a basis for making decisions before further conversions of natural forests to other land cover types such as farmlands and plantation forests.

## 2. Materials and Methods

This study was conducted within and around Nanyuki Forest Block of the larger Mount Kenya Forest in Central Kenya (Figure 1).

Mount Kenya forest covers 277,118 ha while Nanyuki Forest Block (0003°N, 37009°E) covers 9,855 ha at 2309–2387 m above sea level [26]. The area has two distinct dry and wet seasons, with long rains falling from March to June and short rains from October to December. Average annual precipitation ranges from 2,300 mm on the south-eastern slopes to 900 mm in the north [35]. The vegetation is a mix of rainforest, bamboo (*Arundinaria alpina*), open woodland, scrub, Afroalpine moorland, and the high altitude rock peaks. Mount Kenya has a rich montane avifauna that includes 53 out of Kenya's 67 African Highland biome species, at least 35 forest specialist species, and six of the eight species that make up the Kenya Mountains Endemic Bird Area [20, 24].

This study was conducted within farmlands, plantation forests, and natural forests. Farmlands were composed of small-scale subsistence mixed crop farms, with patches of fallow land, isolated trees, bushes, and hedgerows. Natural forest sites were undisturbed dense montane forest characterized by canopy tree species such as Red Cedar (*Juniperus procera*), Podo (*Podocarpus falcatus*), and Olive (*Olea africana*). The dominant shrubs include *Toddalia asiatica*, *Rhus natalensis*, and *Trichocladus ellipticus*. The plantation forest was characterized by Cypress (*Cupressus lusitanica*) plantations without naturally growing understory plants.

**2.1. Study Design.** The study was conducted between March–May and August–September 2014. Data on birds was collected in three distinct habitat types: representing differences in land-use intensity and vegetation structural heterogeneity: natural forest, plantation forest, and farmland. The farmlands were composed of small-scale subsistence mixed crop farms, with patches of fallow land, isolated trees, bushes, and hedgerows. Natural forest sites were undisturbed dense montane forest characterized by canopy tree species such as Red Cedar (*Juniperus procera*) growing to over 30 m, Podo (*Podocarpus falcatus*) with heights of up to 45 meters and the olive trees (*Olea africana*). The dominant shrubs included *Toddalia asiatica*, *Rhus natalensis*, and *Trichocladus ellipticus*. The plantation forest was characterized by Cypress (Family *Cupressaceae*) plantations.

Using a stratified random sampling design, two study plots (1000 meters X 1000 meters) were established in each land cover types (natural forest, plantation forest, and farmland) within the study area. In each study plot five linear transects were randomly established, and five point counts were then established along each transect at distance of 200 meters apart. In total there were 25 point count plots per study plot and 150 point counts in the whole study area. The geographical coordinates of each point count were recorded using a GPS receiver (Garmin eTrex Summit). Sampling was done twice at each point count plot, once in dry season (August and September) and once in wet season (April, March, and may).

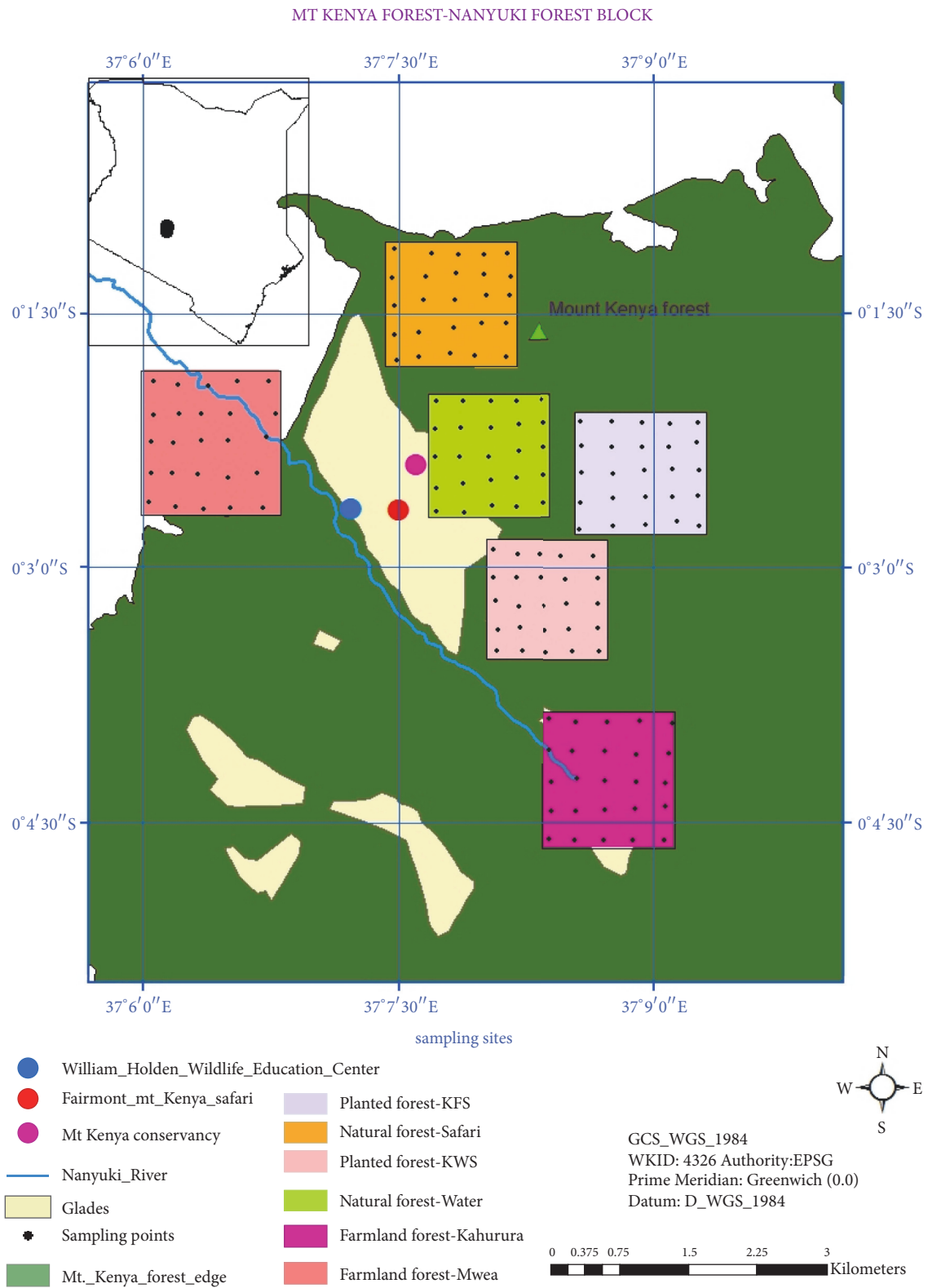


FIGURE 1: Study area map. Bird point counts marked using coloured dots.

TABLE 1: Tukey's HSD test significant results.

Dependent Variable	Habitat Type	Habitat type	P value
Forest Generalists	Natural Forest	Plantation Forest	≤ 0.001
		Farmland	≤ 0.001
	Plantation Forest	Farmland	≤ 0.003
Non Forest Species	Natural Forest	Farmland	≤ 0.001
	Plantation Forest	Farmland	≤ 0.001
Forest Specialists	Natural Forest	Plantation Forest	≤ 0.001
Forest Visitors	Natural Forest	Plantation Forest	≤ 0.001
	Plantation Forest	Farmland	≤ 0.001

**2.2. Bird Counts and Classification.** Birds were counted using the fixed-radius point count method as described by Bibby et al. [36]. On arriving at a point count station, birds were allowed to settle for one minute. All birds seen or heard within the 30 m radius plot were then recorded within a period of 10 minutes. The counts were conducted between 06:30 and 11:00 on fair weather days and were done twice at each point count plot: once in the dry season (August to September) and once in the wet season (March to May). Recorded birds were then classified into guilds according to habitat and diet preferences.

Classification into habitat-preference guilds was guided by the forest-dependence classification of Bennun et al. [37] as follows. "Forest Specialist" (FF) species are true forest birds, characteristic of the interior of undisturbed forest. They are rarely seen in nonforest habitats. "Forest Generalist" (F) species may occur in undisturbed forest but are also regularly found in forest strips, edges and gaps. They are likely to be more common there and in secondary forest than in the interior of intact forest. Breeding is typically within forest. "Forest Visitor" (f) species are often recorded in forest, but are not dependent upon it. They are almost always more common in nonforest habitats, where they are most likely to breed.

Diet classification for African birds was used to group birds according to their diets [38]. Each bird species usually take up to three "major" and three "minor" diets. This was used as a basis for placing all recorded bird species into seven foraging guilds. Only the "major" diets were used in placing birds into guild classifications following Gray et al., [39] that was adapted by Ndang'ang'a et al. [18]. These are carnivores (vertebrates), nectarivores (nectar), frugivores (fruits), insectivores (insects), granivores (seeds), omnivores (insects, leaves), and herbivores (vegetable materials, e.g. leaves, shoots, roots, flowers and bulbs).

**2.3. Data Analyses.** To determine the influence of land cover type on relative richness of avian feeding guilds and forest dependent guilds one way analysis of variance (ANOVA) was conducted. Turkey's highly significant difference test was also conducted. These analyses were carried out using SPSS 16.0.

### 3. Results

A total of 1902 individual birds belonging to 90 species were recorded throughout the study. The highest number of bird

species (77) was recorded in the natural forest, followed by farmlands (59) and plantation forest (19). A large proportion of birds recorded in this study were forest dependent species including 26 forest generalists, 36 forest visitors, 17 forest specialist species and 11 non forest species. All species accumulation graphs reached an asymptote indicating that the sampling was exhaustive and further sampling could not add new species (Figure 2). Natural forest had the highest species richness followed by farmlands and plantation forests respectively. The three land cover types had significant differences in species richness  $F_{2, 147} = 35.92$ ,  $P \leq 0.0001$  at 95% Confidence intervals of Natural forest [2.4811, 3.788], Plantation forest [1.279, 1.6202] and Farm lands [3.5274, 4.0958]

**3.1. Influence of Land-Use Type on Bird Species Richness and Forest Dependent Guilds.** The relative richness of forest specialist and generalist species was high in natural forest while farmlands had a higher richness of nonforest habitat dependent guilds (Figure 3). The three land-use types showed significant differences in relative richness of various habitat dependent guilds, forest generalist species ( $F_{2, 147} = 56.17$ ,  $P \leq 0.0001$ ), nonforest species ( $F_{2, 147} = 9.79$ ,  $P \leq 0.001$ ), forest specialist species ( $F_{2, 147} = 52.45$ ,  $P \leq 0.001$ ), and forest visitor species ( $F_{2, 147} = 20.51$ ,  $P \leq 0.0001$ ) at 95% Confidence interval of generalist [1.4981, 2.0218], Non forest species [0.1268, 0.3731], Forest specialist species [0.5268, 0.9713] and forest visitors species [1.4653, 1.9412].

Significant differences were further analysed using post hoc Tukey's HSD test at 95% confidence level, the analysis showed significant differences in relative richness of avian forest dependence guilds among the three cover types (Table 1).

**3.2. Influence of Land-Use Type on Avian Feeding Guilds.** The relative richness of avian feeding guilds was also differed within different land-use types. There were significant differences in relative richness of frugivores ( $F_{2, 147} = 34.33$ ,  $P \leq 0.0001$ ), omnivores ( $F_{2, 147} = 34.41$ ,  $P \leq 0.0001$ ), granivores ( $F_{2, 147} = 3.73$ ,  $P \leq 0.026$ ), insectivores ( $F_{2, 147} = 33.22$ ,  $P \leq 0.001$ ), and nectarivores ( $F_{2, 147} = 3.22$ ,  $P \leq 0.043$ ) between the three land-use types at 95% CIs [0.9702, 1.40971], [0.8874, 1.2392], [0.2257, 0.4542], [1.3269, 1.7730], and [0.1728, 0.3538], respectively. Natural forest had the highest richness of frugivores, omnivores, insectivores, and nectarivores, whereas

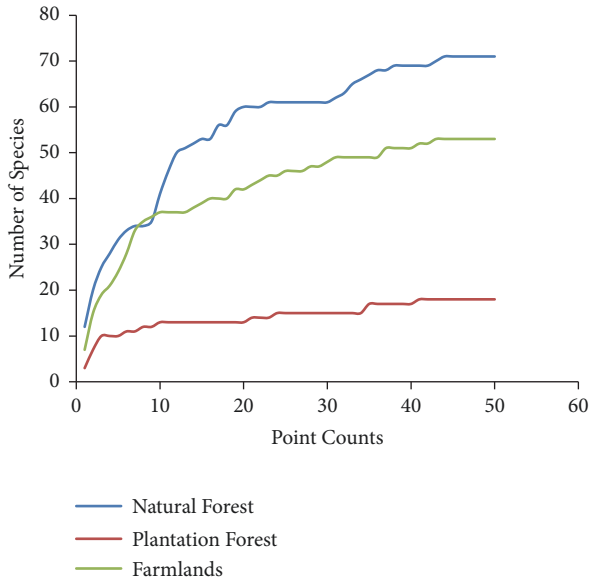


FIGURE 2: Species accumulation rates for birds at Nanyuki Forest Block, Western Mount Kenya: March-May and August-September 2014.

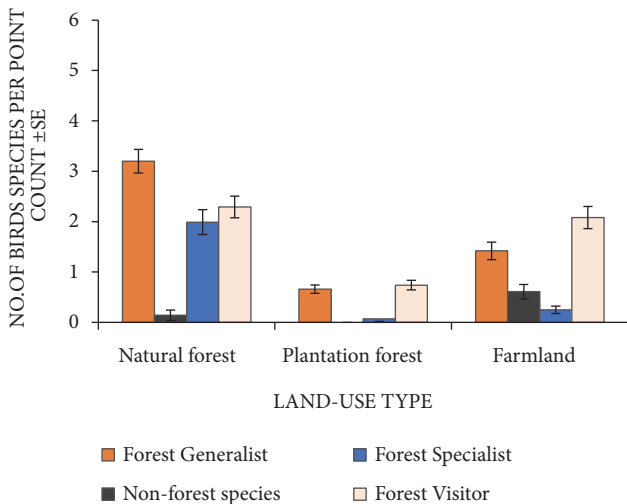


FIGURE 3: Influence of land-use type on bird species richness and forest dependent guilds.

farmlands had the highest relative richness of granivores (Figure 4). Significant differences were further analysed using post hoc Tukey’s HSD test at 95% confidence level (Table 2).

**4. Discussion**

This study provides insights into influence of land-use type on occurrence avian foraging and habitat guilds in natural forest, plantation forest, and farmlands in East African. The study’s focus on habitat guilds and foraging guilds is quite relevant since many of the most important ecosystem services that birds provide result from their foraging behavior [18, 40].

Consistent with other studies elsewhere, for example, in Argentina [41], Uganda [42], Tanzania [43], and Kenya [44],

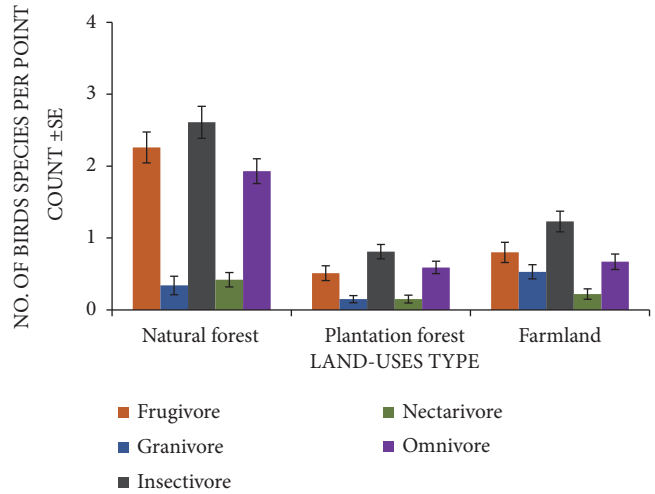


FIGURE 4: Influence of land-use type on relative richness of avian feeding guilds.

we found that plantation forests support far much lower bird species richness as compared to natural forests. Compared to natural forests plantation forests usually have less habitat diversity and complexity [45]. Plantation forests are usually characterized with lower level of biodiversity of canopy trees and other species [46, 47]. Increasing number of studies have discovered that monoculture plantations have lower levels of biodiversity than surrounding native forests, and some of them have considered exotic monocultures as “biological deserts” [48, 49]. However with proper management plantation forests can support biodiversity conservation [50] many studies in the tropics that compared avifauna between forested and agricultural areas have generally shown that forested areas contain more species than agricultural areas (Daily et al., 2001 [41, 51–54]).

Forest modification and fragmentation are known to result in declines of frugivores and insectivores and an increase in granivores [55–57]. This could in turn lead to disrupted avian-mediated seed dispersal thus preventing colonization of fruit trees and persistence of certain frugivores in this disturbed habitat [55]. According to Sodhi et al. [55], Sreekar et al. [58], and Mulwa et al. [14], insectivores are adversely affected by pesticides, lack of leaf litter, and low vegetation diversity associated with farmlands, and these factors could have caused the observed low abundance of insectivores in farmlands within the study area. Insectivores are also very sensitive to habitat modification [42, 57].

In contrast, granivore bird species were more common in farmlands than any other feeding guild. This could be attributable to availability of food resources associated with farmlands since substantial amounts of weed-seed grains are held in cultivations and fallow lands that may provide food especially for seedeaters, canaries, doves, sparrows, and weavers [9], [18]. This is supported by Gray et al. [39] findings that richness and abundance of insectivores and granivores tend to decrease and increase respectively in response to human-induced disturbance. Gray et al. [39] demonstrated that farmlands and plantation forests are highly disturbed with lower vertical stratification and low tree species diversity



TABLE 2: Tukey's HDS test significant results.

Feeding Guilds	Habitat type	Habitat Type	Significance level.
Frugivores	Natural Forest	Plantation Forest	$\leq 0.001$
		Farmland	$\leq 0.001$
Insectivore	Natural Forest	Plantation Forest	$\leq 0.001$
		Farmland	$\leq 0.001$
Nectarivores	Natural Forest	Plantation Forest	$\leq 0.041$
		Farmland	$\leq 0.001$
Omnivore	Natural Forest	Plantation Forest	$\leq 0.001$
		Farmland	$\leq 0.001$

compared to the natural forest [59] and hence recorded more granivores that utilize such disturbed environments. Forest specialists avoided human-modified cover types, with farmlands being preferred by generalist species and plantation forests being suitable for only a small number of nonforest species. Therefore, levels of forest dependence may be considered a useful tool for predicting species sensitivity to vegetation cover type [41, 42, 44, 60–62].

A large proportion of birds (ca. 88%) recorded in this study are forest dependent species including 26 forest generalists, 36 forests visitors, and 17 forest specialist species. The rest were 11 non forest species. Forest-dependent species are the most sensitive to the replacement of natural forests [42, 60, 61]. Most forest-dependent species recorded in our study were found only in the natural forest, whereas bird communities in farmlands were composed mainly of forest-generalist and nonforest species. Generalist guilds in this study were not affected by human disturbance because they depend on more open habitats usually associated with human activities. Similar findings were recorded in Kakamega forest in Kenya [63]. According to Pearman [64], variation in vegetation cover may affect the distribution of bird foraging guilds. Frugivores, insectivores, and omnivores increased with vertical vegetation heterogeneity and number of trees natural forest [9].

## 5. Conclusions

In conclusion, the findings obtained from this study indicated that exotic plantations and farmlands have a limited potential to support forest bird species. Finally, the conversion of tropical forests to farmlands and plantation forests leads to substantial decline in forest bird and especially of the specialized feeding guilds such as insectivores and frugivores. This underscores the importance of the protection of remnant natural forests for the conservation forest biodiversity.

## Data Availability

The birds and vegetation data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

“The authors declare that there are no conflicts of interest regarding the publication of this paper.”

## Acknowledgments

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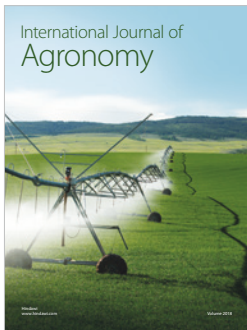
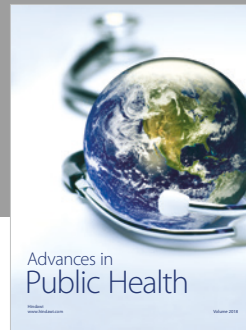
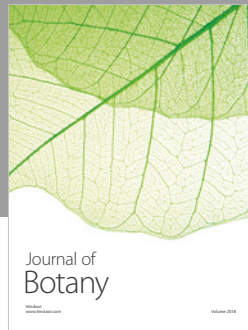
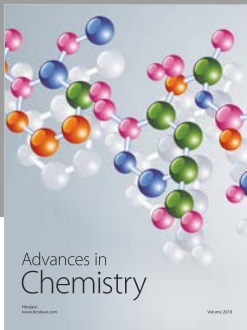
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