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Modeling The Determinants Of Avifauna Distribution In An Agro-Urban Landscape

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Abstract:
Habitat transformation, building constructions, agricultural activities and acceleration of infrastructural developments are critical exogenous drivers behind rapid decline in avifauna populations throughout most landscapes in Kenya. This study investigated the determinants of avifauna distribution in University of Eldoret (UoE). UoE is surrounded by large-scale farms and is undergoing massive building constructions.A hand-held Global Positioning System was used to collect data on avian locations, habitat types and geophysical features. Geophysical variables were extracted by calculating distance buffers of geophysical features using ILWIS Academic software in a Geographic Information System. Data was analyzed using multiple linear regression to determine the relationship between 9 Geophysical variables (distances to dumpsites, power lines, wooded grasslands, open grasslands, wetland, roads, pavements, agricultural farms and buildings) and the spatial distribution of 9 avian foraging guilds (Fruigivores, Granivores, Nectarivores, Omnivores, Insectivores, Carnivores, Piscivores, Insect-granivores and Insect-fruigivores). Multiple regression showed that all the 9 variables were significant determinants of distribution of different avian foraging guilds in UoE but the distribution of most guilds was influenced by 5 variables: wetland, open grasslands, roads, dumpsites, and wooded grasslands. The wetland influenced the distribution of 7 foraging guilds, open grasslands accounted for 5 guilds, roads for 4 guilds whereas wooded grasslands and dumpsites accounted for 3 guilds each. The other 4 factors influenced the distribution of fewer foraging guilds (buildings, agricultural farms and pavements accounted for 2 guilds each whereas power lines accounted for only 1 guild). Understanding of the key determinants of avian distribution is an important pre-requisite for landscape and urban planning to ensure sustainable conservation of birds in agro-urban landscapes. Appropriate planning should conserve existing wetlands and grasslands in areas undergoing urban development. Existing urban areas should establish constructed wetlands and artificial grassland fields between the buildings. Also organic farming should be promoted as it is birds' friendly.

Keywords: *Agro-urban landscapes, Avian foraging guilds, Determinants of avian distribution, University of Eldoret*

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I. Introduction

Aves are among the sumptuous indicators of ecological integrity of any given ecosystem (Bilgrami, 1995), notably pollination and seed dispersal services to plants, as well as controlling populations of invertebrate and vertebrate pests (Sekercioglu, 2006). They have been widely used to evaluate environmental changes throughout history. Birds have received particular attention in terms of research and conservation activities (Ormerod and Watkinson, 2000). This is largely due to their suitability as important health indicators of the ecological conditions and productivity of an ecosystem (Newton, 1995; Desai and Shanbhag, 2007). For their known firm reputation of being beautiful creatures, birds play important roles in vegetation and wetland systems. Their reproductive ability, ranging patterns, distribution and behavioural patterns such as migration have most often been used to analyze the longterm effects of habitat modifications and degradations.

Current calamitous disappearance of global forests is a massive blow and setback to biodiversity and thus is of grave concern to research scientists, nascent wildlife managers, ecologists and conservationists. Human induced deforestation in many parts of the world has led to the transformation of native vegetation into impoverished forest fragments (Laurence and Bierregaard, 1997), secondary forests, pastures, croplands and other human-dominated habitats. Land use changes often have torrid impacts on tropical biodiversity, because land-use intensity affects vegetation structure, which in turn affects diversity,abundance and distribution of animal populations. Nearly, half of the bird species worldwide show decimating populations, 132 (about 1.3%) species have become extinct since 1600, 44% are stable and7% are increasing (Butchart *et al*., 2010). Habitat change due to human activities is the most significant cause of avian declines, followed by unfettered hunting and an upsurge in invasive alien species. The risk of predation has been identified as a critical organizing driver for farmland bird communities (Suhonen *et al*., 1994) and nest predation is undoubtedly a significant cause in bird mortality irrespective of nest-site location with respect to edge (Perrins, 1979). Populations of birds have also plummeted in North America, especially in grassland and arid land habitats and have been attributed mainly to habitat loss dueto agriculture and urbanization (Butchart *et al.*, 2010). Plunging trends in habitats have also been reported in Australia (Olsen, 2008).

Habitats with adequate resources for food, breeding, water, nesting and cover for predators act as a magnet to large avifaunal populations. For aquatic birds such as the Egyptian goose, grebes and cormorants, wetlands are of central pivots in their lifecycle because these areas serve as sites for breeding,nesting, source of drinking water, feeding, resting, shelter and for social interaction. Wetlands provide food for birds in form of plants, vertebrates and invertebrates. Some birds forage for food in wetland soils with worms and other forms of wetland soil related species which are targeted as the source of diet. Birds have daily and seasonal dependence on wetlands for food and other life supporting systems (Stewart, 2001). Those that are associated with vegetation, the existence of trees are pivotal components to their lifecycle.

The distribution of birds is driven by several factors encompassing abiotic processes, processes dominated by biotic interactions and biologically mediated processes. Changes in land use, chemical, physical and biological properties pose a big threat on avifauna specific localities. Many of these factors operate at different spatial and temporal scales imposing threats to species distribution ranging from local to global scales. Altitude being one of the critical drivers of species distribution patterns, abiotic variables such as relief can change dramatically. These factors exert a turbulent impact on wetlands and vegetation as habitats for avifauna communities. These in turn affects the wetland and vegetation dependent communities as well as the ecosystem attributes such as distribution, density and species richness (Burket *et al*., 2004).

While altitude accounts for much of the variability in bird communities, human activities have also had a torrid influence in determining the distribution of an ecosystem's avifauna. Agricultural activities, effluents disposal in wetlands and logging have significantly altered breeding sites, food reserves and important areas for birds' activities. Ultimately, these changes alter the corresponding feeding relationships (food webs and chains) at primary and secondary production levels (Wrona *et al*., 2006). The main aim of this study focused primarily on examining the critical determinants of avifauna distribution by looking at a range of cleared, disturbed and undisturbed sites in University of Eldoret which lie in the same altitudinal range.

II. Methods

Study Area

The study was conducted in University of Eldoret, Kenya, which is centered on 35º 18'E and 0º 30'N (Jaetzold and Schmidt, 1983). The climate of the area is semi-humid with precipitation ranging from 900 to 1300mm with an average annual rainfall of 1124mm being recorded and the average temperaturestands at 18ºC (Jaetzold and Schmidt, 1983).

The bulk of the soils in the study area are volcanic with deep and friable clays dominating them. A few soils with red and brown clays, yellow and red clays stand out in some parts of the study area. Towards Marula swamp, the soils are grayish and alluvial in nature. The soils are fine textured. The areais generally flat and slightly undulating with an overall gentle slope of 1% (Jaetzold and Schmidt, 1983).

The flora of the area is related to the soils and climate of the area. The vegetation is composed of scattered stands of both indigenous and exotic trees, herbaceous and shrub cover that stand out in different parts of the area. At the swamp neighbouring the University, the papyrus reed is a typical indicator of this zone. The fauna of the area comprises of a large variety of bird species, herpertofauna, insects, small mammals and fish. The most notable birds in the study area are the weaver birds, crows, cattle egrets, pigeons, swifts and swallows, bulbuls, Eurasian bee-eaters and wetland birds. Amphibians such as the clawed frog and tree frogs are found in the study area.

The economic livelihoods include activities such as small and large scale maize and wheat farming, livestock keeping, and making of mats from papyrus reeds harvested from the Marula swamp.

Collection of Bird Distribution Data

Data on birds' distribution were collected for 3 months between December 2014 and March 2015. The study area was divided into five habitats which encompassed; the open grasslands, wooded grasslands, buildings, agricultural farms and the wetland. Other areas in which birds were found included;dumpsites, power lines, pavements and roads. All the birds in the study area were classified into 9 groups based on their food preference. These 9 foraging guilds included the insectivores, piscivores, fruigivores, carnivores, granivores, nectarivores, omnivores, insect-granivores and the insect-fruigivores. Five 500m long transects were established per habitat for counting of birds, making a total of twenty five transects in the study area. Two surveys were conducted on transects in different habitats in the morning (0630hrs to 0830hrs) and in the afternoon (1630hrs to 1830hrs) when most birds were active. In total six survey sessions were conducted per habitat which amounted to a total of thirty survey sessions. Direct counting was carried out severally and at every encounter, the X and Y coordinates for locations of birds using GPS, habitat type, numbers and date were recorded in the field data sheets.

The observer moved through the different habitats unobtrusively at a speed of 1km to 2km per hour, moving carefully and very slowly approaching the birds to avoid disturbance, listening for vocalizations, searching visually and with binoculars in the habitat types. Terrific scanning of birds was supplementedby stopping and observing carefully including kneeling and taking closer looks at almost the ground level and maintaining of the hearing and sighting surveillance. At each sampling point the observer moved unobtrusively through the habitats using 8 × 42 binoculars, Global Positioning System (GPS) and field guide to birds of Kenya and Northern Tanzania (Zimmerman *et al*., 1990) and number of birds observed were recorded. A camera was used to take photographs of some bird species that were not identified during the bird surveys so that they could be identified later on.

Mapping of Habitats, Geophysical Features and Birds' Distribution

Using the GPS, the coordinates of each and every building, different habitats, roads, power lines and dumpsites in the University of Eldoret were captured. Coordinates were recorded for every corner of eacha building, habitat type and the other geophysical features. The recorded data were typed in Microsoft Excel sheet and then saved in command delimited (csv) file format. A separate file was prepared for each variable. The files were then imported into the ILWIS Academic 3.3 GIS software for preparation of maps for habitats, buildings, roads, power lines and dumpsites. The coordinates of birds' distribution recorded in section 2.2 were also typed in Microsoft Excel and saved in CSV file format. Separate files were prepared for the 9 bird guilds. The files were then imported into ILWIS as tables and then converted into point maps. Figure 1 shows different habitats, geophysical features and distribution of birds in the study area.

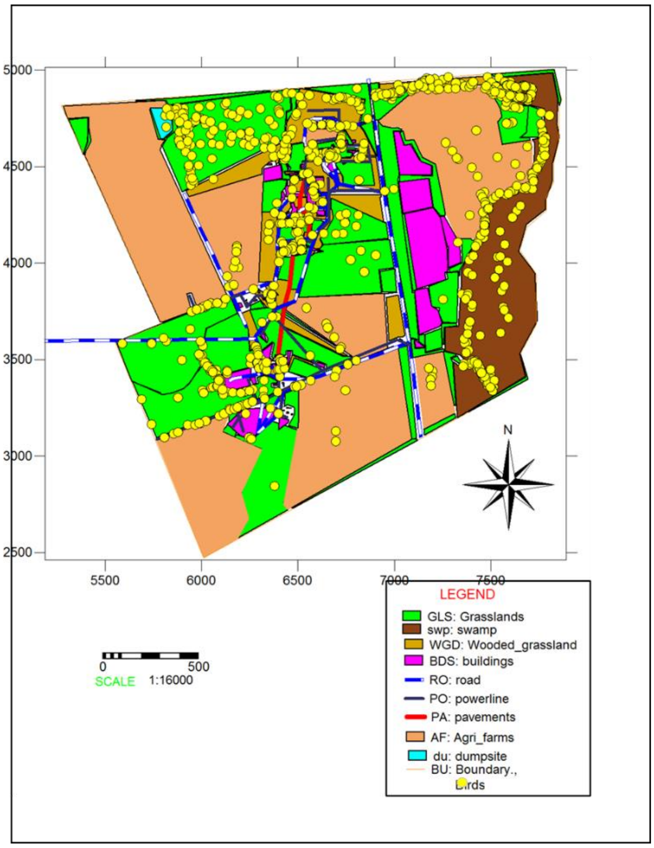

Figure 1: Different habitats, geophysical features and distribution of birds in the University of Eldoret

Spatial and Statistical Data analysis

To enable spatial data analysis in ILWIS all the maps (habitat, geophysical and birds) were converted into raster maps using the rasterization operation. Distance calculations were performed for the habitat and geophysical maps to enable extraction of distance variables. Distance of the birds to various habitats and geophysical features was obtained by crossing each of the 9 bird guild maps with the various maps of habitats and geophysical features. The generated distance data were saved in tables in dbase file format and exported to Statistical Package for Social Sciences (SPSS) for statistical analysis. Data were analyzed using multiple linear regression to determine the variables that significantly influenced the distribution of different avian foraging guilds. The analysis involved 1 dependent variable (the number of birds) and 9 independent variables (that is, distances to dumpsites, power lines, wooded grasslands, open grasslands, wetland, roads, pavements, agricultural farms and buildings).

III. Results

A total of 84 bird species belonging to 9 foraging guilds were recorded in the study area. The birds' species comprised of 1 frugivore, 25 granivores, 4 nectarivores, 13 omnivores, 11 insectivores, 17carnivores, 3 piscivores, 6 insect-granivores and 4 insect-fruigivores. Results of multiple linear regressionshowed that all the 9 factors significantly influenced distribution of different avian foraging guilds. However, the distribution of each foraging guild was determined by different set of factors.

Wetland determined distribution of 7 avian foraging guilds: piscivores, insectivores, carnivores, fruigivores, granivores, nectarivores and insect-fruigivores (Table 1). As the distance from the wetland increased, there was a significant increase in the number of piscivores (β=0.001, *p*=0.001), carnivores (β=0.001, *p*=0.023), fruigivores (β=0.010, *p*=0.009) and insect-frugivores (β=0.002, *p*=0.018). Conversely, as the distance from wetland increased, there was a significant decrease in the number of insectivores (β=-0.009, *p*=0.001), granivores (β=-0.019, *p*=0.013) and nectarivores (β=-0.005, *p*=0.001).

The open grassland was a determinant factor for the distribution of 5 avian foraging guilds: insectivores, fruigivores, nectarivores, omnivores and insect-fruigivores (Table 1). As the distance from open grasslands decreased, there was a significant increase in the number of omnivores (β=-0.015, *p*=0.011), insectivores (β=-0.008, *p*=0.004), fruigivores (β=-0.009, *p*=0.029), nectarivores (β=-0.005,*p*=0.015) and insect-fruigivores (β=-0.002, *p*=0.050).

The roads were critical determinants for the distribution of 4 avian foraging guilds: omnivores, piscivores, granivores and nectarivores (Table 1). There was a significant increase in the number of omnivores (β=-0.049, *p*=0.001), granivores (β=-0.078, *p*=0.048) and nectarivores (β=-0.024, *p*=0.003)and a significant decrease in the number of piscivores (β=0.002, *p*=0.001) as the distance from roads decreased.

Wooded grasslands and dumpsites accounted for the distribution of 3 guilds each. Wooded grasslands had a significant effect on insectivores, nectarivores and insect-fruigivores whereas dumpsites influenced the distribution of carnivores, fruigivores and insect-granivores (Table 1). As distance from thewooded grasslands increased, there was a significant increased in the number of insectivores (β=0.038, *p*=0.003) and nectarivores (β=0.011, *p*=0.002) and a decrease in the number of insect-fruigivores (β=- 0.006, *p*=0.003). Similarly, as the distance from dumpsites increased, there was a significant increased in the number of carnivores (β=0.003, *p*=0.001) and fruigivores (β=0.012, *p*=0.004) and decrease in the numbers of insect-granivores (β=-0.004, *p*=0.046).

Buildings, agricultural farms and pavements accounted for the distribution of 2 guilds each whereas power lines accounted for only 1 guild. Buildings determined the distribution of omnivores and granivores; agricultural farms accounted for piscivores and insectivores; pavements accounted for insectivores and insect-fruigivores whereas power lines accounted for the distribution of insect- fruigivores (Table 1). As the distance from the buildings increased, there was a significant increase in the number of omnivores (β=0.028, *p*=0.014) and granivores (β=0.079, *p*=0.003). On the other hand, as the distance from agricultural farms increased, there was a significant increase in the number of insectivores (β=0.005, *p*=0.026) and a decrease in the number of piscivores (β=-0.001, *p*=0.004). Similarly, as the distance from pavements increased, there was a significant increase in the number of Insect-fruigivores (β=0.005, *p*=0.026) and a decrease in the number of insectivores (β=-0.024, *p*=0.006). Lastly, as the distance from power lines increased, there was a significant decrease in the number of Insect-fruigivores (β=-0.006, *p*=0.033).

Table 1 Regression coefficients and standard errors for factors significantly influencing the distribution ofavian foraging guilds

ForagingGuild	Model Variables	Unstandardized Coefficients		Standardized Coefficients	t	P-Value
		B	Standard Error	Beta		
Omnivores	Open grasslands	-0.015	0.006	-0.234	-2.580	0.011
	Buildings	-0.028	0.011	1.176	2.476	0.014
	Roads	-0.049	0.014	-1.717	-3.504	0.001
Piscivores	Wetland	0.001	0.000	0.508	1875.354	0.001
	Agricultural farms	-0.001	0.000	-0.204	-155.917	0.004
	Roads	0.002	0.000	1.229	1393.701	0.001
Insectivores	Agricultural farms	0.016	0.008	0.250	2.055	0.042
	Wooded grasslands	0.038	0.012	0.964	3.029	0.003
	Pavements	-0.024	0.008	-0.875	-2.820	0.006

	Wetland	-0.009	0.003	-0.630	-3.275	0.001
	Open grasslands	-0.008	0.002	-0.340	-2.432	0.004
Carnivores	Dumpsites	0.003	0.001	0.403	3.412	0.001
	Wetland	0.001	0.001	0.279	2.301	0.023
Fruigivores	Open grasslands	-0.009	0.004	-0.353	-2.346	0.029
	Dumpsites	0.012	0.004	1.359	3.274	0.004
	Wetland	0.010	0.003	1.051	2.879	0.009
Granivores	Buildings	0.079	0.027	0.930	2.953	0.003
	Roads	-0.078	0.039	-0.752	-1.984	0.048
	Wetland	-0.019	0.007	-0.305	-2.496	0.013
Insect- fruigivores	Pavements	0.005	0.002	2.914	2.443	0.026
	Power lines	-0.006	0.002	-2.309	-2.326	0.033
	Wetland	0.002	0.001	1.562	2.608	0.018
	Open grasslands	-0.002	0.001	-0.641	-2.043	0.050
Insect- granivores	Dumpsites	-0.004	0.002	-0.278	-2.026	0.046
	Wooded grasslands	-0.006	0.030	-0.368	-3.126	0.003
Nectarivores	Open grasslands	-0.005	0.002	-0.965	-2.590	0.015
	Wooded grasslands	-0.011	0.003	3.142	3.350	0.002
	Roads	-0.024	0.007	-6.784	-3.251	0.003
	Wetland	-0.005	0.001	-2.399	-3.852	0.001

IV. Discussion

This study demonstrated that various habitats and other related geophysical features are significant determinants of different avian foraging guilds in the University of Eldoret (UoE). On the basis of the number of guilds affected by a single factor, these determinants can be ranked as follows (from most to least important): wetland, open grasslands, roads, wooded grasslands, dumpsites, buildings, agricultural farms, pavements and power lines.

The wetland accounted for much of the variability of avifauna distribution in UoE. The wetland underlined distribution of 7 foraging guilds. Insectivores, granivores and nectarivores preferred thewetland. Wetlands have a higher abundance of resources for protection from predators and food provisionin form of flora, vertebrates and invertebrates which amounts to dietary requirements of these species. Some birds such as the hadada ibises and Egyptian geese among others forage for food in wetland soils with worms and other forms of wetland soil related species which are targeted as the source of diet (Stewart, 2001). Birds have daily and seasonal dependence on wetlands for food and other life supporting systems (Stewart, 2001). Marsh breeding birds such as marsh sand pipers, cranes and egrets have a heavy dependence on wetlands (Culver and Lemly, 2013). On the other hand, piscivores, fruigivores, insect- fruigivores and carnivores did not prefer the wetland. Massive grazing patterns are highly evident at the swamp and this triggers shifting of habitats by birds. A positive correlation between vegetation and birds has been documented in a study by Mulwa (2011) where compressed habitats experienced a dramatic decline in the quality and quantity of resources critical for survival of species. Livestock grazing has an indirect effect on water birds due to removal of vegetation (Richmond *et al*,. 2012). These guilds reduced in numbers as a result of the pollution, disturbance and noise from the periodic papyrus reed harvesting, massive sewage disposal and heavy predation by the free ranging feral carnivores. According to Rathore and Sharma (2000), birds present in or near water bodies are affected by several factors such as pollution, disturbance by human activities and lack of maintenance of water bodies. These guilds preferred the surrounding agricultural farms for perching due to disturbances from ongoing papyrus reed harvesting.

Based on the omnivore, insect-fruigivore, insect-granivore, nectarivore and fruigivore guilds' bird counts, the numbers increased with a decrease in distance from the open grasslands. A study by Cordy (1981) showed that diversity of habitat niches and resources such as water, nest-sites, song posts, coverfor protection against predators and weather conditions provided by a particular habitat determine the diversity of bird species. Substantial areas of the open grasslands are brimming with nesting materials for birds, food ranging from insects, nectar from shrubs and fruits of plants such as lantana plants. Invertebrates are also available in abundance in these habitats and therefore all these attracted these feeding guilds.

The roads affected the number of bird movements across the roads but the net impact of the roads varied among the different foraging guilds. Four feeding guilds (piscivores, granivores, omnivores and nectarivores) were affected by the roads. These birds displayed a distinct preference for the proximity of roads. There are several flowering trees by the road sides at UoE such as the flowering gums and yellow bells that attracted large numbers of nectarivores. Granivores were attracted to the roads by grain droppings from nearby farms and sand that act as grit in their digestion. Omnivores preferred areas near the roads due to food and solid droppings on the roads. Omnivore birds such as the cape rooks and pied crow have a firm and known reputation of consuming solid waste and food remnants that drop on roads.

The number of insectivore and nectarivore feeding guilds did not prefer the wooded grasslands. Food reserves for insectivores tend to decrease in wooded grasslands especially at the understory. These speciesoften decline in abundance near forest edges, avoid clearings (Laurance, 2001) and are highly vulnerable to forest fragmentation. There is a strong positive correlation between the vegetation and species richness and therefore habitat modifications are bound to cause deleterious effects. Patterns of disturbance are veryhigh in wooded grasslands due to periodic coppice management and overgrazing. These species have typically dropped out of the vegetation communities along the gradient to completely urban environmentsto seek microhabitats and other resources and are constrained to breed there (Jaman *et al.,* 2009).Acceleration of urban development may open up areas for abundance and diversity of resources available to birds. However, insect-granivores displayed preference for wooded grasslands. This is due to abundance of resources in terms of food and cover.

Dumpsites triggered distribution of two avian foraging guilds in the study area. The number of insect-granivores increased with a decrease in distance from the dumpsites while the carnivores declined. Insect-granivores preferred the dumpsites due to lots of grains that are disposed to these areas from buildings and insects that inhabit these areas. Carnivores did not prefer these areas due to lack of sufficient prey and the massive waste paper dumping that constraints their digestion. The immediate effects of dumping to avifauna communities range from physical entanglement, ingestion, physicalblockage or damage to feeding appendages or the digestive tract, to possible increased exposure to plastic components and persistent inorganic pollutants from ingested plastics (Moore *et al*., 2001; Arthur *et al*., 2009).

Buildings accounted for much of the variability of granivores and omnivores with the numbers decreasing with decreased distance from buildings. Buildings lead to habitat loss which affects species diversity. Both habitat loss and fragmentation have strong, detrimental effects on plant and animal species (Fahrig, 2003). Habitat fragmentation limits the movement of organisms and materials across landscapes through introduced barriers of a different land cover type between formerly contiguous areas of the same land cover type (Edwards *et al*., 2004). With massive acceleration in construction of buildings and structures in the University, granivores have been relocated to the periphery of buildings for food and habitat resources.

Agriculture affected the insectivore and piscivore communities across the study area. Insectivores decreased with a decrease in distance from the agricultural farms. Agriculture intensification with the use of heavy machinery, pesticides and herbicides are not bird friendly. The existence of birds in farmlands depends, among other factors, on the distance to remnant patches of forests and on the local structural diversity in farmland habitats (Laube *et al.,* 2008). On the other hand, the piscivores preferred proximity of agricultural farms adjacent to the wetland. This is due to massive disturbance at Marula swamp that makes them retreat to these farms and then later on fly back when the disturbance has cooled down.

The prime factor for insectivore distributions was the distinct preference for the proximity of the pavements. Pavements have a higher abundance of synathropic insects (Mckinney, 2002) which attracteda lot of insectivores during the study period. These include ants, termites and cockroaches. On the other hand, number of insect-fruigivores plummeted with a decrease in distance from the pavements. This is because there is little abundance of fruits in the proximity of pavements to supplement their diet. Power lines triggered distribution of insect-fruigivores. They are not electrocuted and therefore preferred these lines for perching.

The torrid disappearance of habitats as a result of logging operations, vegetation colonization and rapid acceleration of infrastructural development in University of Eldoret suggests that the number of clearings and coppicing will increase in the near future. Efforts are required to reverse this rapid downward trend.

V. Conclusion

Although all the 9 variables considered in this study were significant determinants of distribution of different avian foraging guilds in UoE, the distribution of most guilds was influenced by 5 variables: wetland, open grasslands, roads, dumpsites and wooded grasslands. The wetland influenced the distribution of 7 foraging guilds, open grasslands accounted for 5 guilds, roads for 4 guilds whereas dumpsites and wooded grasslands accounted for 3 guilds each. The other 4 factors influenced the distribution of fewer foraging guilds (buildings, agricultural farms and pavements accounted for 2 guilds each whereas power lines accounted for only 1 guild). Understanding of the key determinants of avian distribution is an important pre-requisite for efficient landscape and urban planning to ensure sustainable conservation of birds in agro-urban landscapes. Appropriate planning should preserve existing wetlands and grasslands in areas undergoing urban development. Existing urban areas should establish constructed wetlands and artificial grassland fields between the buildings. There is need to initiate training programs for owners of pastures on appropriate use by extensive cattle farming, where better grass produces best cattle and represents best habitat for obligate grassland bird species (Martinez-Guerrero *et al*., 2014). There is also need to develop mechanisms to accelerate organic farming which is bird friendly. Organic farming usually increases species richness, having on average 30% higher species richness than conventional farming systems (Bengtsson *et al.,* 2005). Inorganic farming with the massive channelization of chemical fertilizers, herbicides and pesticides has deleterious effects on birds and therefore should be discouraged.

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