Sustainability and Biodiversity Conservation

Effects of the establishment of large-scale teak plantations on bird assemblages in Kilombero Valley, Tanzania

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Abstract

The trend of natural land use changes is inevitable following persistent global population increase and demand for wood products. To satisfy these demands, large exotic plantations such as teaks, characterized by simple structure, intensive management activities, and poor in diversity have been favored. However, monitoring using biodiversity indicators such as birds can improve strategies developed to conserve biodiversity in these plantations. This study hypothesized that natural remnants around the teak plantations will have higher bird species composition and diversity than the plantations. Bird surveys were conducted using the point count method with three (3) point count stations of 50 m radius, distanced 100 m from the edge of the habitat and 300 m apart from each other. One-way ANOVA was performed to compare the means of bird species parameters within each habitat and between vegetation types. Sorenson's coefficient was equally calculated between pairs of habitats to assess their similarity. The results showed that natural remnants and teak plantations had 39% similarity in bird species recorded. However, natural remnants had higher bird abundance (806) and species richness (92) compared to teak plantations which had 450 bird abundance from 53 species and 23 families. Also, natural remnants had significantly higher ($p < 0.05$) families and species diversity of birds than teak plantations. Richer species richness and diversity in natural remnants necessitates the importance of retaining and conserving natural vegetation around large-scale teak plantations. Natural remnants act as a refuge for some non-generalist bird species that can rarely survive in plantations.

Keywords: Exotic species, Monoculture plantations, Natural remnants

Introduction

Over the past decades, the world has experienced the continuous transformation of natural vegetation into large-scale tree plantations (Gaveau et al., 2016; Onyekwelu & Olabiwonnu,

2016). Most of these plantations were anticipated to supplying more of social-economic needs than ecological needs to local and international communities (Kanowski et al., 2005). Due to economic reasons, fast-growing trees, often exotic are highly endorsed in large-scale plantations (Calviño-Cancela et al., 2012).

Exotic tree species are believed to survive against pests and diseases while providing higher quantity and quality of wood products, at relatively low costs of production (Cubbage et al., 2012). However, some large-scale exotic tree plantations in Asia have been reported as large green deserts in terms of biodiversity (Horák et al., 2019). The whole process for its development and management practices, have created a very simple vegetation structure that has negatively affected distribution, abundance, and diversity of flora and fauna in Europe and South America (Castano-Villa et al., 2019; Oliveira et al., 2019; Sreekar et al., 2016).

Tanzania is one of the countries with large areas of exotic tree plantations resulted from natural vegetation conversion (Barraclough & Ghimire, 1996). To date, thirty percent (30%) of miombo woodland in Kilombero valley has been converted to teak plantation for timber production (Munishi-Kongo & Jewitt, 2019). To most environmentalists, development of teak plantation in the valley seems to be an evil and less supported practice (Hartmann et al., 2010). Their argument is supported by already markedly observation that development of teak plantation has negatively affected species of mammals and anurans in the valley (Hinde et al., 2001a; Hinde et al., 2001b; Bonnington et al., 2009).

Irrespective of alleged numerous negative effects on biodiversity, large-scale teak plantations are still useful in the country. They lessen harvesting pressure on natural forests while restoring the lost biodiversity and ecosystem services on degraded lands (Kanowski et al., 2005; Lindell & Thurston, 2013). Yet, proper management of such plantations has a chance to reduce negative effects while supporting biodiversity and providing ecosystem services (Calviño-Cancela et al., 2012). To achieve that, regular monitoring to acquire pragmatic information on how exotic teak plantations affects biodiversity in it, is necessary through the use of biodiversity indicators (Proenca et al., 2010).

Among the bio-indicators, birds are comparatively easy to survey and have mostly been used in various studies worldwide (Stephens & Wagner, 2007; Mohd-Azlan et al., 2019; Ramírez-Mejía et al., 2020; Pálsdóttir et al., 2022). Birds forage on different varieties of food resources in a vast range of habitats and play a key ecosystem roles including pollination and seed dispersal services (Krimmer et al., 2019). Due to that, they possess a remarkable ability in explaining the effectiveness of any exotic plantations in supporting biodiversity (Calviño-Cancela et al., 2012).

Considering the paucity of information on the influence of teak plantation on bird species composition and diversity in Kilombero valley, this study appeared necessary. In this study, it was assumed that the remained natural remnants around teak plantations possess and support bird species that were present in the valley before the establishment of teak plantations. Thus, we investigate how exotic teak plantations support bird species composition and diversity that was inherited from the previous original natural vegetation in the area. We predicted that natural remnants around the large-scale teak plantations would have higher bird species composition and diversity than teak plantations in Kilombero valley.

Materials and methods

Study site description

This study was conducted in teak plantations owned by the Kilombero Valley Teak Company (KVTC) located in Morogoro region in Tanzania. Kilombero Valley is one of the largest East Africa seasonal wetlands, centered $8^0$30'16.96" S; $36^0$15'51.19" E covering an area of about 7,946 km^2 (Jenkins et al., 2002; Höllermann et al., 2021). The KVTC plantation in the valley was established for the first time in 1992 to supply the world market with teak wood (Bekker & Monteuus, 2004).

The development of teak plantations in the valley caused the clearance of natural miombo woodland (Hinde et al., 2001a). Out of the 28,000 ha that KVTC holds, half its size was found to be suitable for producing high-quality teak wood (Bekker & Monteuus, 2004). To date, about 57 percent of the land has been converted to teak plantations. The established KVTC plantations have been divided into four blocks, two on each side of the river Kilombero. Those blocks include the Nakafulu block (in Ulanga districts), Mafinji block (in Malinyi districts), Narabungo block, and Ichima block (both in Kilombero district). Each block has several compartments with trees of different ages, surrounded by small to large conserved natural remnants (Fig. 1).

Climate

The climate in the valley is normally sub-humid tropical with a distinct seasonality (Höllermann et al., 2021). The rainfall is largely unimodal with an annual mean between 1200 and 1400 mm (Jenkins *e*t al., 2002).

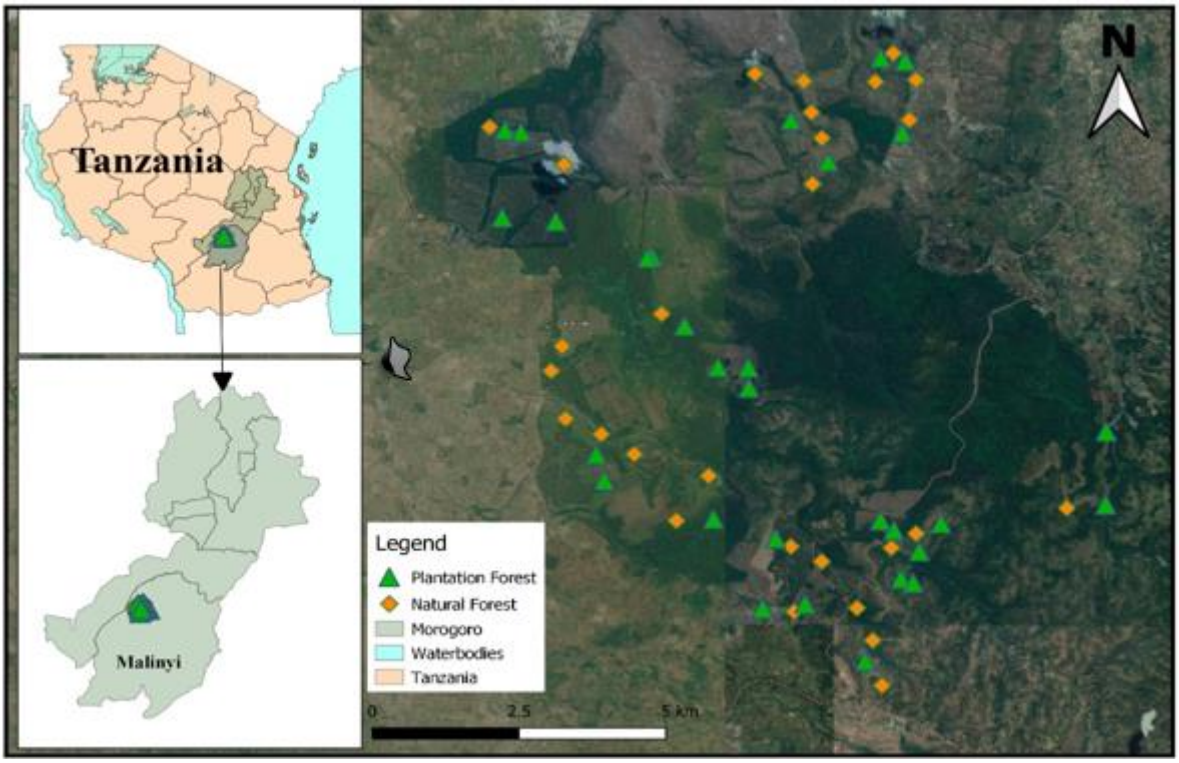

Figure 1: Map of a study area

Sampling design

Data were collected from plantation compartments of different ages and natural remnants around the plantation to assess the effects of the established large-scale teak plantations on bird species composition and diversity. Preliminary surveys were conducted between October and November 2020 before actual field data collection. Mafinji block was purposively selected out of the rest blocks for data collection as it possessed most of the vegetation types present in other blocks. Stratified sampling was employed based on variations in habitats of plantations and natural remnants (hereafter, the major vegetation) observed at the study site. Such habitats included young-age (compartments aged 0 to 5 years), medium-age (compartments aged 6 to 10 years), and old-age (compartments aged 11 to above years) in teak plantations. Natural remnants around the plantations included woodland, grassland, riparian, wetland, and forest habitats. Sixty-seven (67) belt transects of 1km x 50 m were established within each habitat.

Data collection

Bird surveys were conducted from early December 2020 to late February 2021. During this period, there was low rainfall and long sunny periods while also most of the management activities were on progress. The point count method as described by Bibby et al. (2000) was used

to investigate bird species richness and abundance in teak plantations and natural remnants. Three (3) point count stations distanced 100 m from the edge of the habitat and 300 m apart from each other were established at each belt transect to make a total of 201-point count stations. The timing of field visits was only on a sunny day, between 06:00 to 10:00 hr. and between 15:00 to 18:00 hr. when birds were more active. All birds seen or heard were recorded within a 50 m radius with the aid of a binocular (Nikon Monarch 3, 10 x 8 m). A total of fifteen (15) minutes were spent at each point count station.

The observed or heard birds were identified by their common name and counted on the field. Later on, they were assigned their scientific name, and family and classified according to the main food resources they consume such as insects, grains, fruits, flower nectar, and flesh or the remains of a dead animal. Information on bird identification and food resources were mainly from Brown et al. (1982), Campbell & Lack (1985), Fry & Keith (2004), Clark & Davies (2018), Fry et al. (2000), and bird's electronic field book (eGuide to Birds of East Africa Version 1.2.0) by Stevenson & Fanshawe (2002). Also, all birds were classified based on their IUCN RedList conservation status and global population trend as either Least Concern (LC), Endangered (EN), or Non-Threatened (NT). The conservation status was adopted from (Birdlife International, 2022).

Data analysis

Bird species richness and number of families were computed by counting the number of each bird species and family in each particular habitat. To obtain relative abundance for each bird species, we divided the number of individuals for a particular species by the total number of all individual species combined in such vegetation as follows;

Relative abundance = n / N

where n is the total number of birds of a particular species and N is the total number of birds of all species.

One-way ANOVA was performed in R-program to compare means of bird species richness and families, within each habitat and between vegetation types. A proportion of each bird feeding guild was generated and illustrated in a histogram for each vegetation type by summing up individuals in a particular bird guild in habitat over the overall sum of all individual bird guilds in a particular habitat. Moreover, Sorenson's similarity coefficient was equally calculated between pairs of habitats as follows;

Similarity = $2a / (2a + b + c)$.

Where a = number of species common to both two habitats; b = number of species only belonging

to the 1st habitat; c = number of species only belonging to the 2nd habitat.

The Bray–Curtis's dissimilarity index was used in PAST software to measure the extent of similarity in bird species composition between all habitats in this study. Shannon-Weiner Diversity Index (*H′*), Dominance (*D*), and Evenness were also computed in PAST software. Shannon-Weiner Index (*H′*) was calculated to know the species diversity based on species abundance using the formula;

$H' = -(\Sigma Pi * LN(Pi))$

where *H′* is the Diversity Index, Pi is the proportion of each species in the sample, and LN (Pi) is the natural logarithm of this proportion.

Dominance (*D*) was measured by the following formula;

$D = 1- ((\Sigma n / n-1)/ (N * (N-1)))$

where *n* is the total number of birds of a particular species and *N* is the total number of birds of all species.

Evenness Index (*J′*) was calculated using the ratio of observed diversity to maximum diversity using the equation;

$J' = H' / H_{max}$

where *H′* is the Shannon Wiener Diversity index and H_{max} is the natural log of a total number of species.

A diversity t-test was used to compare bird species diversity between the two vegetation types. The level of significance was set at $p < 0.05$.

Results

Bird species composition and relative abundance

A total of 1256 bird individuals belonging to 104 species and 47 families, were recorded in both natural remnants and teak plantations. Forty-one (41) bird species were common to both plantations and natural remnants while 51 species were unique to the natural remnant and 12 species were unique to teak plantation (Figure 2). Family Accipitridae had the highest number of bird species (11), followed by Estrildidae, Malaconotidae, and Muscicapidae both with seven (7) species, Ploceidae (6), Bucerotidae, and Nectariniidae both with five (5) species while the rest had below five species.

Six bird feeding guilds; carnivorous, frugivorous, granivorous, insectivorous, nectarivorous, and omnivorous were recorded in both natural remnants and teak plantations. Natural remnants had a

significant higher number of bird species ($F_{1, 51}$ = 15.64, p = 0.00024), and families ($F_{1, 51}$ = 22.05, p = 0.001) than teak plantations.

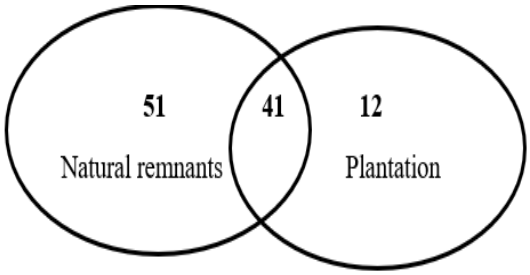

Figure 2. Number of bird species common and unique to natural remnants and teak plantations

Based on IUCN Red List conservation status, 102 bird species recorded belonged to Least Concern (LC) category, 1 (*Terathopius ecaudatus*) as Endangered (EN) (recorded in old age plantation and woodland remnants) while the other (1 species, *Ciconia episcopus* recorded in woodland, grassland remnants, and old age plantation) was categorized as Non-Threatened (NT) (See also appendix 1).

Bird species composition and relative abundance in natural remnants

A total of 806 bird individuals belonging to 92 bird species and 44 families in natural remnants were recorded. Most of those species were recorded in woodland, followed by grassland, forest, riparian, and wetland habitats. The highest numbers of bird families were recorded in woodland followed by riparian, grassland, forest, and wetland habitats. Woodland was observed to have a higher relative abundance followed by forest and grassland while the least was recorded in wetland habitats (Table 1).

Table 1. Birds species composition and relative abundance in natural remnants

Habitats	Species richness	Family	Relative abundance (%)
Woodland	65	35	40.7
Forest	38	25	19.1
Grassland	40	26	18.2
Riparian	35	27	12.3
Wetland	24	17	9.7

There were no significant variations (p > 0.05) in species richness, number of families, and abundance between natural remnants habitats. Relative abundance for all recorded bird species in natural remnants ranged from 0.080 to 7.82. Eight bird families from four bird feeding guilds

contributed the highest proportion of bird species abundance in natural remnants. Such species included *Merops apiaster*, *Pycnonotus tricolor*, *Lonchura nigriceps Crithagra mozambica*, *Turtur chalcospilos*, *Lonchura cucullate*, *Terpsiphone viridis*, *Streptopelia capicola*, *Hirundo rustica*, and *Dryoscopus cubla* (Table 2).

Table 1. Bird species with high relative abundance in natural remnants

Common name	Species	Family	Guild	Relative abundance (%)
European bee-eater	*Merops apiaster*	Meropidae	Insectivores	7.82
Dark-capped bulbul	*Pycnonotus tricolor*	Pycnonotidae	Frugivorous	5.83
Red-backed Mannikin	*Lonchura nigriceps*	Estrildidae	Granivorous	4.47
Yellow-fronted canary	*Crithagra mozambica*	Fringillidae	Granivorous	4.34
Emerald-spotted wood dove	*Turtur chalcospilos*	Columbidae	Granivorous	4.34
Bronze manikin	*Lonchura cucullate*	Estrildidae	Granivorous	3.97
African paradise flycatcher	*Terpsiphone viridis*	Monarchidae	Insectivores	3.97
Ring-necked dove	*Streptopelia capicola*	Columbidae	Granivorous	3.35
Barn swallow	*Hirundo rustica*	Hirundinidae	Insectivores	3.1
Black-backed puff back	*Dryoscopus cubla*	Malaconotidae	Omnivorous	2.85

Insect and grain-eating birds recorded were the most abundant in woodland, forest, grassland, and riparian remnants. However, the highest proportion of birds feeding guild was observed for grain-eating birds in wetland habitats. Fruit-eating birds were higher in the forest followed by woodland, riparian, and grassland while the least was in wetland remnants. Mix feeder birds were highest in forest and grassland followed by woodland and riparian while wetland had the least proportion. A small proportion of birds feeding guild was observed for nectar feeding birds followed by flesh-eating birds in almost all of the natural remnant habitats (Fig. 3).

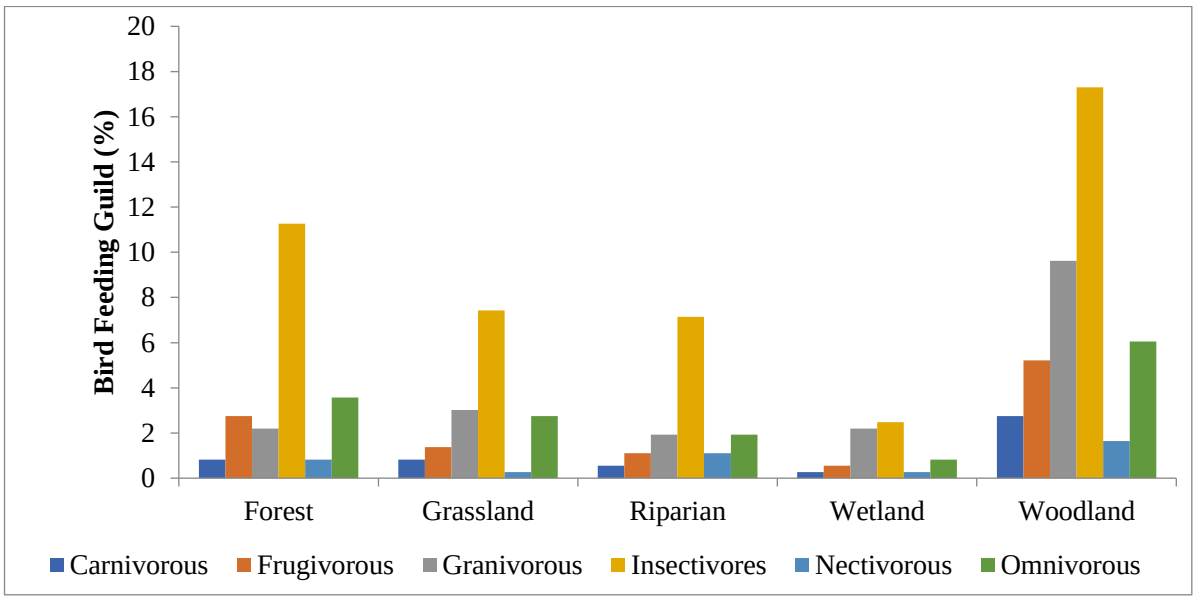

Figure 3. The proportion of bird feeding guilds in a natural remnant

Bird species composition and relative abundance in teak plantation

A total of 450 bird individuals from 53 different bird species and 23 families on the teak plantation were recorded. The highest number of species was recorded in old age followed by young and medium age habitats. Bird family increased as teak aged from young, medium to old age respectively. The highest relative abundance was recorded at young age followed by old age while the least was in medium-age habitats (Table 3).

Table 3. Bird species composition and relative abundance in teak plantation

Habitats	Sp. Richness	Family	Relative abundance (%)
Young age	30	15	37.1
Old age	33	20	34.7
Medium age	28	16	28.2

However, the observed variations in bird species richness, number of families, and abundance between teak plantation habitats were not statistically significant ($p > 0.05$). Within the teak plantation, relative abundance ranged from 0.22 to 16.44. The highest proportion in relative abundance was contributed by *Merops apiaster*, *Lonchura nigriceps*, *Camaroptera brevicaudata*, *Cyanomitra olivacea*, *Pycnonotus tricolor*, *Cypsiurus parvus*, *Turtur chalcospilos*, *Hirundo rustica*, *Bycanistes brevis*, and *Buteo buteo* species. Each species in the list came from a different family among six-bird feeding guild recorded (Table 4).

Table 2. Bird species with high relative abundance in teak plantation

Common name	Species	Family	Guild	Relative abundance
European bee-eater	*Merops apiaster*	Meropidae	Insectivores	16.44
Red-backed Mannikin	*Lonchura nigriceps*	Estrildidae	Granivorous	15.11
Grey-backed camaroptera	*Camaroptera brevicaudata*	Cisticolidae	Insectivores	6
Olive Sunbird	*Cyanomitra olivacea*	Nectariniidae	Nectarivorous	4.89
Dark-capped bulbul	*Pycnonotus tricolor*	Pycnonotidae	Frugivorous	4.22
African palm swift	*Cypsiurus parvus*	Apodidae	Insectivores	4
Emerald-spotted wood dove	*Turtur chalcospilos*	Columbidae	Granivorous	3.78
Barn swallow	*Hirundo rustica*	Hirundinidae	Insectivores	3.56
Silvery-cheeked hornbill	*Bycanistes brevis*	Bucerotidae	Omnivorous	3.33
Common buzzard	*Buteo buteo*	Accipitridae	Carnivorous	2.89

Insectivores and granivorous are recorded to have the highest proportion of individuals among teak plantation habitats. A peculiar bird feeding guild was noted in the old age habitat. Within it, carnivorous, frugivorous, granivorous, and omnivorous had almost nearly equal proportions of individuals. In young age habitat, nectarivorous was recorded to have the least proportion followed by omnivorous, frugivorous, and carnivorous. In medium age habitat, carnivorous had the least bird proportion followed by omnivorous, frugivorous, and nectarivorous (Fig. 4).

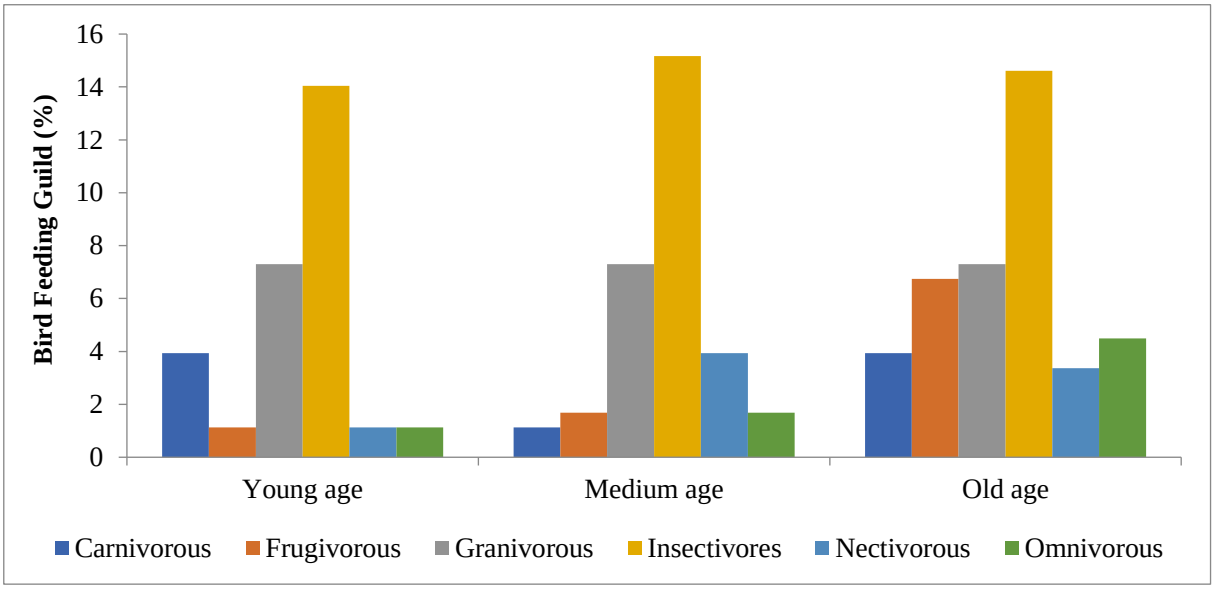

Figure 4. The proportion of bird feeding guilds in teak plantations

The minimum value of bird species similarity in different habitats was recorded between wetlands against medium age and forest habitats (0.387). The maximum value of bird species similarity was recorded between forest and old age habitats (0.620) (Table 5).

Table 5. Bird species similarity among habitats in teak plantations and natural remnants

Type	Young age	Medium age	Old age	Forest	Grassland	Riparian	Wetland
Young age							
Medium age	0.395						
Old age	0.571	0.59					
Forest	0.412	0.515	**0.62**				
Grassland	0.4	0.529	0.466	0.436			
Riparian	0.394	0.476	0.529	0.603	0.507		
Wetland	0.407	**0.387**	0.421	**0.387**	0.469	0.441	
Woodland	0.447	0.435	0.598	0.529	0.558	0.566	0.409

The comparison of bird species composition between the two vegetation showed that woodland was similar to medium age, old age, and forest habitats. Riparian and grassland were observed to

be more similar to each other than to young age plantation and wetland remnants thus together were very less similar to the rest (Fig. 5).

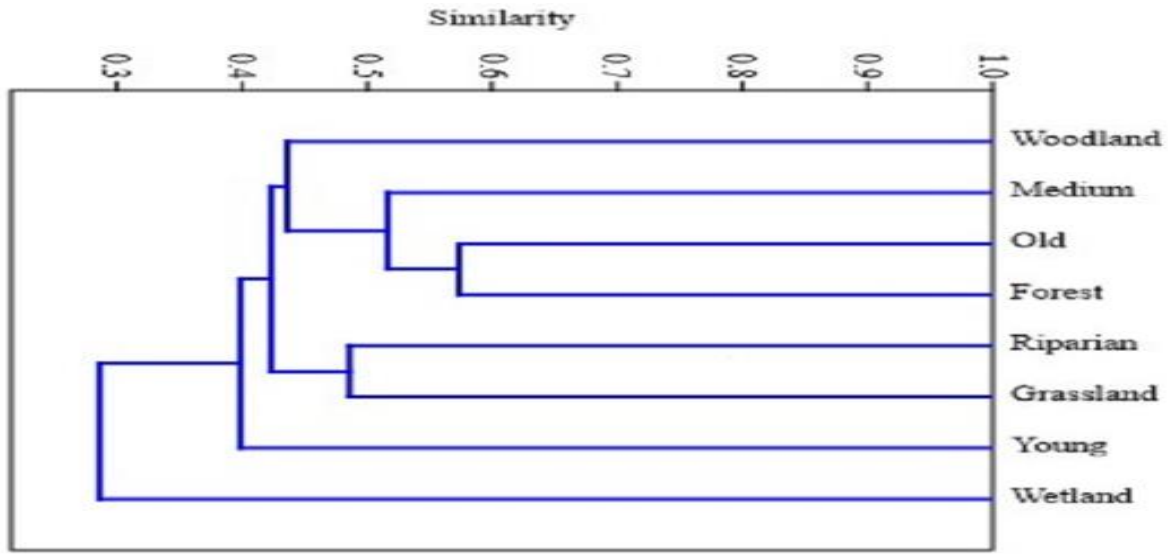

Figure 5. Bray–Curtis's similarity measure of bird species composition between vegetation

Bird species diversity

This study recorded higher species dominance (D = 0.97), evenness (J = 0.54) and diversity (H' = 3.91) in natural remnants than in teak plantation (D = 0.93; J = 0.47; H' = 3.22 respectively). Species diversity was observed to be high (H' = 3.91) and significantly different (t = -10.29, p = 0.01) from that of teak plantation (H' = 3.22).

Bird species diversity, dominance, and evenness in natural remnants

Bird diversity was highest in woodland and the least in wetland habitats. Wetland was recorded to have the highest species dominance followed by forest while the rest remnants showed no notable sign of species dominance. Bird species were highly distributed in riparian followed by forest, grassland, and woodland and the least were in the wetland. However, the observed variation in bird species diversity, dominance, and evenness were not significant (p>0.05) between the natural remnant habitats (Table 6).

Table 6. Bird species diversity, dominance, and evenness in natural remnant

Parameter	Forest	Grassland	Riparian	Woodland	Wetland
Shannon (H')	3.3	3.3	3.3	3.7	2.5

Dominance (*D*)	0.1	0	0	0	0.2
Evenness (*J'*)	0.7	0.7	0.8	0.6	0.5

Bird species diversity, dominance, and evenness in teak plantation

Bird species diversity increased from a young age, and medium age to old age habitats. However, such habitats showed no notable variation in bird species dominance. Old age and medium age habitats had no marked variation on bird species evenness but both differed from young age habitats. Between the plantation habitats, there is no significant variation (p = 0.05) in either bird species diversity, dominance, or evenness (Table 7).

Table 7. Bird species diversity, dominance, and evenness in teak plantation

Parameter	Young age	Medium age	Old age
Shannon (*H'*)	2.6	2.8	3.1
Dominance (D)	0.1	0.1	0.1
Evenness (*J'*)	0.5	0.6	0.6

Discussion

Bird species composition and relative abundance

This study has revealed that both teak plantations and natural remnants provide important habitats to support a considerable number of bird species including endangered bird species such as *Terathopius ecaudatus* (Bateleur) (Birdlife International, 2022). Observation of endangered bird species in a teak plantation in this study is line with study of Warema & Howell (2015), who reported that "*plantations can support species of bird with conservation value including those which are endemic and endangered*". About 61% of all birds recorded had a strict occurrence between teak plantation and natural remnants. However, other species (e.g. *Buteo buteo,*

Cypsiurus parvus, Dryoscopus cubla, Terpsiphone viridis, and *Turtur chalcospilos*) were found in both habitats suggesting that the ecosystem of these major vegetation, provides rich dietary guild to birds with a wide range of habitats.

Overall, natural remnants were noted to have higher bird species richness, family, and relative abundance than a teak plantation. Our results agree with other studies on Pine plantations (Iezzi et al., 2018) and Eucalyptus plantations (Goded et al., 2019). Natural remnants are characterized by richer floristic composition and different vegetation structures as compared to exotic plantations (Teuscher et al., 2015). According to Issa (2019), floristic composition and varied vegetation structure have a direct association with the presence of main life requirements (e.g. food, water, and shelter) and suitable condition for the presence and survival of bird species (Karuniyanti et al., 2018). Unrelatedly, exotic plantations (like this teak) are characterized by very simple vegetation structures, with few plant species that can supports mostly generalist bird species (Castano-Villa et al., 2019).

The lower number of bird species observed in the teak plantation is contributed to poor habitat type heterogeneity and the absence enough food resources (Estades & Temple 1999; Bennett et al., 2018). On top of that, the presence of management activities in teak plantations affects negatively the growth of understory vegetation composition that affects the richness and abundance of bird species (Jemal & Sultan, 2019). However, a decrease in the intensity of management activities (e.g. weeding, pruning, and thinning) as teaks mature to an old age plantation leads to increased vegetation cover and understory vegetation (Teuscher et al., 2015). As a result, bird species richness in teak plantation habitats were more similar to natural remnants as teak plantation matured from young, to medium to old age.

However, there was no significant difference in bird species richness, number of families and abundance between teak plantation habitats. According to Karuniyanti et al. (2018) and Asare et al. (2020) presence of an open canopy, and management activities (in young and medium age habitats) can still support the presence and abundance of bird species in plantations given that there are main life requirements for birds. In this study, we noted that most of teak plantation plots had a relatively higher relative abundance than most natural remnants and were more similar to most natural remnants. That is an indication that the teak plantation possesses a complex vegetation structure with essential main life requirements and suitable conditions to support a large population of birds as for the case of natural remnants (Najera & Simonetti, 2009; Rodríguez et al., 2021).

Bird species diversity

Bird species diversity was higher in natural remnants than in teak plantations as hypothesized earlier. The observed difference is certainly due to the presence of a more diversified vegetation structure, floristic composition, and high population density of plants in natural remnants than in teak plantations (Gumede et al., 2022). According to Issa (2022), vegetation structure and composition contribute positively to foraging, breeding sites, and cover for different bird species. Woodland is recorded to have high bird diversity and species evenness than the rest remnants.

However, the size of the woodland habitat was noted to be relatively larger as compared to the rest remnants in this study (Pers. observation). The large area size observed in woodland is indeed believed to influence higher species diversity and evenness in it as Jemal et al. (2019), support that, an increase in the size of habitat associates with an increase in richness and diversity of bird species available. Among the natural remnant habitats, wetlands are recorded to have low species evenness and high dominance leading to poor diversity recorded. Forest, grassland, and riparian habitats had no notable variation in bird species diversity. The observation is supported by high species similarity recorded between the three habitats in this study.

Contrary to other studies on the teak plantation (Yudea & Santosa, 2019; Ramlah et al., 2021) our study recorded lower bird diversity in young age habitat as compared to an old age habitat. However, the higher relative abundance and bird species evenness recorded in old age habitat contributed to the richer diversity recorded in it as supported by Gonçalves et al. (2017). According to Calvino-Cancela et al. (2013), old age habitat has lower management activities and high habitat complexity. As a result, they possess favored habitat characteristics to support diverse bird species Carnus et al. (2006).

This study has demonstrated a significant variation in bird species composition and diversity between natural remnants and teak plantations. The observed variation entails how richer natural remnants are, compared to monoculture large-scale teak plantations. Teak plantations have proved to be far from being a large green deserts, by supporting a relatively few unique numbers of species of high abundance. However, there is a high possibility that a number of species recorded in this teak plantation contributed with the closeness of the natural remnants around the plantations. The closeness of natural remnants to the teak plantation can support some of the essential requirements (such as water sources) that could be missing in most plantation habitats. Considering the rate of land use change to teak trees grown in the valley, this study recommends that any further expansion or development of a new teak plantation should consider retaining natural remnants around it as done by KVTC.

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