INFLUENCE OF VEGETATION COVER TYPES ON THE COMPOSITION OF AVIAN FORAGING GUILDS IN THE AGRICULTURAL LANDSCAPE OF MUHORONI SUB-COUNTY, WESTERN KENYA

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Influence of Vegetation Cover Types on the Composition of Bird Foraging Guilds in the Agricultural Landscape of Muhoroni Sub-County

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

This work is dedicated to my wife Gaudence Kerubo for her support and emphasis on the value of sound education. I will always be thankful to her. For my three sons Wan'pablo, Clinton and Liam, I cherish you all. To my parents Andrew and Hellen, thank you very much for your continued support and encouragement.

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ABBREVIATIONS AND ACRONYMS

GLMs	Generalized Linear Models
GPS	Global Positioning System
IDH	Intermediate Disturbance Hypothesis
IUCN	International Union for Conservation of Nature
MTW	Ministry of Tourism and Wildlife
MSC	Muhoroni Sub-County
PCA	Principal Component Analysis
SE	Standard Error

ABSTRACT

Most wild biodiversity is found outside protected areas, in human-modified landscapes, it is therefore important to study the influence of human activities in these landscapes. Such studies guide how best to manage especially agricultural landscapes for the benefit of biodiversity and provision of ecosystem services. Many studies of this nature have been done in Africa. In Kenya, no study has been conducted in the sugarcane dominated agricultural landscapes. Muhoroni Sub-County (MSC) in Kenya provides a good case study and birds are recognized as good environmental indicators in such studies. The objective of this study was to determine the influence of vegetation types on the composition of birds of respective foraging guilds in study sites dominated by farmlands and sites dominated by natural shrubs in MSC. The bird counts were undertaken using standard-point-count method within 100 30-m radius plots set at intervals of 200 m along 10 transects measuring 2 km each. Percentage vegetation type within the same plots revealed that the farmland was more heterogenous than the natural shrubs. A total of 1450 birds representing 122 species from 46 families were recorded. Mann-Whitney U test revealed that there was significant difference in bird species abundance in the farmlands and natural shrubs ($U = 2449$, $p < 0.05$), while the magnitude in true diversity indicated that the farmland was 4 times more diverse than the indigenous shrubs. There was a significant association on how the farmers used their land ($X^2 = 977.96$, $p<0.05$). Generalized Linear Models showed significant correlation between vegetation cover types and abundance of some foraging guilds. The higher bird species composition in the farmland dominated site could be explained by the Intermediate Disturbance Hypothesis and the high vegetation heterogeneity. This study recommends similar studies for other taxa, especially those that have economic importance for agriculture, for example invertebrates and small mammals, to elucidate general patterns that may guide management of vegetation covers in MSC and beyond.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

This section expounds the research title. It explains the context of the study and clarifies the research problem by providing a brief discussion on vegetation type heterogeneity, bird composition, bird foraging guilds and agricultural landscape.

1.1.1 Vegetation cover types

In Kenya, the natural landscape is experiencing rapid transition due to the expansion of human activities. According to IUCN (2009), only about 10% of the land surface is protected area. The rest (90%) is immensely subjected to human disturbance culminating to different types of land cover. For instance, in Muhoroni Sub-County (MSC), the main observable vegetation cover types are sugarcane, grassland and scattered shrubs with cereals and woodlands representing a small proportion.

In most bird habitats, including those found in Muhoroni Sub-County, vegetation provides the main structure of the ecosystem and biodiversity. Gardner *et al.* (2009) observed that vegetation complexity can facilitate biological diversity by providing key ecosystem services. Globally, it has been observed that measures of vegetation structure indicate restoration feat and conservation value (Ruiz-Jaen & Aide, 2005). More heterogeneous vegetation structure supports a higher number of specialized bird species by providing more niches and microhabitats. According to (Tews *et al.*, 2004), much of this habitat heterogeneity is provided by plants through their diverse and complex growth forms leading to variation in plant physical structure that in turn shape a range of micro-environments significant to other organisms.

Increasingly large areas of vegetation modified habitats are being superimposed on natural areas, greatly transforming the landscape (Gardner *et al.*, 2009; Ndang'ang'a *et* *al.*, 2013). Indeed, the future of many natural habitats and bird species is closely bound to land use patterns in agricultural landscapes (Bennet *et al.*, 2006). Muhoroni Sub-County is covered by a significant proportion of non-vegetation habitats it therefore has the potential of hosting a high diversity of birds and other wild taxa. In addition, the patterns of both natural and human-modified vegetation are likely to have a significant influence on composition of birds and other taxa.

Globally, the influence of vegetation cover types in the agricultural landscape has received substantial attention, for instance, in Canada they offer shelter to a broad range of species potentially useful for biological pest control (Vickery, Feber, & Fuller, 2009). On the other hand, in West Africa, Usieta (2013) showed that hedge size and structure, rather than plant species composition, was an important predictor of bird species richness in hedgerows encircling farmlands.

In Africa the impact of vegetation cover types on bird composition have mostly focused on implications for promoting natural pest enemies, controlling diseases and increasing productivity of particular crop species (Songa *et al.*, 2007). In contrast, the effect of vegetation cover types on other aspects of bird composition has received minimal attention (Nalwanga, 2011) despite receiving much consideration elsewhere, especially in the European countries (Benton *et al.*, 2003).

In Kenya, studies have been undertaken on the effect of vegetation on bird species composition; for example in the agroecosystems surrounding Kakamega forest (Eshiamwata *et al.*, 2006), and the effect of farming on the diversity and abundance of birds in the agricultural landscape of Trans-Mara Sub-County (Oyondi & Muya, 2017).

1.1.2 Bird species composition

Birds are a group of endothermic vertebrates which are characterized by feathers, beaks, hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a strong light weight skeleton. According to (Gregory *et al.*, 2003), birds are largely distributed in different habitats in significant numbers where they make superb indicators for biodiversity, the environment and the sustainability of human activities.

Bird species richness is the number of bird species in an area, and is greatly affected by the structure of the habitat (Colwell & Robert, 2009). For instance, Laube *et al.* (2008) investigated the impact of habitat structure and the expanse from the nearest forest on the bird richness in the farmland near Kakamega forest and concluded that high vertical vegetation heterogeneity and a large number of woody plant individuals were related to high species richness of forest and shrubland birds, whereas open-country birds evaded such habitats. In the same study area, Eshiamwata *et al.* (2006) assessed bird assemblages in isolated fruiting ficus trees and concluded that ficus trees perform a substantial role for frugivorous bird communities.

Dependent on the need of enumerating bird species richness, individual birds can be sampled in discrete ways e.g using point count method, classified to species level and species richness determined (Collwell & Coddington, 1994). Indeed, according to Chao (2005), if species richness of a sample is pondered to show species richness of the underlying habitat, values can only be comparable if sampling efforts are harmonized in an appropriate way.

Bird species richness can be influenced by a number of factors not limited to the number of individual species, the heterogeneity of the landscape and human intrusion. As per Scheiner (2003), species richness is high when species are drawn from dissimilar habitats, and usually low due to habitat deterioration as a result of uncontrolled human intrusion (Cordeiro, 2005; Westphal, *et al.*, 2006).

Bird species abundance is number of individual bird species in an area per unit time (Bartelt *et al.,* 2001). For birds, these methods may consist of point counts, track counts and opportunistic counts, along with occurrence at monitoring locations (Wright & David, 1991). Globally and unlike in Muhoroni Sub-County, many investigators have evaluated the influence and benefits of human subsistence activities on bird species abundance. In Costa Rica, for example, Hughes (2002) observed that eliminating tall trees and hedges from farmlands would lead to approximately 40% decline in bird abundance. In Northern Kenya, Borghesio (2005) observed that the abundance of forest bird specialists decreased in plots with severe human activities.

Worldwide, many bird species have been subjected to many threats and probably the case in Muhoroni. The collective effect of landscape degradation triggered by agricultural development, urbanization, forestry practices and accelerated climate revolution is the greatest current threat facing bird species (Hole *et al.*, 2011). This observation is supported by Pimm (2002) that landscape dilapidations have been deliberated as the leading reason for bird species endangerment, particularly in Afro-tropical forests. This has hastily deteriorating as a result of anthropogenic disturbances resulting in loss of many bird habitats, as well as the extinction of many bird species, native biodiversity, and habitats required to support unique bird biodiversity (Pimm *et al.*, 2002).

Different bird species select specific habitats that suit their requirements for successful reproduction and survival, though some generalists may utilize several habitats (Oyondi *et al.*, 2017). Buckley and Freckleton 2010) observed that differences among bird habitat requirement have caused specificity on habitat requirement e.g. the Mountain plover (*Charadrius mountainus*) feeds solely on insects (grasshoppers, crickets, beetles, flies and ants); uses the ground for nesting and prefer short grass while, the Mongolian sand plover (*Charadrius atrifrons*) feeds on invertebrates (molluscs, worms, crustaceans and insects), uses trees for nests and prefer shore of the lakes.

Still concerning bird species habitat selection, habitat characteristics such as floristic complexity, cover and density of vegetation are the significant factors in contemplation (Whittingham & Evans, 2004). When these habitat geographies are interrelated they display positive correlation, since they provide food, nesting materials and concealment from predators. Habitat heterogeneity features play a huge role in the determination of species abundance and occurrence within a habitat type (Pennington & Blair, 2011).

Bird species diversity is the number of different bird species and their relative abundance in an ecosystem (Bibby *et al.,* 2000). This variable can be possibly altered by increasing the area sampled because large areas are environmentally more heterogeneous than small areas (Colwell & Robert, 2009) and according to Soutullo (2010), more bird species diversity lives in human dominated ecosystems.

Many bird researchers have over and over again used different diversity indices to measure diversity, namely; Shannon Wiener diversity index, the Simpson diversity index, and the complement of the Simpson diversity index. According to Jost (2006), Shannon Wiener diversity index is the most preferred index for measuring bird species diversity because it accounts for both abundance and evenness of the species present. When these indices are interpreted in ecological terms, each one of them relates differently, and their values are therefore indirectly comparable (Teyssedre, 2007).

Worldwide many studies on different facets of bird species have been undertaken. For example: the influence of remnant bush land on the diversity of birds in Australia (Parsons *et al.,* 2003), breeding bird communities of the fir-beech to the dwarfed pine vegetation tiers in Bratislava (Saniga, 1995). Other studies undertaken worldwide are by Sekercioglu *et al.* (2006) on ecological significance of bird population in Barcelona; Hulme (2007) on the density and diversity of Birds on farmland in West Africa; Jost (2006) on Conserving native trees increases native bird diversity and community composition on commercial office developments in Canada.

In Kenya, many bird studies have been undertaken among them: the diversity and abundance of birds across different habitat types in North Nandi Forest (Bett *et al.*, 2017); Effect of farming on the diversity and abundance of birds in Trans-Mara Sub-County (Oyondi *et al.*, 2017); Birds in fragmented Eastern Mau forest (Milka *et al.*, 2014) and the birds of Gongoni forest reserve (Ogoma *et al.*, 2010). Despite all these efforts to study birds in Kenya, no effort has been directed to the birds of Muhoroni Sub-County, an area dominated by majorly sugarcane plantations and scattered shrubs.

1.1.3 Bird foraging guilds

Foraging guilds are individuals of species in a community that utilize similar fit of ecological resources in a comparable way, although are not essentially narrowly associated taxonomically (Hockey *et al.*, 2005). As a good example, birds that search for insects on the base of shrubs represent guild e.g. tropical humming-birds; and seed consuming guilds e.g sparrows.

Worldwide, seven bird species foraging guilds are recognized (Hockey *et al.* 2005). They include insectivores (insect eaters), granivores (grain eaters), carnivores (flesh eaters), omnivores (flesh and vegetation), nectarivores (nectar eaters), frugivores (fruit eaters) and molluscivores (mollusc eaters).

Several studies have been conducted on bird species foraging guilds. For example in Malaysia, Zakaria (209) examined bird feeding guilds in Paya Indah Wetland Reserve, Peninsular, where it was observed that insectivores were the most abundant foraging guild (37%), while Carnivores and Granivores were the least dominant guilds with 3% each. This research clearly indicated that Paya Indah Wetland Reserve is an important habitat in providing food, shelter, nesting materials and breeding sites for different bird species.

In Tanzania the diversity, abundance and distribution of various bird species foraging guilds depend on many factors not limited to habitat type, habitat features, human activities, altitude and climate (Bideberi & Hassan, 2002). In Kenya studies of bird foraging guilds have been undertaken for example Mulwa *et al. (*2012) investigated the abundance of bird foraging guilds in structurally heterogeneous farmlands adjacent to Kakamega forest in Western Kenya; while Ndang'ang'a *et al.* (2013) investigated the composition and ecological function of bird foraging guilds in the agricultural landscape of Nyandarua, Central Kenya. These results failed to capture the patterns of foraging guilds in habitats dominated by sugarcane plantations, a reason why Muhoroni Sub-County, within the Nyando wetlands represented a good study case.

1.1.4 Agricultural landscape and biodiversity conservation

Ndang'ang'a *et al. (*2013), describes landscape as a mosaic of heterogeneous land forms, vegetation types and land use patterns. The ecological usefulness of a landscape concept is in its recognition that structural components of a landscape will always interact closely. Due to the expansion of agricultural farmland, the conservation of biodiversity in the agricultural landscape is a better approach. This particular approach allows for the management of unknown components of biodiversity, since it is likely to gain support from key decision makers as compared to species-centered approaches.

Worldwide and particularly outside Africa, studies on birds in the agricultural landscape have been undertaken. In Africa, some studies have comprehensively examined bird communities in the agricultural landscapes (Eshiamwata *et al.,* 2006). In Burkina Faso, West Africa, for instance, the response of bird communities to a gradient of agricultural intensity and availability of food and nest sites as the principal factors affecting bird distribution has been investigated (Soderstrom *et al.,* 2003).

In Kenya, the assessment of bird assemblages in isolated fruiting ficus trees in farmlands adjacent to Kakamega forest has been carried out (Eshiamwata *et al.,* 2006) and suggested the planting of Ficus trees as an important management tool for sustaining the diversity of frugivorous birds in agricultural landscapes. Moreover, in Kakamega forest, Laube investigated the effect of habitat structure and the distance from the nearest forest on bird community in the farmed landscape nears the forest (Laube *et al.,* 2008).

These studies have clearly shown the importance of agricultural landscape to the conservation of birds, but failed to capture the patterns in foraging guilds in a habitat transforming from sugarcane to natural shrubs and vice versa; knowledge that this study intended to bridge and provide the baseline for key decision making concerning the conservation of birds in these type of landscape

1.2 Statement of the problem

Throughout the Kenyan landscape, and especially in Muhoroni Sub-County, more land is being converted from natural habitats into farming and human settlement. The remnant indigenous vegetation is being overexploited for charcoal and firewood (Figure 1.1). This has possibly pushed birds from their natural habitats to human habitats without clear guidelines on how human interests coexist with them. This has led to the problem of land fragmentation, natural resource dilapidation and consequential loss of biodiversity.

1.3 Justification of the Study

Bird species are an important tool in indicating any change in the health status of the environment and this emphasizes the need to study them away from protected areas. Prior to this research, there was urgent need to provide knowledge on the various aspects of bird species and vegetation, particularly on the composition of birds and how they are influenced by different vegetation types in MSC. Despite the increasing focus on agricultural productivity in Muhoroni Sub-County, limited consideration was being given to the survival of avians in the agricultural landscape. In addition, there was no basic information on the requirements for survival of avians in the agricultural landscape of Muhoroni Sub-County. Information from this research helped to fill in the gaps and update the scanty information available on bird species in MSC. This information will help the government of Kenya, non-governmental organizations and the local community to justify, plan and formulate effective conservation and management policies and programs on the conservation of bird species in the agricultural landscape without disrupting human comfort. Furthermore this study will provide a check list of the bird species of Muhoroni, including the threatened and endangered species. This will help researchers willing to undertake further research on the habitat preference of specific bird species, their breeding biology and effect to agricultural crops; knowledge that will help justify the integration of birds' conservation in the farmlands.

1.4 Hypotheses

i) There is no difference in diversity, abundance and richness of bird species between the farmlands and natural shrubs in Muhoroni Sub-County.

ii) Vegetation types have no effect on the abundance of respective foraging guilds in the agricultural landscape of Muhoroni Sub-County.

1.5 General objective

To determine the influence of different vegetation types on the abundance of respective foraging guilds in the agricultural landscape of Muhoroni Sub-County, Kenya.

1.6 Specific objectives

i) To assess the percentage composition of different vegetation types in farmlands and natural shrubs in Muhoroni Sub-County.

ii) To determine bird species abundance, distribution, richness and diversity in the farmlands and natural shrubs in Muhoroni Sub-County.

iii) To establish the influence of vegetation types on abundance of respective foraging guilds in Muhoroni Sub- County.

1.7 Scope of the study in Muhoroni Sub-County

A few limitations ranged from inability to do bird counts at night to common migratory habits of birds that may have kept some species away from being observed and thirdly, some shy and skulking birds may not have been observe

CHAPTER TWO

LITERATURE REVIEW

2.1 Intermediate disturbance hypothesis (IDH)

Intermediate Disturbance Hypothesis theory (IDH) by Wilkinson & David (1999) that, local species diversity is maximized when ecological disturbance is intermediate because species that blossom at both initial and later successional phases can cohabit; and that at extreme levels of disturbance, caused by recurrent forest fires or human influences like deforestation, species have the possibility of being wiped out (Wilkinson & David , 1999).

According to Wilkinson & David (1999), ecological disturbance has profound influence on the richness of species in disturbed areas. In support to this hypothesis, Kricher & John (2011) observed that interspecific competition ensues from one species pushing competitors to extinction and dominating the ecological systems. According to the IDH moderate ecological disturbances thwarts this interspecific competition (Catford *et al.*, 2012). Land clearing is likely to cause disturbance, disrupting stable ecological systems leading to species being moved into the freshly cleared habitats. As observed by Vandermeer *et al. (*1996), once an area has been cleared, there is a gradual escalation in species richness culminating to further competition, while on the contrary when disturbance is eradicated, species richness reduces as competitive exclusion surges.

Fairly low ecosystem disturbances lead to reduced species diversity and high habitat disturbance cause a rise in species migration (Connell, 1978). This is well explained by Catford *et al. (*2012). When K-selected and r-selected species coexist in the same area, species richness reaches its maximum. K-selected species largely exhibit more competitive attributes by primarily investing resources and directing them towards growth, making them dominate stable ecological systems for long periods of time;

while, r-selected species inhabit open ecosystems rapidly and can dominate in land that has just been cleared through disturbance (Catford *et al.*, 2012).

Research and discussions on the validity of this hypothesis are continuing within the field of ecology as the IDH is being tested in a number of ecological communities. Evidence does exist for the theory (Mackey *et al.*, 2001 and Hughes *et al.*, 2007). For example in Western Australia, Phillip (2008), investigated whether or not the exceptionally high species diversity witnessed in macro-algal communities was caused by wave disturbance where it was observed that the relationship between species diversity and disturbance index was significant (Phillip *et al.*, 2008); a conclusion that is coherent with the intermediate disturbance theory. Regardless of this study being biased to Western Australian coast, it indeed supports the validity of the hypothesis.

In West Africa, Burkina Faso, a study was conducted to investigate the impacts of different fallow ages, type of soil and grazing intensity on the foraging guilds of birds in an agricultural landscape (Soderstrom & Robin, 2008). In concurrence to the intermediate disturbance hypothesis theory it was observed that bird species richness was high in disturbed land and progressively decreased with extreme disturbance. In Ghana, Bongers evaluated the intermediate disturbance hypothesis on a wider area by comparing wet tropical rain forest types and dry forest (Bongers *et al.,* 2009). In agreement to IDH it was discovered that species diversity peaked at intermediate disturbance levels, but minimal variation was clarified outside forests that were dry. In general these results backed the hypothesis as clarification why species diversity fluctuates across different habitat sites. In Kakamega, Western Kenya, Mulwa investigated the relationship in diversity of bird foraging guilds between disturbed forest (farmlands) and undisturbed natural forest. It was observed that bird species richness was high in the disturbed forest (agricultural farmlands) than in the natural forested bird habitats (Mulwa *et al.,* 2012). Though restricted to Western Kenya, this observation clearly supports the intermediate disturbance hypothesis.

Intermediate disturbance theory has received immense criticism since its commencement, but not to the scale of other ecological hypotheses. In recent times there have been pleas for a detailed reexamination of theory (Fox & Jeremy , 2013). Most critiques have been focused on the rising amount in empirical data that opposes the hypothesis, and this can be discovered in nearly 80 % of the reevaluated studies that are scrutinizing the projected peak of species diversity in intermediately disturbed levels (Fox & Jeremy , 2013).

Other criticisms are proposing some subtle theoretic issues with this theory: Firstly, while disturbances lessen competition by decreasing the densities of species and rates of growth, it similarly reduces the depth of competition required to push growth into a depressing territory and moderate species density to nil (Fox & Jeremy, 2013). Secondly that, intermediate disturbances slows down competitive exclusion by escalating the long-standing mean death rate and thus reducing the variances in the mean growth rates of the species that are competing for scarce ecosystem resources (Fox & Jerem , 2013). Thirdly, that intermediate disturbances provisionally impact relative species fitness because no matter the rate of disturbance, the species with favourable traits will exclude the rest of the species from the habitat (Vandermeer *et al.*, 1996).

In 2012, a suggestion to revise the theory was put forward that, "the diversity of species in a disturbance-mediated cohabitation among species is maximized by the existence of a disturbance system similar to historical processes" (Hall *et al.*, 2012). This is attributed to the fact that many species usually adapt to different levels of disturbance in their ecological system via evolution. This suggestion is yet to be universally adopted as it is still debatable.

Globally, intermediate ecological disturbances over and over again act swiftly and with great influence to modify the physical structure or organization of biotic and abiotic factors, and for instance in Muhoroni Sub-County, this is not an exception. In Kenya and especially in Muhoroni, major ecological disturbances include but not limited to; fires, flooding, insect outbreaks, animal trampling (due to over grazing), deforestation for charcoal burning, firewood, construction materials, farming and settlement (Catford *et al.*, 2012). In summary, this theory applies to this research in the sense that MSC is exposed to different levels of disturbance, and this is likely to affect the vegetation cover types which in turn will influence the composition of respective foraging guilds of birds.

2.2 Conceptual Framework

This section shows how the particular variables in this study connect with each other. It identifies the variables required in the research investigation. The diagram below shows the conceptual framework with independent, dependent and moderating variables clearly shown (Figure 2.1).

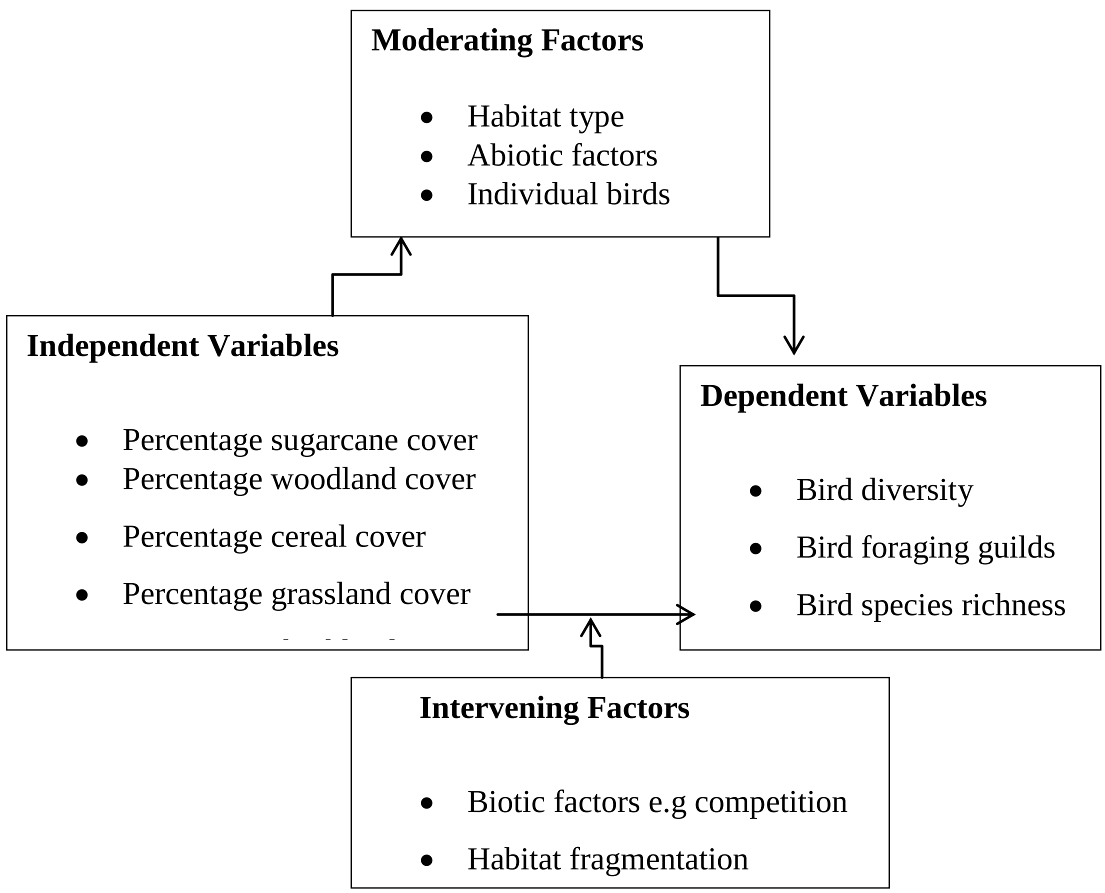

Figure 2.1: Conceptual framework of factors affecting bird diversity

2.3 Avian species

2.3.1 Ecological role of bird species

According to Bond (2004), birds are vital in island ecology as they have regularly reached islands that mammals have not. In this islands bird species may fulfill ecological roles majorly played by larger animals. Today nesting seabirds affect the ecology of islands principally through the deposition of large quantities of guano (Bond *et al.*, 2004). Worldwide, bird species inhabit many trophic levels from mid-level consumers to top predators. As with other indigenous organisms, birds help maintain sustainable population levels of their prey and predator species, and after death provide food for scavengers and decomposers (Rouche, 2006).

Many bird species are important in plant reproduction through their services as pollinators or seed dispersers (Bett *et al.,* 2017). They also provide critical resources for their many host-specific parasites, including lice that eat only feathers, flies adapted for living on birds, and mites that hitchhike on birds from plant to plant and even between countries. Moreover, some bird species are considered keystone species as their presence in (or disappearance from) an ecosystem affects other species indirectly (Smith, 2011). For example, woodpeckers create cavities that are then used by many other species. After the extinction of the dodo, it was discovered that a tree whose fruits had been a primary food item of the dodo was unable to reproduce without its seeds passing through the dodos' digestive tracts, which process scarified the seed coat and enabled germination.

According to Gregory *et al.* (2005), good indicators of the general habitat conditions are credited to birds, although their potential to directly bring about changes in ecosystem properties coupled with the influences of such changes on other taxa still exist with reservation. The advantages of using birds as indicator species are: Bird species are very easy to detect and their presence is easy to observe in the environment, they publicize their presence using calls, bright colours and numerous species are diurnal (Gregory *et* *al.,* 2005), they have a well-treated classification and individual species are easy to identify directly in the field, they are widely distributed and occupy a broad range of habitat types and ecological niches. In addition their distribution, abundance, habitat preference, biology, ecology and life history are well known Moreover; birds also exist near the top of the food chain thereby making them to be sensitive to changes at lower levels of the food chain and environmental contaminants concentration (Gregory *et al.*, 2005).

2.3.2 Economic value of avian species to humans

Some bird species are domesticated for meat and eggs as the largest source of animal protein eaten by humans (Reed *et al.,* 2003). Many species of birds are also hunted for meat purposes. Bird species hunting is largely a frivolous activity excepting particularly undeveloped areas (Brown, 2005). Other commercially precious products from birds comprise feathers used as insulation in bedding and clothing, and guano (seabird faeces), a valuable source of nutrients into the soil in the form of phosphorus and nitrogen (Keane *et al.,* 2005).

Worldwide, bird species have been domesticated by humans both as pets (Rouche, 2006). Colourful birds, such as parrots are reared in captivity or kept as pets, a system that has led to the illegal trafficking of some endangered bird species. In line with this practice, bird feeding has developed into a multi-million industry; for example, an estimated 75% of households in Great Britain provide food for bird species during the winter. Bird species play a prominent role in religion. Bird species may serve as messengers or priests and leaders for a deity (Vickery *et al.*, 2009). They may also serve as religious symbols, as when Jonah embodied the fright, passivity, mourning, and beauty traditionally associated with doves.

Bird species have also featured in art since prehistoric times when they were represented in early cave paintings (Smith, 2011). John James Audubon is among the most famous of these bird artists whose paintings of North American birds were of a great commercial success in Europe.

Bird are also important figures in poetry e.g. Homer incorporated nightingales into his *Odyssey*, and Catullus used a sparrow as an erotic symbol in his Catullus. In music bird songs have influenced composers and musicians in several ways, they can be inspired by birdsong; they can intentionally imitate bird song in a composition (Taylor, 2011).

2.3.3 Threats to birds and conservation strategies in place to mitigate their decline

State of the world's birds IUCN (2018), found that one in eight birds is in danger of extinction, and about 40% of the world's more than 10,000 bird species are declining. Disturbingly, the bird species in danger now include common bird species such as the Atlantic Puffin (*Fratercula arctica*), Snowy Owl (*Bubo scandiacus*) and European Turtle-dove (*Streptopelia Turtur*). The main driving forces against bird species are invariably of humanity's making due to industrial farming, logging, and introduction of invasive species, indiscriminate hunting, climate change and wild fire out breaks (IUCN, 2018). BirdLife International (2018) came up with many ways of protecting and conserving bird species in natural and human inhabited habitats. Some of these mitigation measures include the following:

Birds tend to hit windows because they cannot see them as an obstruction. This usually leads to death after birds accidentally crash on the windows. Birds may also encounter life-ending injuries such as broken wings and necks. Marking windows is the solution. This is best served by using decals and frosted glass, allowing the birds to avoid the glass.

Cats and other house pets are fond of hunting smaller animals, especially birds. This harms the population of the birds, which can be devastating in the case of endangered species. The problem can be contained by ensuring that the pets remain indoors and are unable to attack the birds.

Many bird species predate on smaller rodents and animals to sustain themselves. These rodents feed off of grain and cereals that they find in the open. Some birds feed of the same grains as well. However these food sources for birds can be tampered with by using chemicals. Chemical pesticides such as Dichlorodiphenyltrichloroethane, while very effective as pesticides, do not organically decompose quickly and can be passed from pest to bird. This means that any birds that feed off of pests or seeds that have come into contact with this chemical slowly accumulate fatal amounts of the chemical within their blood streams. Natural pest control measures ensure that this does not happen. Due to the very reasons stated above, it is very important that individuals convince their lawmakers to stop farmers from using the chemicals by making up legislation that can be enforced. This ensures that the chemicals are not imported into nations and at the same time dissuade individuals from using them. It will keep birds free from harm.

The endangered bird species' are numerous and they all attract high prices on the black market due to their rarity. By purchasing these birds as pets, one bolsters the market and provides an incentive for poachers to continue to decimate the already fragile populations. By not participating in the market, the poachers are starved of profits and the incentive to poach the birds is lost.

Parasites are part of the reason why birds suffer and their dwindling numbers. Attacks by ticks and mites can lead to weakened bird populations. This is mostly due to a rise in the number of parasites in the wild. Their increase can be traced to the rising global temperatures that make for shorter winters with higher average temperatures. This means that more insects survive the winter cycle each season. To combat this, we should reduce greenhouse gas emissions.

Conservation groups actively participate in conservation attempts in order to protect endangered species. These groups are especially beneficial as they are able to pull in larger amounts of funds from donors. They also practice better coordination tactics that have more of an impact on bird conservation efforts.

Birds tend to be curious about the garbage that people produce. Dumping things in the open usually leads to birds attempting to eat whatever has been dumped. This includes materials such as paper and shiny plastic beads. This could end up harming the birds or causing diseases and infections. It also places the birds at risk of being attacked by other animals as they try to pick out food. Putting trash in inappropriate places lessens the chances of these problems.

A number of bird deaths occur when they run into vehicles while flying low over the tarmac. While it is hard to avoid, there is a chance that more birds could be saved if more individuals slowed down around country regions, especially if flocks of birds had been sighted closely.

By sharing your love of birds, the conservationist will increase awareness on the plight of endangered species of birds. Sharing interests also increases the chances that there will be increased donations and participation by the general public. This helps create a bigger impact on the conservation effort.

Fledglings are birds that have not yet left the nest. They are very sensitive to things such as temperature and the parent birds are usually very protective over them. The problem with handling these birds is that it can harm the birds by introducing bacteria from the human and may also cause physical harm.

Native plant species provide a conducive environment for endangered bird species to breed and increase in population. This is particularly important because those particular birds are adapted to the indigenous plant types that grow in their areas. The plants also host other types of animals and insects which form important ecosystems and increase the biodiversity of the region.

Most birds have lost their habitat due to human expansion into what was formerly forest land used by birds for nesting. Individuals can put up structures that act as small habitats within their compounds. These may include bird feeders and baths which act to attract endangered species and serve to provide them with food, water and shelter. This increases the population of the species in the region and provides an incentive for more birds to settle in order to breed with the other birds in the region. One of the best options is to protect the existing habitats for endangered species by exempting them from human commercial activities such as logging and deforestation. This could be done by proposing to the government and local communities to protect endangered species habitats.

Aquatic birds are especially at risk when it comes to waste management, especially considering oil pollution, sewage and industrial waste. The waste dumped in the water, sometimes without treatment, destroys food sources for the birds such as fish and also reduces marine life diversity. There is also the possibility that the waste increases the nutrient levels for microbes in the water, which leads to the growth of algal blooms. Algal blooms are toxic and can lead to the death of thousands of fish, therefore, poisoning the birds if they happen to consume the dead or poisoned fish.

Birds are very sensitive to human action. Even when they live in close proximity to populations of humans, attempts to approach nests to force the birds to fly away. For some birds, this means expending a lot of energy to leave the nest and perch on other trees. This constant stress and use of physical strength to move could lead to overworking the bird. A lifestyle of constant movement caused by human interference also makes it difficult for birds to find food that can starve the young ones.

Visiting specially designated habitats provides awareness to the plight of endangered species and provides the government with funds from entrance fees that go into protection of the national parks. This ensures that the species habitats remain protected therefore protecting the birds nesting in the area. Another way to protect endangered species is to get involved in the conservation projects by volunteering services or making cash donations. Your time can also be used for non-specialized tasks such as helping in trash collection while the money goes into the funds required to maintain the parks. This helps secure the habitats that provide homes to thousands of birds.

By reducing energy use, a person can help in conserving birds. Reducing the amount of energy reduces carbon emissions, in turn, reducing the occurrence of extreme weather events that can wipe critical ecosystems necessary for a bird's survival. The final action that goes towards protecting endangered species of birds is enjoying nature. Being active in bird watching and nature walks ensures that there is a constant appreciation for birds' beauty. This sort of appreciation can be shared among people and continue to help raise awareness of the birds' plight thus gather help in any form that would go towards protecting all the endangered birds in your region.

2.4 Factors affecting bird species diversity, abundance and distribution

2.4.1 Habitat type

Bird species select habitats that suit their requirements for productive reproduction and survival however some generalist bird species may exploit several habitats (Rodríguez-Estrella, 2007). Disparities in requirement amongst bird species have triggered specificity on habitat requirement (Buckley & Freckleton, 2010). In nearly all habitats, plant communities ascertain the physical structure of the environment, and consequently, have a considerable influence on the distributions, abundance and diversity of birds and interactions of other animal species. For example, for bird species diversity in forest habitats Tewes *et al.* (2004) observed that the physical structure of a plant community may be more vital than the real composition of plant species. According to Ranganathan *et al.* (2007), agricultural farmlands also have been an important habitat for farmland bird. This demonstrates that some bird species are habitat specific though some are generalist. Presently, due to land uses revolutions it is challenging to find forest habitat covering large areas. Studies of bird species diversity, distribution and abundance become significant not only for know-how but also for conservation reasons as birds have been used as ecological indicators (Rittiboon & Karntanut, 2011).

2.4.2 Habitat features

Habitat geographies such as floristic complexity, vegetation cover type and density are the key factors in bird habitat choice. When these features are compared they display positive association, since they offer food, nesting materials and cover from predators (Whittingham & Evans, 2004). Habitat heterogeneity can portray a big part in the determination of species abundance and occurrence within a specific habitat type (Pennington & Blair, 2011). Elimination or decline of vegetation decreases the total area of adjacent habitat accessible to birds and escalates the isolation of the habitat which causes land fragmentation. The disintegrated habitat provide through routes to various predators that may exploit species by eating bird eggs, young and even adults which impact bird populations (Schlossberg & King, 2008).

2.4.3 Anthropogenic activities

Bird habitat destruction, fragmentation and loss have been noted due to surge in human population (Manhaes & Ribeiro, 2005). Some forests have been transformed to urban settlement, agricultural grounds, and pasture land and sometimes to open land. These human actions have an influence on bird species abundance, distribution and diversity due to isolation and fragmentation (Westphal *et al.*, 2006). The decline in bird species abundance and species loss due to human interferences, have been observed in the tropics (Cordeiro, 2005).

2.4.4 Altitude

Altitude impacts bird species distribution and diversity in the montane topographies (Hobson *et al.*, 2003). Montane elevation forms a microclimate which then may determine temperature, soil characteristics and vegetation cover type of the given habitat (Waterhouse *et al.,* 2002). This eventually directly or indirectly affect the distribution and diversity of bird species by limiting the availability of the requirement and energy flow into the ecosystem. Most ecological studies show that lower altitude of habitats has more bird species than higher altitude, while some bird species are restricted to certain ecological zones and others occurring throughout the altitudes (Jankowski *et al.*, 2009).

2.4.5 Climate

The role of weather on the abundance of bird species has been a major field of study by ornithologists. Climatic changes not only impacts on the metabolic rate of, but also exerts other direct and indirect effects on bird behavior, for example, it can influence feeding conditions and the ability to conduct other important behaviors like courtship. Weather changes greatly affect breeding success (Humphrey, 2004). According to Humphrey (2004), extreme weather conditions, such as prolonged frozen spells and drought can have catastrophic effects on bird populations, including long-term effects on whole cohorts.

2.5 Previous studies on bird composition, vegetation types and foraging guilds

2.5.1 Bird diversity, abundance and richness

In Burdwan, West Bengal India (Asia), Asif and Gautam (2014) assessed bird abundance, diversity and richness in the agricultural landscape using line transect method and opportunistic counts were used to conduct bird surveys. Bird species richness was high for the order *Pass-eriformes* followed by *Charadriidae* and majority of the bird species (51.85 %) were correlated with the agricultural fields. They conclude that richness of bird species in the study area calls for further studies on habitat preference, census and breeding biology to help highlight species specific roles in ecosystem functions and sustenance of ecosystem services. In Brazilian Atlantic Forest, Morante *et al.* (2015) investigated the diversity and abundance of birds in 40 forest sites using the point count standard method. The composition of the bird community was surprisingly not influenced by variation in forest cover in this area.

The area of land farmed in Africa is predicted to double by the year 2050 yet very few African studies have investigated the impact of different farming intensities and regimes on bird communities. This study examined bird species richness and diversity along with the densities of some common bird species on the Jos Plateau, Nigeria, in relation to habitat features on farmland over a gradient of differing farming intensities. The study area exhibited a variety of different levels of farming which differed in the habitat available for birds. Birds normally associated with savanna woodland were more associated with less intensive farming, and open-country birds were more associated with more intensive sites, with more species of birds observed where farming was less intensive. Common species of birds using cultivated land associated with different crops, with acha and millet being the most commonly used.

Tree density was the most important variable predicting bird species richness and diversity, with medium tree density predicting the highest species richness and diversity. The densities of two common farmland birds were predicted best by tree density, but varied in their responses to the habitat variables, with common bulbul, a savanna generalist, associating more with less intensive, wooded areas and red-cheeked cordon-bleu, an open savanna granivore, associating with medium intensity, more open farmland. Whinchats were common in open, intensively farmed areas with few trees and good herbaceous vegetation cover. The data presented indicates the importance of retaining natural features of savanna habitat in farmland in order to maintain high bird diversity on farmland. More detailed studies are needed in order to determine the mechanisms involved in the associations observed and collaborations between ecologists and social scientists will be necessary to develop effective policies to limit the impact of the intensification of agriculture in Africa on bird biodiversity.

In Egypt, Zagazig & Issa (2019) conducted a research on bird abundance, diversity and richness in agriculture water canals and field crops habitat. The composition of birds was high in the agricultural water habitat. They recommended further research on habitat requirement of each bird species and conservation measures on the degraded habitats. In Ethiopia, Girma (2017) assessed bird species composition, relative bird abundance and bird distribution in a natural forest and the surrounding agricultural area using line transects. Bird species richness and bird abundance differed significantly between different habitat types.

In Kenya, Oyondi & Muya (2017) researched on the diversity, abundance, and bird conservation status in Etago Sub-County, Kisii County using standard point count and timed species counts to conduct bird census in sugarcane plantations, secondary forest, mixed farms and human settlement. Human settlement had the highest composition of birds while mixed farms had the little. Bird composition significantly differed in all the study sites. Among the recommendations was for the concerned authorities to come up with strategies to help conserve dilapidated habitats.

2.5.2 Effect of vegetation cover types on bird diversity, abundance and richness

In Germany, Redlich (2018) investigated the relative influence of vegetation cover types and agricultural landscape heterogeneity on bird species richness across 5 spatial scales from 250-3000 m radius. He further assessed whether habitat preference, feeding guilds, conservation status and nesting patterns affect responses to crop diversity and landscape heterogeneity. She observed that crop diversity has no effect on bird richness and the functional groups but landscape heterogeneity strongly influenced bird richness in all sites. In Australia, Stuart *et al.* (2009) established the influence of different vegetation cover patterns to bird species diversity in the agricultural landscape. They observed that bird species richness and diversity were higher in less disturbed habitats. They concluded that non-crop habitats within farmland provide important habitat for a unique and diverse assemblage of native birds.

In Mississippi, USA, Myung-Bok Lee & Martin (2017) investigated correlation between bird diversity and vegetation cover in agricultural landscapes. They took into account species richness estimated from a multi-species dynamic occupancy model, and functional diversity centered on features of arising species. It was also established how agricultural lands in a conservation platform managed on behalf of decreasing early successional bird species affects bird diversity. Species richness did not indicate any significant response to environmental parameters, whereas species diversity responded positively to vegetation cover heterogeneity. This result suggests that the relationship connecting bird diversity and landscape heterogeneity may differ depending on the facet of diversity in consideration. In Tanzania, Chacha *et al.* (2017) conducted a research on bird composition and the role of kopjes in agricultural lands. The study area was divided into degraded shrubland, farmland, riparian vegetation and kopjes (protruding granite outcrops). The birds were sampled by line transects as this method covered large tracts quickly. Bird composition was higher in the kopjes as compared to the human habitats. They concluded that kopjes and adjacent habitats are significant for bird species conservation.

2.5.3 Effect of vegetation cover types on abundance on respective foraging guilds

Worldwide, studies on vegetation cover and abundance of foraging bird guilds have been undertaken. In South Indian, Somasundaram *et al.* (2019) investigated the feeding behavior of bird species observed. This study overlay the significance of plant structure in sustaining bird species, mainly the shrub and forest layers frequently wedged by human activities. They recommended protection of forests, eco-friendly development of the surrounding settlement and involvement of communities in re-establishment of forests and conservation. In Burkina Faso (West Africa) an investigation was conducted on the response of bird foraging guilds to a gradient of agricultural intensity (Soderstrom & Robin, 2008). They observed that bird species richness was higher on aggressively perturbed land and progressively decreased with time. They concluded that woodlots should comprise of a variety of tree species and that bird conservation is compatible with human activities as long as land use patterns maintain a more heterogeneous habitat.

In Kenya similar studies have been undertaken by Mulwa *et al*. (2012) and Ndang'ang'a *et al*. (2013) among other studies. Mulwa *et al*. (2012) investigated the diversity of bird foraging guilds in structurally heterogeneous farmlands adjacent to Kakamega forest in Western Kenya. Bird density and species richness were observed on average to be high in agricultural farmlands than in forested bird habitats. This study also confirmed that tropical agricultural farmlands are unlikely to host forest specialists. It was concluded that structurally rich tropical farmlands host unexpectedly rich and distinct bird guilds that is threatened by conversion of subsistence farmland into sugarcane plantations. Ndang'ang'a *et al.* (2013) observed that bird species diversity and richness of particular foraging guilds increase with escalating heterogeneity of vegetation cover types. It was noted that crop diversity has a significant positive impact on bird species richness.

CHAPTER THREE

STUDY AREA, MATERIALS AND METHODS

3.1 Study area

This study was carried out between the months of August and December in Muhoroni Sub-County (667.30 km^2); Latitude of 0° and 26' south and Longitude of 34° 52' east and 35° 19' east, with an estimated population of about 184, 220 people (Raburu, 2009). Muhoroni Sub-County has high agricultural potential with annual bio-modal rainfall pattern averaging between 1,100 mm and 1,600 mm with the highest levels during the months of March, April, May, June and October while low levels during the months of December, January and February (Raburu, 2009). Over the course of the year, the temperature typically varies from 22°C to28 °C and is rarely below 18C° or above 30C°. Muhoroni Sub-County is drained by; Nyando, Mbogo and Oseng' rivers which flow into Lake Victoria. The landscape is gently undulating and underlain by granitic and basement complex rocks, which weather to give deep, moderately fertile black cotton soils.

The Muhoroni Sub-County area has high agricultural potential and human densities around it are also increasing. This area is characterized by several economic activities. The main crops under cultivation include sugarcane, maize, sorghum and beans with the main cropping system being intensive mono-cropping of sugarcane. Large-scale sugarcane farming is done by Chemelil Sugar Company, Simba sugarcane farms and Muhoroni Sugar Company. The area's natural vegetation is mainly composed of dwarf shrubs which cover significant parts of Gull hills.

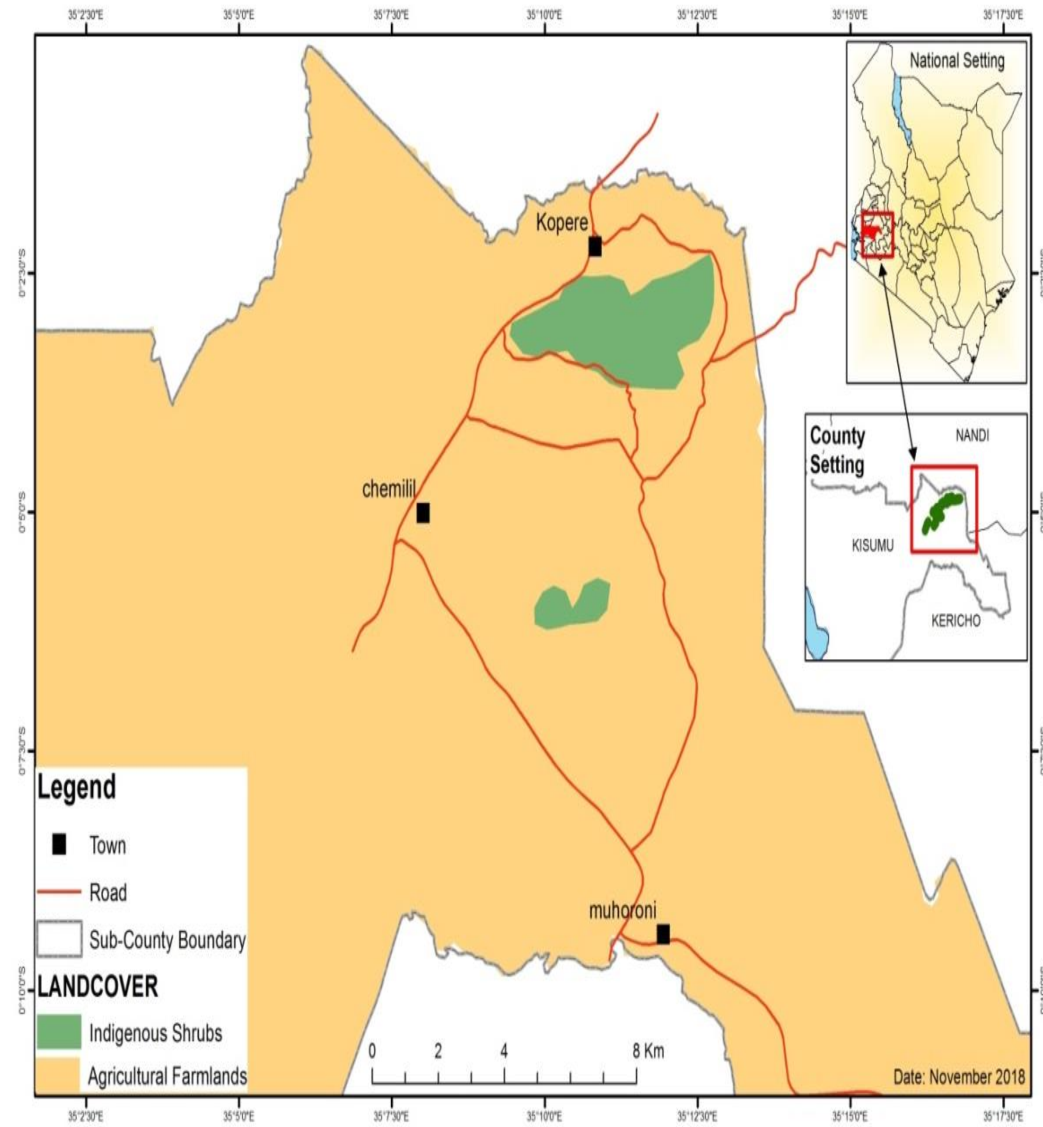

Figure 3.1: Map showing the study sites in Muhoroni Sub-County; Source: Daniel Mogaka, 2018

3.2 Research Design

Systematic sampling was used to collect data for this research. This research design offered more accurate results, allowed for easy statistical analysis and eliminated cluster selection. This research design has been previously utilized successfully by Oyondi & Muya (2017) and Ndanganga *et al.* (2013).

Much of Muhoroni Sub-County (MSC) is characterized by two major landscapes. Those dominated by the farmlands mostly composed of sugarcane plantations and secondly, those with significant proportion of natural vegetation mostly the shrubs. Within the sugarcane farmlands the non-crop features included live fences, grasslands, scattered bushes, trees and field margins. On the basis of this landscape composition and to capture the influence of vegetation cover types on the composition of birds in MSC, the study area was stratified into natural shrubs and agricultural farmlands. Within the agricultural farmlands, live fences, field margins, cereal crops, trees, grasslands and some shrubs occupied a significant proportion. The natural shrubs comprised of significant proportion of grassland.

3.3 Sample size

According to Bibby (2000) what constitutes an adequate survey sample depends on the degree of natural variability, the objectives of the research, time, cost, appropriate statistical power provision and the methods employed by the study. The total number of point count stations was 50 per sampling site as recommended by Bibby (1998). Species accumulation curve was used to exhaustively search for new species both within and outside the point count stations for the purpose of developing bird species check list of MSC.

3.4. Pilot study

For this research two pilot studies were conducted together with an experienced researcher from the National Museum of Kenya. The first visit helped to familiarize to the map of the area and design of the sampling technique and data sheets. Possible challenges that were likely to be faced like access were also noted for appropriate action. In the second visit (pilot study) the real investigation was conducted in small scale along one transect in both the farmland and natural shrubs. This enabled understanding of the procedures, equipment, the nature of data, and financial estimates. In this pilot study all identified loopholes ranging from equipment, methods and data were addressed.

3.5 Sampling techniques

3.5.1 Bird species sampling by point count method

For this research birds were sampled using standard point count method. This method was chosen because it is quick, easy to administer and can be used randomly. In the standard point count method census plots were marked along a pre-determined line transect at fixed intervals (Bennun & Howell, 2002). The observer stands at the centre of the plot and records all birds seen or heard within the point count plot for 10 minutes. The bird species seen outside the point count and those flying over the point count station are assumed not to be part of the station and are therefore ignored (Bibby *et al.*, 2000). Every point count episode is granted a one minute bird settling in period. In this method, the numbers of birds within the radius of each point count are counted against the total area in hectares, to get density of birds per hectare. The number of point counts in each habitat depends on percentage of its representation in the study area. This is used in calculating absolute densities (Bibby *et al.* 2000). The number of different bird species was used to calculate the diversity index and equitability index.

For this research, both in the agricultural farmlands and natural shrubs, study sites of 10 km long (cumulatively) of line transects were preferred since they were found suitable as they would each accommodate a total of 50 point count plots. A total of five 2 km long transects were picked at random in each study area. Ten sets of 30 m radius census plots were then located along the 2 km long transect at intervals of 200 m. Based on ease of traversing, it took varied times to complete sampling along one transect.

Upon arriving at the point count station, the birds were allowed time to settle for one minute and then birds seen or heard within a fixed radius of 30 m (hereafter referred to as ‘local’) were recorded for a period of 10 minutes. Surveys were conducted at 6.30 a.m.-10.30 a.m. and 3.30 p.m.-6.30 p.m. on fair weather days. The species type, number of birds and foraging behavior were recorded. All birds were identified using Zimmerman bird identification key (Zimmerman *et al.*, 1996) and grouped into seven feeding guilds based on description of major food items taken by respective species (Hockey *et al.*, 2005): carnivores (invertebrates), frugivores (fruits), granivores (seeds), molluscivores, insectivores (insects), nectarivores (nectar) and omnivores (plant and animal materials).

Opportunist counts were organized outside the point count stations to exhaustively search the study area for new species. New sightings were recorded for 17 days and a species accumulation curve used to give an indication as to whether continued searching would increase the number of species recorded. Data from the opportunistic counts was incorporated in generation a bird species check list.

3.5.2 Types of vegetation sampling technique.

Ocular cover estimates are obtained when an observer examines a plot and estimates the percentage of the plot that is covered by the canopy of each vegetation type (Ndang’ang’a *et al.*, 2013). This is best done by visually estimating progressively larger proportions of the plot, and then comparing the area covered vegetation type to a known percentage of the area within the plot.

The percentage vegetation types were sampled using the ocular estimation method (visual estimation by observer) at the local scale (30m radius plots) with an area of 0.28 hectares. The following vegetation variables were estimated using ocular estimation method: woodland percentage, grassland percentage, shrubland percentage, sugarcane percentage and cereal crop percentage expressed to the nearest 5%. These estimations are carried out by multiple observers immediately the 10 minutes for observing birds elapse and an average calculated. This reduces one observer bias limitation.

3.6 Data analysis methods

Data on bird species abundance was first tested for normality test and then subjected to square root and log transformation since it was just count data. Then the formula; number of birds of each species/Total number of birds×100, was applied to determine relative density. A probability of type I error of 0.95 ($\alpha = 0.05$ or less) was accepted as significant (unless otherwise noted)

3.6.1 Shannon Wiener diversity index

Data recorded on bird species diversity in the two stratified study sites was calculated using the Shannon Wiener diversity index (H'). The Shannon Wiener diversity index theoretically ranges from 0: a community with only one species. In practice, a value of 7 indicates extremely rich community. Values below 1 suggest a community with low diversity. Values above 1.7 indicate a relatively diverse community. True diversity (exponential of the diversity index) is used to explain difference in diversity between the farmland and natural shrubs. Shannon-Wiener Index is defined and given by the following function:

$$\mathbf{H=\sum [(pi) \times ln\ (pi)]}$$

Where:

- **pi** = Proportion of total sample represented by species i. Divide number of individuals of species i by total number of samples.

Shannon's equitability (E_H) is calculated by dividing H by H_{max} (here H_{max} = ln$S$). Equitability assumes a value between 0 and 1 with 1 being complete evenness.

$$E_H = H / H_{max} = H / \ln S$$

Where:

- ***E***= Evenness = **H/H_{max}**
- ***S*** = Species richness
- **H_{max} = ln(S)** = Maximum diversity possible

3.6.2 Mann-Whitney U-test

Mann Whitney U-test was used to find how significantly different bird species abundance was between the farmland and natural shrubs. This is a non-parametric test of the null hypothesis that for randomly selected values X and Y from two populations, the probability of X being greater than Y is equal to the probability of Y being greater than X. this test assumes that all the observations from both groups are independent of each other, the responses are at least ordinal (i.e., one can at least say, of any two observations, which is the greater), under the null hypothesis H_0, the distributions of both populations are equal and the alternative hypothesis H_1 is that the distributions are not equal.

The test statistic for the Mann Whitney U Test is denoted **U** and is the smaller of U_1 and U_2, defined below.

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2$$

Where R_1 = sum of the ranks for group 1 and R_2 = sum of the ranks for group 2.

3.6.3 Chi-square statistic

The Chi-Square statistic was used for testing how farmers chose to use their land. The null hypothesis of the Chi-Square test is that no relationship exists on the categorical variables in the population; they are independent. In the standard applications of this test, the observations are classified into mutually exclusive classes. If the null hypothesis that there are no differences between the classes in the population is true, the test statistic computed from the observations follows a χ^2 frequency distribution. The purpose of the test is to evaluate how likely the observed frequencies would be assuming the null hypothesis is true. Test statistics that follow a χ^2 distribution occur when the observations are independent. There are also χ^2 tests for testing the null hypothesis of independence of a pair of random variables based on observations of the pairs. The formula for chi-square is:

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where**:**

c = Degrees of freedom

O = Observed value(s)

E=Expected value(s)

3.6.4 Principal component analysis (PCA)

Principal Component Analysis (PCA) was done to compress the set of vegetation cover variables at the local scale into a smaller number of axes of habitat variability having the advantage of being orthogonal and uncorrelated. The principal components were then interpreted using component loadings i.e. correlations between the principal components and each original residual variable. Extracted PCA factors that accounted for most of the variability within the variables were reserved as measures of vegetation cover for the succeeding multivariate modeling analysis. Factor loadings of <0.2 were considered significant (Llyod, 2008). Values of parameters were standardized relative to each other to translate them into a small scale, before performing the PCA. This was accomplished by calculating z scores for each variable so that it has a mean of zero and a standard deviation of one (Quinn and Keough, 2002).

3.6.5 Generalized linear mixed models

Generalized Linear Mixed Models (use of both fixed and random effects) were used to establish the relationship between vegetation cover variables and bird composition of individual feeding guilds. According to Zuur (2009), this model is used when the data has hierarchical forms, time series, repeated measures and blocked experiments. GLMs consist of three components namely: random component (response variable), systematic component (predictors in the model), and the link function that links the systematic component and the random component. It also links the expected value of Y to the predictors by the function (Zar, 1999):

$$\mathbf{G\ (\mu_y) = b_0 + b_1X_1 + b_2X_2 + \ldots.. + b_k\,X_k}$$

Where $\mathbf{\mu_{y=}}$ expected value of y (dependent variable)

$\mathbf{b_0}$= regression coefficient for the intercept

$\mathbf{b_1}$= regression coefficients for variables 1 to k as computed from the data

$\mathbf{X_1}$= predictor variables 1 to k

CHAPTER FOUR

RESULTS

4.1 Bird species abundance in Muhoroni sub-county

A total of 1450 individual birds belonging to 122 species from 46 families were documented in the entire study area. The agricultural farmland had the highest abundance with 898 birds, whereas the natural shrubs recorded 552 birds. Muhoroni Sub-County is a haven for species that are of important conservation value. These birds were observed both in the natural shrubs and farmlands and they include the Grey Crowned Crane (*Balearica regulorum*) (endangered), the Fischer's Lovebird (*Agapornis fischeri*) (near threatened), and the Steppe Eagle (*Aquila nepalensis*) (endangered) (Table 4.1).

Table 4.1: Species Listed in the IUCN Red List

Common Name	Species Name	IUCN Status	Threat Score
Grey Crowned Crane	*Balearica regulorum*	Endangered	2
Fischer's Lovebird	*Agapornis fischeri*	Near Threatened	5
Steppe Eagle	*Aquila nepalensis*	Endangered	2

Out of the 122 species of birds documented in Muhoroni Sub-County, 6 bird species (5%) were forest generalists (F), 40 bird species (33%) forest visitors (f) while 76 bird species (62 %) were non-forest birds (Figure 4.1).

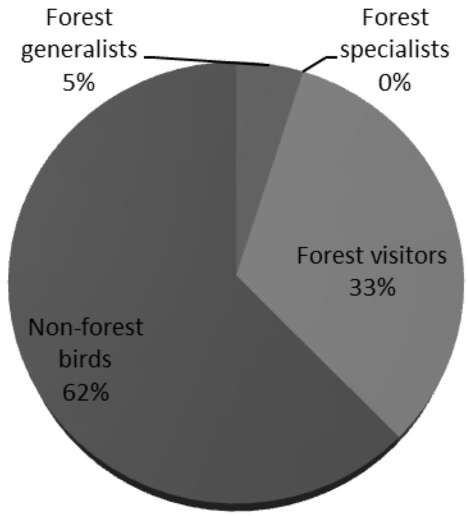

Figure 4.1: Forest Dependency in Muhoroni Sub-County

The Agricultural farmlands had the highest numbers of forest visitors (22), forest generalists (4) and non-forest birds (59). On the other hand, the indigenous shrubs had the lowest numbers; forest visitors (20), forest generalists (2) and non-forest birds (39) (Figure 4.2) (Appendix II).

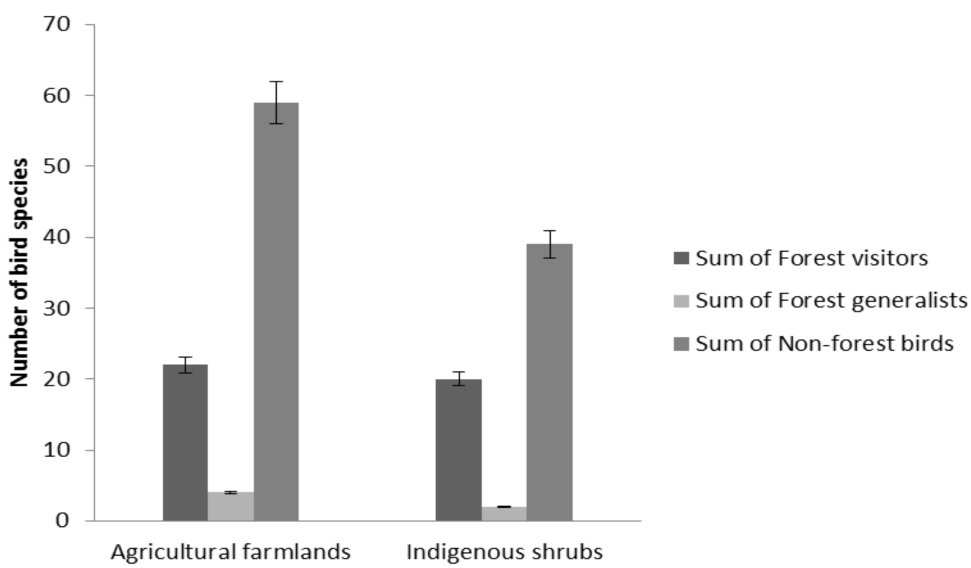

Figure 4.2: Forest dependency in the two habitats

Twenty one (21) birds species observed in the study area were biome-characteristic species. In the entire landscape there were 6 Afrotropical migrants (am) comprising of 5%, 12 Palearctic migrants (pm) comprising of 10% and 3 both Afrotropical and Palearctic migrants (am, pm) comprising of 2%. The rest of the birds (101) were residents comprising of 83% (Figure 4.3) (Full list in appendix I).

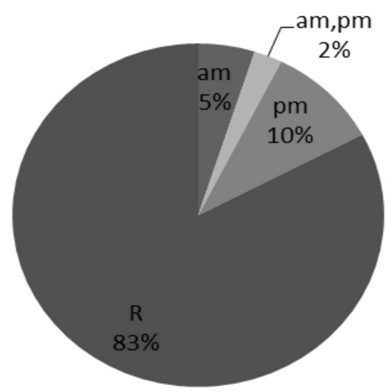

Figure 4.3: Migration status of birds in Muhoroni Sub-County

Muhoroni Sub-County was rich in insectivores with 64 birds species (53%) trailed by frugivores with 17 birds species (14%), Granivores 16 birds species (13%), Carnivores 11 birds species (9%), Nectarivores 6 birds species (5%), omnivores 5 (4%) and molluscivores 3 bird species (2%) (Figure 4.4) (Full list in appendix III and IV).

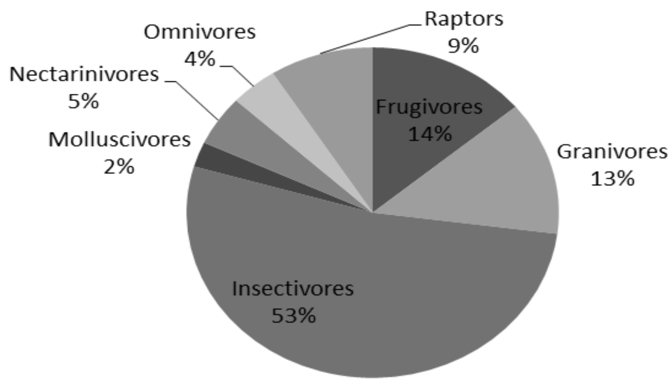

Figure 4.4: Bird foraging guild in the study area

Generally, the classification of birds into the 7 feeding guilds showed that the insectivores dominated the species composition, with molluscivores being the least dominant (Figure 4.5).

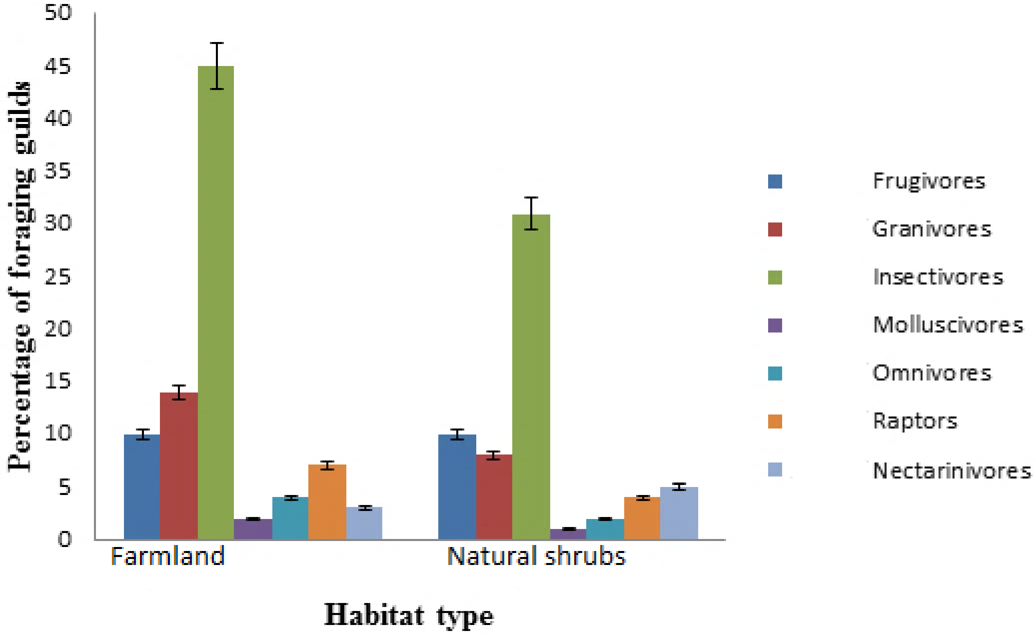

Figure 4.5: Bird foraging guild in the two habitats

4.1.1 Bird species abundance in the natural shrubs

The little swift (*Apus affinis*) was the most abundant species with a density of 9.83 birds/ha followed by the common bulbul (*Pycnonotus barbatus*) with a density of 4.60 birds/ha and Tropical Boubou (*Laniarius aethopicus*) with a density of 4.10 birds/ha. The remainder bird species had a density of lower than 2.00 birds/ha as shown in (Figure 4.6) (Full list in appendix VI).

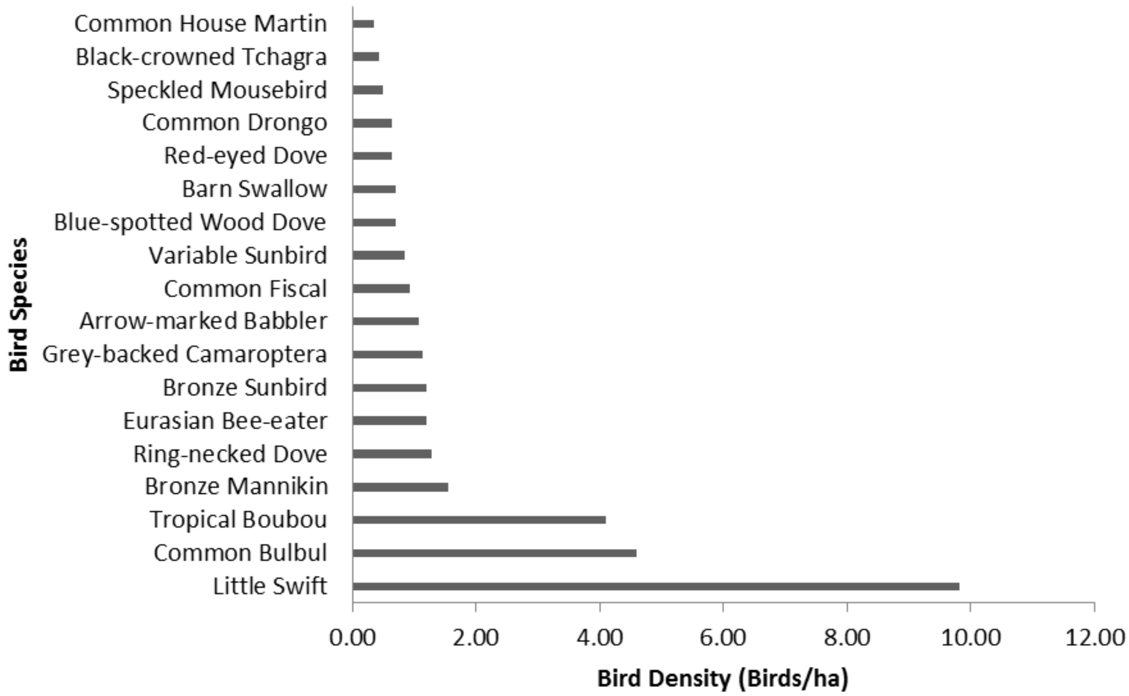

Figure 4.6: Indigenous shrubs bird density (Birds/ha)

4.1.2 Bird species abundance in the agricultural farmlands

In the agricultural farmlands, the Bronze Mannikin (*Spermestes cucculatus*) was the most abundant bird species with a density of 9.26 birds/ha followed by the Little Swift (*Apus affinis*) with a density of 7.92 birds/ha, the Common Bulbul (*Pycnonotus barbatus*) with a density of 4.10 birds/ha and the Fan-tailed Widowbird (*Euplectes axillaris*) with a density of 4.03 birds/ha. The rest of the bird species had abundance of below 4.00 birds/ha (Figure 4.7) (Full list in appendix 7).

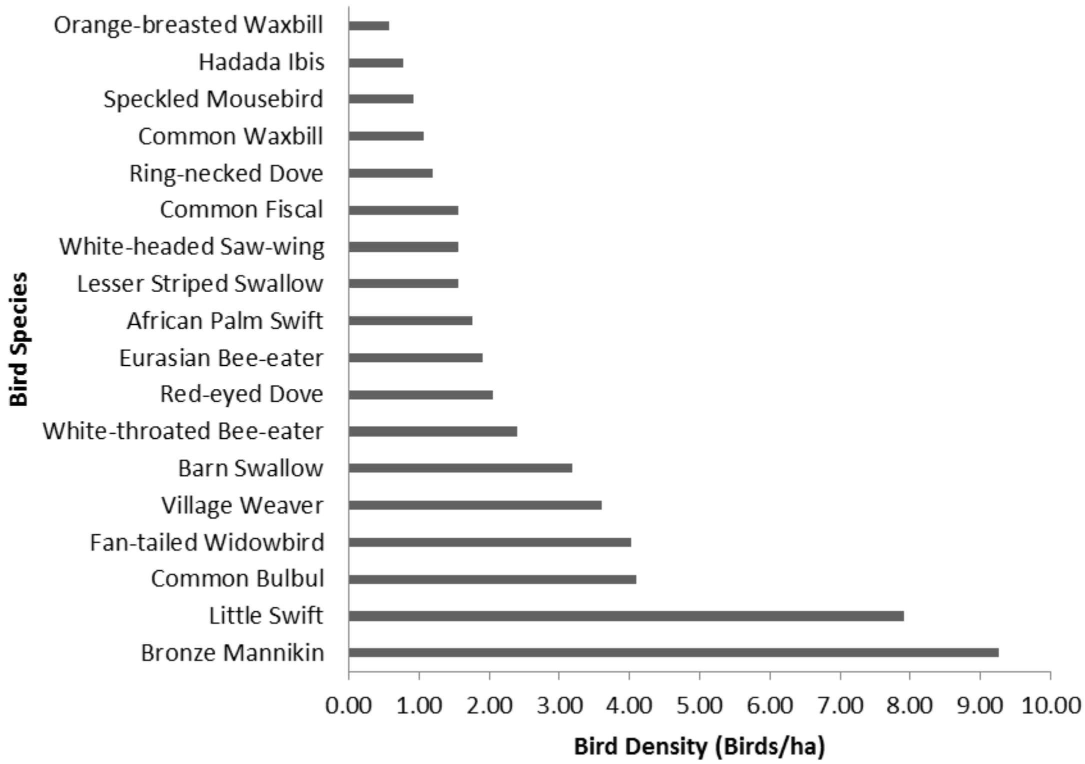

Figure 4.7: Agricultural Farmlands bird Density (Birds/ha)

4.1.3 Bird species mean abundance in the natural shrubs and farmland

Bird species abundance was higher in the agricultural farmland with a mean of 2.065±1.11 birds per hectare as compared to the natural shrubs with a mean of 1.644±0.70 birds per hectare (Figure 4.8).

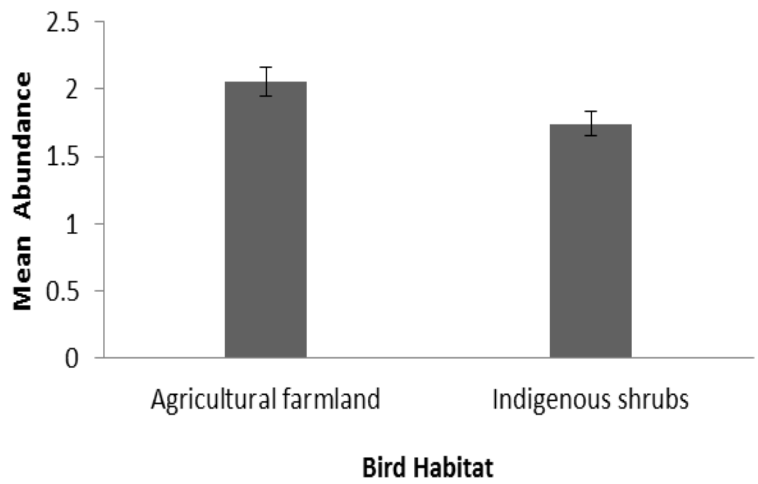

Figure 4.8: Mean bird abundance in Muhoroni sub-county

The frequency of group mean revealed that most birds were observed in small groups (Figure 4.9) while a few bird species like the Barn Swallow, Bronze Mannikin, Little Swift and Village Weaver were observed in large groups . To calculate the mean of grouped data, the first step is to determine the midpoint of each interval, or class. These midpoints must then be multiplied by the frequencies of the corresponding classes. The sum of the products divided by the total number of values will be the value of the group mean.

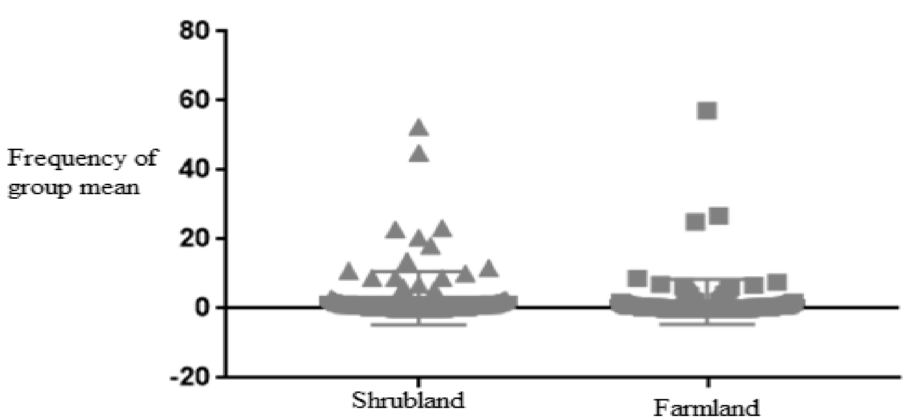

Figure 4.9: Mean bird abundance in Muhoroni sub-county

Mann-Whitney U test revealed that there was a significant difference in number of bird recorded in the farmlands (Mdn=3) compared to those recorded in the natural shrubs (Mdn=2), U=2449, $p<0.05$. From the group size frequency of different bird species, it was observed that most birds were encountered in smaller groups (Figure 4.10).

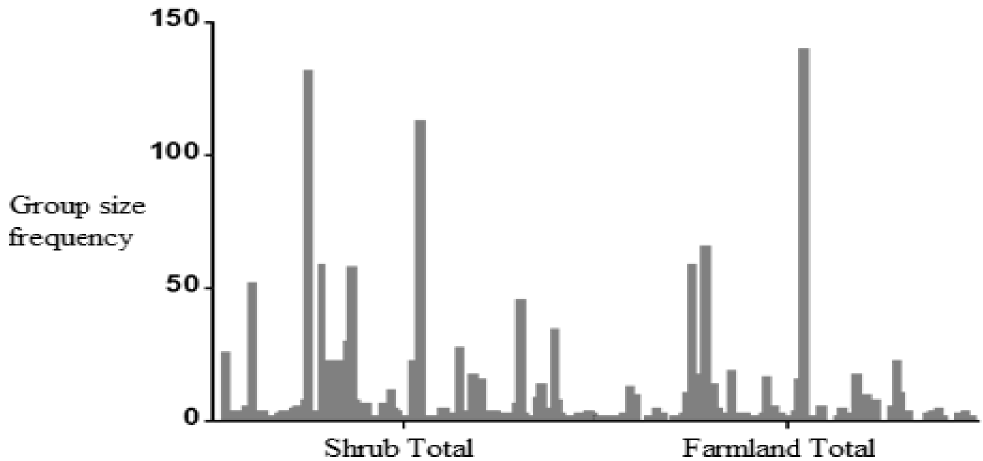

Figure 4.10: Group size frequency distribution

4.2 Birds species diversity in Muhoroni sub-county

Species accumulation curves indicate that a complete bird community may not have been captured during the study (Figure 4.11). Species predictive curve modeled however revealed that with more effort, species expected in Muhoroni are at least 180 species (Figure 4.12). In the agricultural farmlands 86 species were cumulatively recorded while 60 species were recorded in the indigenous shrubs.

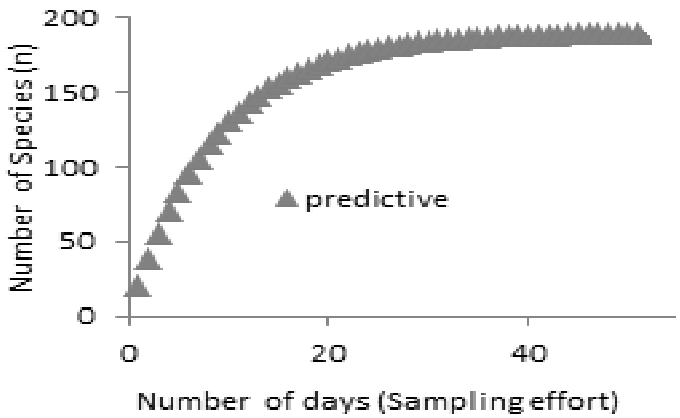

Figure 4.11: Bird species predictive curve

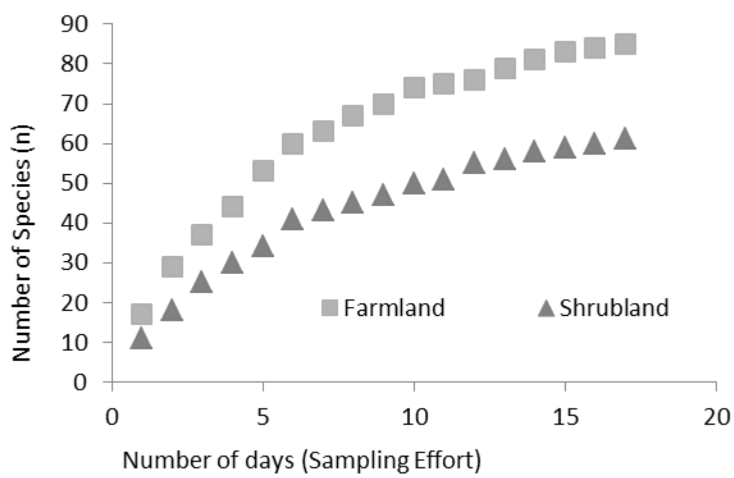

Figure 4.12: Species accumulation curves for the two habitat

Bird species diversity index (H') in MSC was 3.2. The habitat patches seem to have dissimilar species that are restricted to particular habitat patches and only a few utilize the habitat mosaics as shown by the species equitability/evenness E_H of 0.67. The indigenous shrubs had a Shannon diversity index (H’) of 2.5 while the agricultural farmland had a Shannon diversity index (H’) of 3.9 (Figure 4.13).

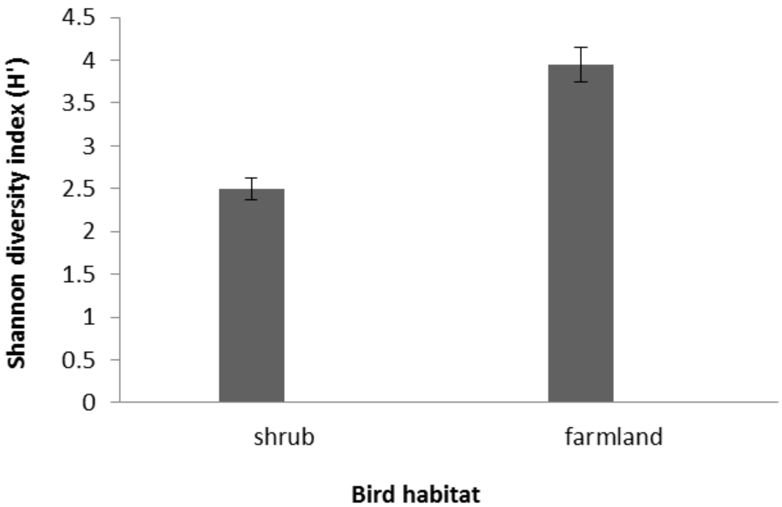

Figure 4.13: Bird species diversity in Agricultural Farmlands and natural Shrubs

The Shannon diversity index was converted to the effective number of species by calculating the exponential of the diversity index (Table 4.2). The effective number of species refers to the number of equally abundant species needed to obtain the same mean proportional species abundance as that observed in the dataset of interest (where all species may not be equally abundant). The magnitude of the difference in effective number of species indicated that the farmland was four times (49/13) more diverse than the indigenous shrubs. This difference could not be drawn from the raw diversity index as it utilizes a non-linear scale.

Table 4.2 Effective number of species

Habitat	Shannon diversity index	True diversity
Farmland	3.9	49
Shrubland	2.5	13

4.3 Bird species richness in Muhoroni sub-county

Agricultural farms had the highest species richness of 86 species as contrasted to the natural shrub with 60 bird species (Table 4.3). Shannon equitability index indicated that the individual bird species were more evenly distributed in the farmlands than in the shrubland.

Table 4.3: Bird species richness per habitat

Habitat	Species Richness(S)	Shannon Equitability (E_H)
Natural shrub	60	0.6081
Agricultural farmlands	86	0.8891

4.4 Percentage vegetation cover types in MSC landscape

In the agricultural farmlands the dominant vegetation cover type was sugarcane at 55.6% followed by grassland cover type (20.4%), shrubland cover type (12.8%) and woodland cover type (2.8%). The least coverage type was cereal crop cover with 8.8%. Shrubland cover type dominated vegetation in the natural shrubs at 55.8% while cereal crop cover type recorded 0%. Grassland cover type comprised of 42.2% and woodland cover type 1.6%. This indicated that horizontal vegetation cover was more heterogeneous in the agricultural farmlands than in the indigenous shrubs (Figure 4.14).

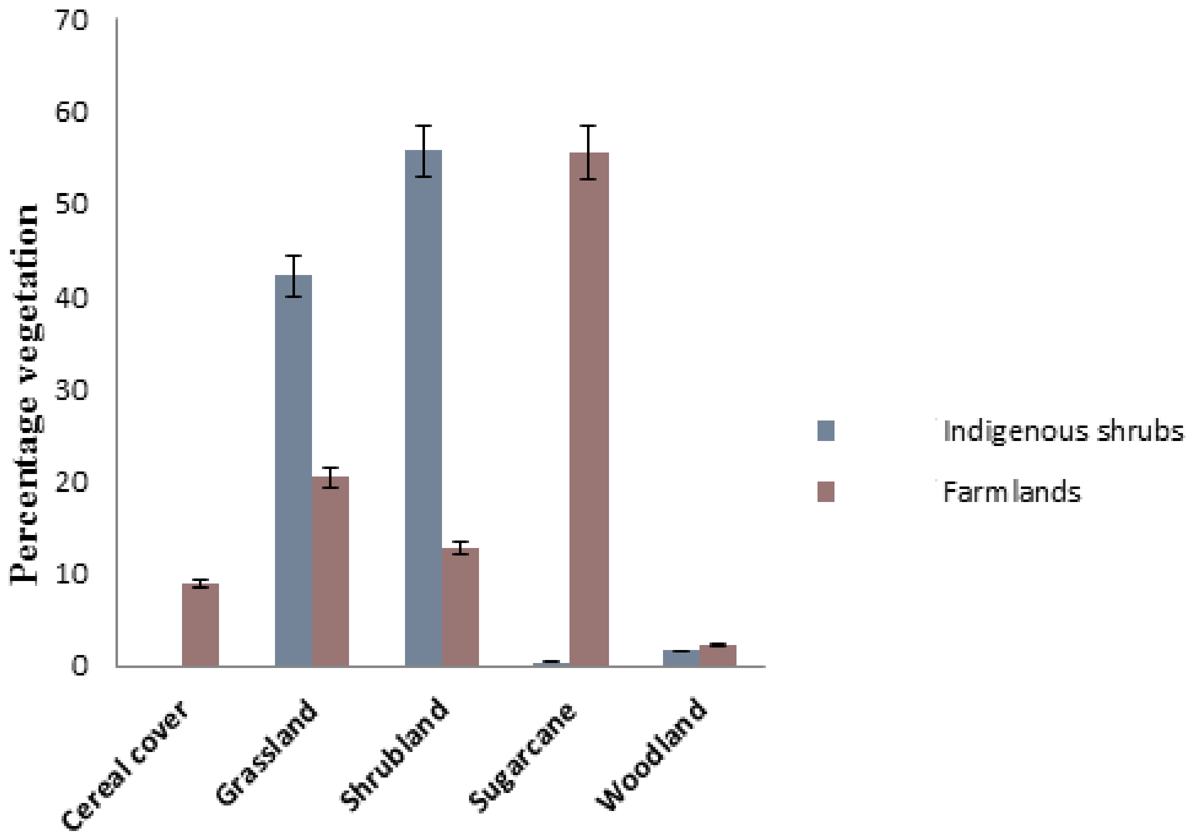

Figure 4.14: Percentage vegetation cover in the study area

There was a significant association on how the farmers used their land (X^2 = 977.96, p <0.05). Each farmer chose to use their farms for their preferred use culminating to five land cover use types (Figure 4.15). Most farmers preferred to grow sugarcane and leave their farms fallow while few farmers chose to have woodlots on their farms and grow cereals. This was based on the percentages per plot of sugarcane, grassland, shrubland, cereals, and woodland.

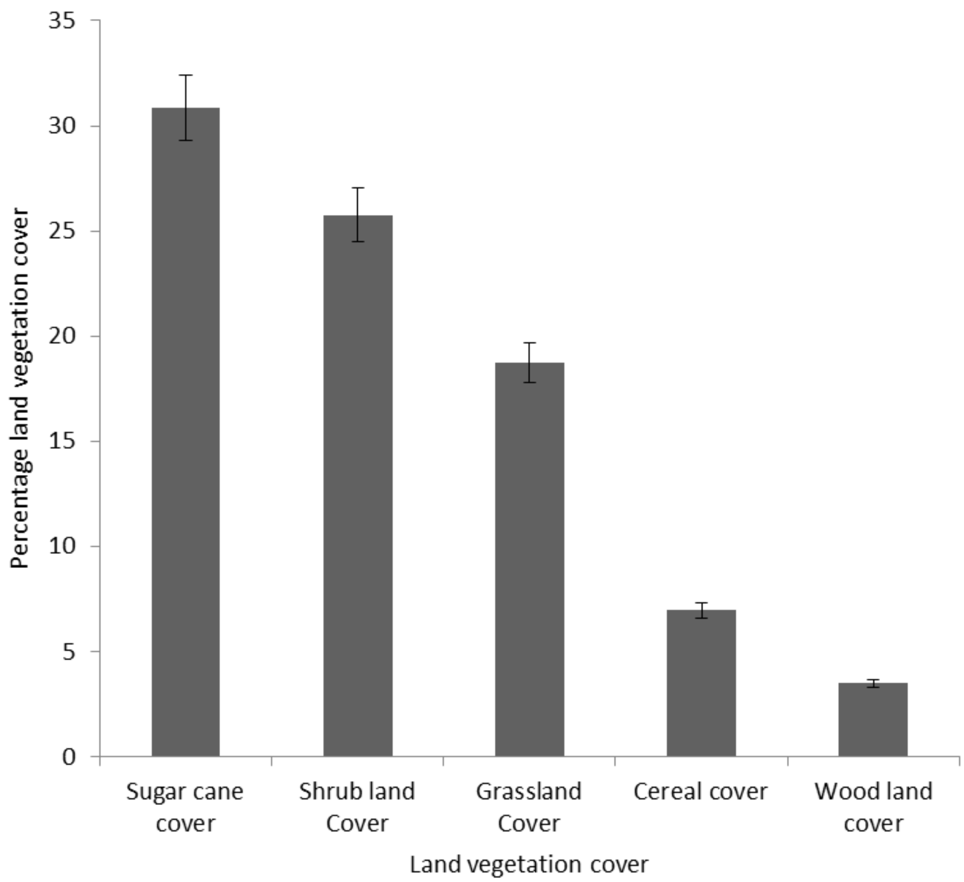

Figure 4.15: Land use patterns in Muhoroni

4.5 Effects of landscape percentage vegetation cover type factors on birds at a local scale

Principal components analysis was used to identify and compute composite scores for the underlying factors. Principal component analysis extracted 3 factors and initial eigen values indicated that the first three factors explained 34%, 25%, and 23% of the variance respectively (Table 4.4). The three factor solution, explained 82 % of the variance, was preferred because of: (a) its previous theoretical support; (b) the ‘leveling off’ of eigen values on the scree plot after three factors; and (c) the insufficient number of primary loadings and difficulty of interpreting the fourth factor and subsequent factors

Principal Component 1 (Principal component hereafter referred to as PC 1) corresponded to the removal of shrubland and sugarcane with the retention of grasslands. PC 2 corresponded with the removal of sugarcane with the retention of shrub lands. PC3 corresponded to removal of all the loaded factors and retention of none. This indicated that the overall bird species diversity per plot was positively affected by the retention of grasslands and shrub lands in a plot (Table 4.4).

Table 4.4: Principal component analysis results on vegetation composition variables

Components Loaded	PC1	PC2	PC3
Grassland	**0.970**	-0.149	
Sugar Cane	**-0.842**	**-0.487**	
Shrub Land		**0.991**	
Wood Land	0.108		
Cereal Cover	**-0.207**	-0.156	
Importance of the components	PC1	PC2	PC3
Standard deviation	1.706	1.266	1.139
Variance (%)	34.113	25.327	22.770
Cumulative (%)	23.11	59.44	82.11

Factor loadings greater than 0.2 are in bold and significant; positive value= retention and negative value= removal

Since the factor loadings extracted (Shrubland and grassland) are not more than two, they could not explain much of the overall variability of the original variables, and therefore could not substitute them. Due to this, the extracted variables were not used as variables in GLMs, but instead GMLs was run on all the original variables.

4.6 Effects of vegetation cover type on abundance of respective foraging guilds

Significant associations between vegetation parameters and abundance of respective foraging guilds were observed. There was a significant negative association between the frugivores with grassland cover and woodland cover. Granivores also showed a significant negative association with shrub land cover. On the contrary, there was a significant positive association between: granivores and sugarcane cover and cereal cover, insectivores and grassland cover, nectarivores with sugarcane and shrubland covers. Carnivores were also significantly associated with woodland cover. The omnivores and molluscivores were not significantly attracted to any of the vegetation variables (Table 4.5).

Table 4.5: Logistic GLMs of the vegetation compositions on feeding Guilds

Parameters	**Abundance According to Foraging Guilds**						
	Carnivore	**Frugivore**	**Granivore**	**Insectivore**	**Molluscivore**	**Nectarivore**	**Omnivore**
Grassland Cover	-0.086	**-0.508****	0.186	**0.363****	0.032	0.087	-0.71
Sugarcane cover	0.167	-0.084	**0.265****	-0.016	0.044	**0.299****	0.25
Shrubland Cover	0.187	-0.86	**-0.283****	-0.108	-0.076	**0.295****	0.001
Woodland cover	**0.48****	**-0.210***	-0.057	0.153	0.009	0.022	0.25
Cereal cover	0.141	-0.86	**0.374****	0.112	0.001	0.065	0.82

Fluctuations in the habitat variables with significance at P < 0.01 & P < 0.05 are printed in bold and asterisked (& * respectively).**

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 Bird species abundance, richness and diversity

Bird abundance, species richness and diversity significantly differed between the farmland dominated and the natural shrubs dominated habitats, being higher. This could be due to the intermediate disturbance hypothesis which states that local species diversity is maximized when ecological disturbance is intermediate because species that blossom at both initial and later successional phases can cohabit; and that at extreme levels of disturbance species have the possibility of being wiped out.

The patterns observed in the study area are due to the fact that the farmland areas in MSC are not intensively cultivated and still leave some non-crop habitat within them, allowing for high level of vegetation structural complexity. The patterns also concur with the findings of Bideberi & Hassan (2002), Chace & Walsh (2006), Sandstrom *et al.* (2005), Issa & JobBAZ (2019) and Asif & Gautam (2014), who observed that human inhabited habitats offer more resources that draw some human tolerant species like the Common Bulbul and the Common Fiscal. This pattern may not always be the same, especially within forest habitats, as demonstrated by Chacha *et al.* (2017) who observed lower bird species abundance in human habitats. Dissimilar patterns were also observed by Somasundaram *et al. (*2019) and Redlich *et al.(* 2018), showing that enrichment of the landscape by expansion of natural habitats and reducing agricultural activities was likely to increase species diversity.

The higher bird abundance in the agricultural farmlands could also be attributed to the occurrence in large numbers of a few of the bird species that have a preference for human-modified landscapes, such as some of the granivores (e.g. Bronze Mannikinn (*Spermestes cucullatus*), House Sparrow (*Passer domesticus*) and the Grey-headed

Sparrow (*Passer griseus*).) and some generalist species such as the Common Bulbul (*Pycnonotus barbatus*) (Bideberi & Hassan, 2002).

Despite the overall higher bird abundance in the farmlands, there are some particular species that were significantly more abundant in the natural shrubs than in the agricultural farmlands, e.g. the Little Swift. This could be due to the species' association with habitat openness offering aerial foraging opportunities for insects sustained by the shrubs. The natural shrubs could be delivering food and other important resources for particular species of birds (Askins *et al.*, 2012).

According to Hobson *et al.* (2003), the high species diversity exhibited by agricultural farmlands is due to accessibility to breeding sites, food, water, breeding material and cover from predators. This could be the case in Muhoroni Sub-County as well. On the other hand, the lower bird diversity observed in the natural shrubs than in the agricultural farmland was perhaps due to low percentage of vegetation cover types and extreme degradation of the natural shrubs particularly from fires (Fahrig *et al.*, 2010).

Species richness is the number of species, without taking into account the abundances of the species or their relative abundance distributions (Colwell & Robert, 2009). Observed species richness is not only affected by the number of individuals, but also by the heterogeneity of a sample (Colwell & Robert, 2009). In this study bird species richness was higher in the agricultural farmland as compared to the indigenous shrubs. This was probably the case due to the high vegetation cover type heterogeneity in the agricultural farmlands that were composed of shrubs, grassland, woodland, cereal crops and sugarcane that deliver important bird resources such as food, breeding sites and nesting materials. This is in concurrence with the observation that species richness is high if the species are derived from dissimilar habitats, than if all species are drawn from related habitats (Scheiner, 2003). In fact the structure of bird community is greatly shaped by the composition and configuration of its habitat (Laube *et al.*, 2008).

Jones *et al.* (2005) and in consistent with this results observed that bird populations and community structure respond in a different way to the distribution of vegetation and juxtaposition of agricultural landscape elements in agroecosystems, thus the creation of suitable bird habitats within agricultural landscapes may help in the conservation of many bird species (Jones, 2005).

Decline in bird species richness by reason of extreme human interference has been reflected in the tropical regions (Cordeiro, 2005), and undoubtedly in the natural shrubs of Muhoroni Sub-County. In this habitat the percentage vegetation cover type was not high as projected. For example woody plants comprised a surprising 1.6%. This could be due to the unsustainable exploitation for charcoal and firewood. This dilapidation seems to reduce the important resources required by some birds. Grass burning as a pasture management procedure was observed in the indigenous shrubs. This could also explain the low species richness as compared to the farmlands. This finding is consistent with Simberloff and Dayan (1991) that the major effect of habitat degradation is a decrease of bird population size and increased vulnerability to extinction.

The natural shrub habitat was less vegetatively covered in terms of heterogeneity. This could justify why fewer species (61) were recorded in the natural shrubs than in the farmlands. This is coherent with Mulwa *et al.* (2012) and Ndang'ang'a *et al.* (2013) who demonstrated that vegetatively heterogeneous habitats in Kenya's farmlands support a surprisingly high diversity of birds and therefore contributed substantially to the overall landscape biodiversity. Somasundaram *et al.* (2019) observed that birds are likely to be more diverse in 100 % natural forests, a case that findings in this study dispute.

According to Vickey and Arlettaz (2012), birds require access to a wide variety of resources over spatial and temporal gradients (Vickery & Arlettaz, 2012). They noticed that this is more likely to be delivered by a heterogeneous rather than a homogenous landscape (Vickery & Arlettaz, 2012). This is consistent with this study as more birds were seen and heard in agricultural farmlands.

In the natural shrubs, vegetation structure has been simplified due to intense human activities like charcoal burning, cattle grazing, mining and pasture burning. Tscharntke *et al.* (2005) recommended avoidance of habitat simplification as a measure of conserving biodiversity by preserving important ecosystem services.

5.2 Bird species of conservation interest

Bennun and Njoroge (1996) noted that some bird species have intrinsic conservation interest for the reason that they are endangered, threatened, vulnerable, rare, or endemic. In MSC, the Fischer's Lovebird (*Agapornis fischeri*) was recorded as near threatened, Grey crowned cranes (*Balearica regulorum*) as vulnerable, Steppe Eagle (*Aquila nepalensis*) as endangered and the Speckled Mousebird (*Colius striatus*) as endemic. This could be due to bird habitat loss which concurs with IUCN that habitat loss due to growth of human activities such as urbanization, settlement and agricultural activities is the main threat facing 85% of all bird species described in the IUCN Red List. Despite the fact that human activities have allowed the expansion of a few species, they have caused population reductions and extinction of many other bird species. Worldwide, many bird species are declining, with 1,227 species listed as threatened by BirdLife International and the IUCN (2009).

Twenty one (21) of the 122 species observed in Muhoroni Sub-County were biome-characteristic species. There was 12 Palearctic migrants (10%), 6 Afrotropical migrants (5%), 3 both Afrotropical and Palearctic migrants (2%) and the rest (101 species) were Residents comprising (83%) of the total number of bird species observed. This indicates that MSC is ecologically significant to some migratory birds because if they were to be conserved in one area, that can lead to their extinction. The presence of migratory birds could be attributed to this study coinciding with the time (October) migrant species are recorded in Kenya. These results concur with the findings by Zimmerman *et al.* (1996).

5.3 Forest dependency of birds

In Muhoroni Sub-County 6 birds (5%) were forest generalists (F), 40 birds (33%) forest visitors (f) while 76 birds (62 %) were non-forest birds. As the forest habitat becomes increasingly threatened, the birds they host are attracting enormous attention. According to Bennun (1996), studies on forest birds are worthwhile for at least two whys and wherefores (Bennun & Njoroge, 1996). First of all, the composition and richness of forest birds can signify its overall value for the conservation of biodiversity (Thirgood & Heath, 1994). Secondly, habitat modification and its impacts and more hardly restoration can be gauged by censoring bird communities (Furness and Greenwood, 1993).

Conservationists need supplementary guidelines as to the significance of particular species of birds in indicating forest status and value. The 0 % of 'forest specialists' (FF) is an indicator that forests in Muhoroni have been modified to the extent that they cannot support forest specialists. The Forest generalists (F), occur in undisturbed forest and in forest edges, strips, gaps or in modified and fragmented forests. However, forest generalists continue to depend upon forests for some of their resources, such as nesting sites (Bennun & Njoroge, 1999). The presence of these species in the study area is attributed to the live fences composed of woody plants and scattered trees that provide breeding sites for the birds. There were more forest generalist birds in the farmland compared to the indigenous shrubs. This is because farmlands had a higher percentage of woodland cover.

Forest visitors (f species) comprised of 33% of all the birds observed. Bennun (1999) defines them as those birds which are often recorded in the forest, but are not fully dependent upon it (Bennun & Njoroge, 1999). They can certainly survive in habitats where the forest has completely become extinct (Bennun & Njoroge, 1996). The presence of these species in Muhoroni is an indication of forest deterioration.

5.4 Influence of vegetation cover types on abundance of respective foraging guilds

There were clear distinctions in the composition of bird species of some foraging guilds and the occurrence of some common species between the natural shrubs and agricultural farmlands. The agricultural farmlands were more vegetatively heterogeneous in terms of percentage cover as compared to the natural shrubs. This explicates why agricultural farmlands hosted a higher number of species together with frugivores that are known to be reliant on secluded fruiting trees in agricultural farmlands. This concurs with Tscharntke *et al.* (2008). This also concurs with Oyondi & Muya (2017) who observed that the composition of birds is low when sampled from one cover type only.

The positive effect of grassland cover on insectivore abundance could be attributed to the fact that grasslands tend to host many grassland specialist birds most of which are insectivores, spending time foraging for invertebrates on the ground or sallying for them in the air. These include species found in families such as larks, pipits, longclaws, swallows, and shrikes among others. The strong positive effect of cereal and sugarcane cover on granivores could be attributed to increasing food (seed) resources associated with these cover types. Substantial amounts of weed seeds are held in cultivations and fallow, providing food especially for seedeaters, canaries, doves, sparrows and weavers (Ndang'ang'a *et al.*, 2013). They are also a source of seeds form crops commonly grown in the area, e.g. maize, sorghum etc. Shrub cover does not provide such resources and there have a negative influence on granivores abundance. Nectarivore abundance was positively influenced by shrubs cover, possibly due to the foraging and nesting opportunities provided by the shrubs in form of nectar from flowers and cover for nesting. Grassland cover reduces chances of there being fruiting trees that can be utilized for food by frugivores, thereby negatively influencing their abundance, whereas increased woodland cover is likely to offer nesting, perching and cover resources for carnivorous birds (raptors) thus positively influencing their abundance.

Agricultural farmlands recorded a higher density of insectivores and granivores whereas the natural shrubs recorded a higher percentage of nectarivores. This coincides with Tscharntke that insectivores and granivores prefer exposed habitats and their richness decline with tree cover upsurge (Tscharntke *et al.*, 2008). The higher % of nectarivores in the natural shrub habitats could be as a consequence of a higher % of flower producing plant species which fed nectar to the birds.

The high percentage of granivores in the agricultural farmlands (14%) compared to natural shrubs (8%) could be ascribed to increasing seeds as food sources. In cultivated habitats cereal crops, particular weeds and wild plants produce seeds that provide abundant food for seed eaters, doves, sparrows, weavers and carnivores. Maclean (1970) remarked that seed production is seasonal leading to the scarcity of seeds at certain times of the year. This could clarify why fewer granivores were encountered during some months.

In Muhoroni Sub County, insectivores dominated the foraging guild at 53%. This observation is perhaps caused by the presence of significant proportion of grasses and grass-like vegetation in both habitats that host a variety of insects that are eaten by these birds. This outcome is consistent with the conclusion by Murray *et al.* (2008).

5.5 Conclusion

- The following conclusions were drawn from this research:
- There was significantly higher bird species abundance, richness and diversity in the farmland dominated habitats as compared to natural shrubs dominated. This could be explained by the Intermediate Disturbance Hypothesis.
- Vegetation cover types were more heterogenous in the agricultural farmlands than in the natural shrubs.
- The carnivores, frugivores, insectivores and nectarivores were significantly influenced by different vegetation cover types.

- Different vegetation types had no influence on omnivore and molluscivore bird species.
- Increased farmland cover, especially of sugarcane and cereals seemed to favour increased abundance of granivorous species due to their potential for availing abundant food (seed) resources.
- Some bird species were habitat specific e.g the Eastern grey plantain eater, African jacana, White faced whistling duck and the African green pigeon.
- Human undertakings that moderately recuperate the heterogeneity of the habitat tend to attract more birds as contrasted to extremely disturbed natural habitats and therefore, studies relating to the conservation of bird species in the agricultural farmland need to be prioritized and apportioned more resources.

5.6 Recommendations

5.6.1 Recommendations for adoption from this research

- The retention of farmland vegetation covers heterogeneity through discouraging of large homogenous plantations in favour of a mix of small crop and non-crop vegetation fields and/or field margins. This will help avail more resources to the farmland birds.
- Planting of more Spermatophyte plants within the farmlands to increase the abundance of frugivores and nectarivores whose density was low.
- Use of the check list compiled from this work to sensitize the local community on the different bird species in Muhoroni, the importance of conserving birds, and how they can economically benefit them.

5.6.2 Recommendations for further studies

- Similar studies for other non-avian taxa, especially those that have economic importance for agriculture, for example invertebrates and small mammals, to elucidate general patterns that may guide management of vegetation cover in MSC and beyond.

- Further research on the habitat preference of different species, breeding biology and effect to agricultural crops. This will help in formulation of an integrated program that will safeguard the affected crops without compromising bird conservation.
- Further research on the red listed species of Muhoroni Sub-County (a list provided in this work) to help come up with recommendations on their conservation.

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APPENDICES

Appendix I: A list of bird species observed in Muhoroni

Family	Common Name	*Scientific Name*	Migration	IUCN Red List Status
Accipitridae	African Black-shouldered Kite	*Elanus caeruleus*	R	LC
Accipitridae	Black Kite	*Milvus migrans*	am, pm,	LC
Accipitridae	Common Buzzard	*Buteo buteo*	PM	LC
Accipitridae	Palm-nut Vulture	*Gypohierax angolensis*	R	LC
Accipitridae	Steppe Eagle	*Aquila nepalensis*	PM	EN
Accipitridae	Wahlberg's Eagle	*Aquila wahlbergi*	am	LC
Accipitridae	Western Banded Snake Eagle	*Circaetus cinerascens*	R	LC
Accipitridae	Western Marsh Harrier	*Circus aeruginosus*	PM	LC
Acciptridae	African Harrier Hawk	*Polyboroides typus*	R	LC
Turdidae	African Thrush	*Turdus pelios*	R	LC
Alaudidae	Fawn-coloured Lark	*Mirafra africanoides*	R	LC
Alaudidae	Flappet Lark	*Mirafra rufocinnamomea*	R	LC
Motacillidae	African Pied Wagtail	*Motacilla aguimp*	R	LC
Alcedinidae	Malachite Kingfisher	*Alcedo cristata*	R	LC
Alcedinidae	Woodland Kingfisher	*Halcyon senegalensis*	R	LC
Anatidae	White-faced Whistling Duck	*Dendrocygna viduata*	R	LC
Apodidae	African Palm Swift	*Cypsiurus parvus*	R	LC
Ardeidae	Black-headed Heron	*Ardea melanocephala*	R	LC
Ardeidae	Grey Heron	*Ardea cinerea*	am, pm	LC
Ardeidae	Little Egret	*Egretta garzetta*	R	LC
Ardeidae	Striated Heron	*Butorides striata*	R	LC
Campephagidae	Black Cuckooshrike	*Campephaga flava*	am	LC
Estrildidae	Bronze Mannikin	*Spermestes cucculatus*	R	LC
Ardeidae	Cattle Egret	*Bubulcus ibis*	AM	LC
Capitonidae	Double-toothed Barbet	*Lybius bidentatus*	R	LC
Capitonidae	Spot-flanked Barbet	*Tricholaema lacrymosa*	R	LC
Charadriidae	African Wattled Plover	*Vanellus senegallus*	R	LC
Charadriidae	Spur-winged Plover	*Vanellus spinosus*	R	LC
Ciconiidae	Marabou Stork	*Leptoptilos crumeniferus*	R	LC
Sylviidae	Green-backed Eremomela	*Eremomela canescens*	R	LC
Cisticolidae	Grey-backed Camaroptera	*Camaroptera brachyura*	R	LC

Cisticolidae	Red-faced Cisticola	*Cisticola erythrops*	R	LC
Cisticolidae	Tawny-flanked Prinia	*Prinia subflava*	R	LC
Cisticolidae	Winding Cisticola	*Cisticola galactotes*	R	LC
Coliidae	Blue-naped Mousebird	*Urocolius macrourus*	R	LC
Coliidae	Speckled Mousebird	*Colius striatus*	R	LC
Columbidae	African Green Pigeon	*Treron calvus*	R	LC
Columbidae	Blue-spotted Wood Dove	*Turtur afer*	R	LC
Columbidae	Red-eyed Dove	*Streptopelia semitorquata*	R	LC
Columbidae	Ring-necked Dove	*Streptopelia capicola*	R	LC
Columbidae	Speckled Pigeon	*Columba guinea*	R	LC
Coraciidae	Lilac-breasted Roller	*Coracias caudatus*	am	LC
Corvidae	Pied Crow	*Corvus albus*	R	LC
Malaconotidae	Black-crowned Tchagra	*Tchagra senegalus*	R	LC
Cuculidae	Common Cuckoo	*Cuculus canorus*	PM	LC
Cuculidae	Jacobin Cuckoo	*Clamator jacobinus*	am, pm,	LC
Cuculidae	Klaas's Cuckoo	*Chrysococcyx klaas*	R	LC
Cuculidae	White-browed Coucal	*Centropus superciliosus*	R	LC
Dicruridae	Common Drongo	*Dicrurus adsimilis*	R	LC
Estrildidae	African Firefinch	*Lagonosticta rubricata*	R	LC
Estrildidae	Red-billed Firefinch	*Lagonosticta senegala*	R	LC
Estrildidae	Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	R	LC
Fringillidae	Oriole Finch	*Linurgus olivaceus*	R	LC
Fringillidae	Yellow-fronted Canary	*Crithagra mozambica*	R	LC
Hirundinidae	Black Saw-wing	*Psalidoprocne pristoptera*	R	LC
Hirundinidae	Lesser Striped Swallow	*Cecropis abyssinica*	R	LC
Hirundinidae	Mosque Swallow	*Cecropis senegalensis*	R	LC
Hirundinidae	Red-rumped Swallow	*Cecropis daurica*	R	LC
Hirundinidae	Wire-tailed Swallow	*Hirundo smithii*	R	LC
Indicatoridae	Lesser Honeyguide	*Indicator minor*	R	LC
Jacanidae	African Jacana	*Actophilornis africanus*	R	LC
Laniidae	Common Fiscal	*Lanius collaris*	R	LC
Leiothrichidae	Arrow-marked Babbler	*Turdoides jardineii*	R	LC
Lybiidae	Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	R	LC
Macrosphenidae	Moustached Grass Warbler	*Melocichla mentalis*	R	LC
Malaconotidae	Black-headed Gonolek	*Laniarius erythrogaster*	R	LC
Malaconotidae	Tropical Boubou	*Laniarius aethopicus*	R	LC
Nectariniidae	Bronze Sunbird	*Nectarinia kilimensis*	R	LC
Meropidae	Eurasian Bee-eater	*Merops apiaster*	PM	LC
Apodidae	Little Swift	*Apus affinis*	R	LC

Meropidae	White-throated Bee-eater	*Merops albicollis*	AM	LC
Motacillidae	Tree Pipit	*Anthus trivialis*	PM	LC
Motacillidae	Yellow Wagtail	*Motacilla flava*	PM	LC
Motacillidae	Yellow-throated Longclaw	*Macronyx croceus*	R	LC
Monarchidae	African Blue Flycatcher	*Elminia longicauda*	R	LC
Muscicapidae	African Paradise Flycatcher	*Terpsiphone viridis*	am	LC
Muscicapidae	Northern Black Flycatcher	*Melaenornis edolioides*	R	LC
Muscicapidae	Spotted Flycatcher	*Muscicapa striata*	PM	LC
Muscicapidae	Swamp Flycatcher	*Muscicapa aquatica*	R	LC
Muscicapidae	White-browed Scrub Robin	*Cercotrichas leucophrys*	R	LC
Musophagidae	Eastern Grey Plantain-eater	*Crinifer zonurus*	R	LC
Gruidae	Grey Crowned Crane	*Balearica regulorum*	R	V
Musophagidae	Ross's Turaco	*Musophaga rossae*	R	LC
Nectariniidae	Green-headed Sunbird	*Cyanomitra verticalis*	R	LC
Nectariniidae	Purple-banded Sunbird	*Cinnyris bifasciatus*	R	LC
Nectariniidae	Scarlet-chested Sunbird	*Chalcomitra senegalensis*	R	LC
Nectariniidae	Variable Sunbird	*Cinnyris venustus*	R	LC
Numididae	Helmeted Guineafowl	*Numida meleagris*	R	LC
Hirundinidae	Barn Swallow	*Hirundo rustica*	PM	LC
Oriolidae	Black-headed Oriole	*Oriolus larvatus*	R	LC
Accipitridae	Great Sparrowhawk	*Accipiter melanoleucus*	R	LC
Passeridae	Grey-headed Sparrow	*Passer griseus*	R	LC
Passeridae	House Sparrow	*Passer domesticus*	R	LC
Picidae	Cardinal Woodpecker	*Dendropicos fuscescens*	R	LC
Picidae	Nubian Woodpecker	*Campethera nubica*	R	LC
Picidae	Red-throated Wryneck	*Jynx ruficollis*	R	LC
Platysteiridae	Black-headed Batis	*Batis minor*	R	LC
Platysteiridae	Brown-throated Wattle-eye	*Platysteira cyanea*	R	LC
Ploceidae	Compact Weaver	*Ploceus superciliosus*	R	LC
Ploceidae	Fan-tailed Widowbird	*Euplectes axillaris*	R	LC
Ploceidae	Holub's Golden Weaver	*Ploceus xanthops*	R	LC
Ploceidae	Red-headed Weaver	*Anaplectes melanotis*	R	LC
Ploceidae	Spectacled Weaver	*Ploceus ocularis*	R	LC
Ploceidae	Village Weaver	*Ploceus cucullatus*	R	LC
Ploceidae	Yellow-backed Weaver	*Ploceus melanocephalus*	R	LC
Psittacidae	Fischer's Lovebird	*Agapornis fischeri*	R	NT
Psittacidae	Meyer's Parrot	*Poicephalus meyeri*	R	LC

Pycnonotidae	Common Bulbul	*Pycnonotus barbatus*	R	LC
Pycnonotidae	Yellow-throated Leaflove	*Chlorocichla flavicollis*	R	LC
Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	PM	LC
Scolopacidae	Green Sandpiper	*Tringa ochropus*	PM	LC
Sturnidae	Greater Blue-eared Starling	*Lamprotornis chalybaeus*	R	LC
Sturnidae	Red-billed Oxpecker	*Buphagus erythrorhynchus*	R	LC
Sturnidae	Rüppell's Starling	*Lamprotornis purpuroptera*	R	LC
Sturnidae	Superb Starling	*Lamprotornis superbus*	R	LC
Threskiornithidae	Hadada Ibis	*Bostrychia hagedash*	R	LC
Threskiornithidae	Sacred Ibis	*Threskiornis aethiopicus*	R	LC
Timaliidae	Black-lored Babbler	*Turdoides sharpei*	R	LC
Muscicapidae	Whinchat	*Saxicola rubetra*	PM	LC
Muscicapidae	White-browed Robin Chat	*Cossypha heuglini*	R	LC
Viduidae	Pin-tailed Whydah	*Vidua macroura*	R	LC

Legend: NT = Globally Near threatened; V=Vulnerable; LC=Least concern; am = Afrotropical migrant; pm = Palearctic migrant; R=Resident

Appendix II: Bird species recorded in the two study areas showing forest category

Common Name	*Scientific Name*	Forest dependency
African Black-shouldered Kite	*Elanus caeruleus*	Non f
African Blue Flycatcher	*Elminia longicauda*	F
African Firefinch	*Lagonosticta rubricata*	Non f
African Green Pigeon	*Treron calvus*	F
African Harrier Hawk	*Polyboroides typus*	F
African Jacana	*Actophilornis africanus*	Non f
African Palm Swift	*Cypsiurus parvus*	Non f
African Paradise Flycatcher	*Terpsiphone viridis*	F
African Pied Wagtail	*Motacilla aguimp*	Non f
African Thrush	*Turdus pelios*	F
African Wattled Plover	*Vanellus senegallus*	Non f
Arrow-marked Babbler	*Turdoides jardineii*	Non f
Barn Swallow	*Hirundo rustica*	Non f
Black Cuckooshrike	*Campephaga flava*	F
Black Kite	*Milvus migrans*	Non f
Black Saw-wing	*Psalidoprocne pristoptera*	F
Black-crowned Tchagra	*Tchagra senegalus*	Non f
Black-headed Batis	*Batis minor*	Non f
Black-headed Gonolek	*Laniarius erythrogaster*	Non f
Black-headed Heron	*Ardea melanocephala*	Non f
Black-headed Oriole	*Oriolus larvatus*	F
Black-lored Babbler	*Turdoides sharpei*	Non f
Blue-naped Mousebird	*Urocolius macrourus*	Non f
Blue-spotted Wood Dove	*Turtur afer*	F
Bronze Mannikin	*Spermestes cucculatus*	Non f
Bronze Sunbird	*Nectarinia kilimensis*	F
Brown-throated Wattle-eye	*Platysteira cyanea*	F
Cardinal Woodpecker	*Dendropicos fuscescens*	F
Cattle Egret	*Bubulcus ibis*	Non f
Common Bulbul	*Pycnonotus barbatus*	F
Common Buzzard	*Buteo buteo*	Non f
Common Cuckoo	*Cuculus canorus*	Non f

Common Drongo	*Dicrurus adsimilis*	Non f
Common Fiscal	*Lanius collaris*	Non f
Common Sandpiper	*Actitis hypoleucos*	Non f
Compact Weaver	*Ploceus superciliosus*	F
Double-toothed Barbet	*Lybius bidentatus*	F
Eastern Grey Plantain-eater	*Crinifer zonurus*	Non f
Eurasian Bee-eater	*Merops apiaster*	F
Fan-tailed Widowbird	*Euplectes axillaris*	Non f
Fawn-coloured Lark	*Mirafra africanoides*	Non f
Fischer's Lovebird	*Agapornis fischeri*	Non f
Flappet Lark	*Mirafra rufocinnamomea*	Non f
Great Sparrowhawk	*Accipiter melanoleucus*	F
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	Non f
Green Sandpiper	*Tringa ochropus*	Non f
Green-backed Eremomela	*Eremomela canescens*	Non f
Green-headed Sunbird	*Cyanomitra verticalis*	F
Grey Crowned Crane	*Balearica regulorum*	Non f
Grey Heron	*Ardea cinerea*	Non f
Grey-backed Camaroptera	*Camaroptera brachyura*	F
Grey-headed Sparrow	*Passer griseus*	Non f
Hadada Ibis	*Bostrychia hagedash*	Non f
Helmeted Guineafowl	*Numida meleagris*	Non f
Holub's Golden Weaver	*Ploceus xanthops*	Non f
House Sparrow	*Passer domesticus*	Non f
Jacobin Cuckoo	*Clamator jacobinus*	Non f
Klaas's Cuckoo	*Chrysococcyx klaas*	F
Lesser Honeyguide	*Indicator minor*	F
Lesser Striped Swallow	*Cecropis abyssinica*	Non f
Lilac-breasted Roller	*Coracias caudatus*	F
Little Egret	*Egretta garzetta*	non f
Little Swift	*Apus affinis*	Non f
Malachite Kingfisher	*Alcedo cristata*	Non f
Marabou Stork	*Leptoptilos crumeniferus*	Non f
Meyer's Parrot	*Poicephalus meyeri*	Non f
Mosque Swallow	*Cecropis senegalensis*	Non f
Moustached Grass Warbler	*Melocichla mentalis*	Non f

Northern Black Flycatcher	*Melaenornis edolioides*	Non f
Nubian Woodpecker	*Campethera nubica*	Non f
Oriole Finch	*Linurgus olivaceus*	F
Palm-nut Vulture	*Gypohierax angolensis*	Non f
Pied Crow	*Corvus albus*	Non f
Pin-tailed Whydah	*Vidua macroura*	Non f
Purple-banded Sunbird	*Cinnyris bifasciatus*	F
Red-billed Firefinch	*Lagonosticta senegala*	Non f
Red-billed Oxpecker	*Buphagus erythrorhynchus*	Non f
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	Non f
Red-eyed Dove	*Streptopelia semitorquata*	F
Red-faced Cisticola	*Cisticola erythrops*	Non f
Red-headed Weaver	*Anaplectes melanotis*	F
Red-rumped Swallow	*Cecropis daurica*	Non f
Red-throated Wryneck	*Jynx ruficollis*	F
Ring-necked Dove	*Streptopelia capicola*	F
Ross's Turaco	*Musophaga rossae*	F
Rüppell's Starling	*Lamprotornis purpuroptera*	F
Sacred Ibis	*Threskiornis aethiopicus*	Non f
Scarlet-chested Sunbird	*Chalcomitra senegalensis*	Non f
Speckled Mousebird	*Colius striatus*	Non f
Speckled Pigeon	*Columba guinea*	Non f
Spectacled Weaver	*Ploceus ocularis*	Non f
Spot-flanked Barbet	*Tricholaema lacrymosa*	Non f
Spotted Flycatcher	*Muscicapa striata*	Non f
Spur-winged Plover	*Vanellus spinosus*	Non f
Steppe Eagle	*Aquila nepalensis*	Non f
Striated Heron	*Butorides striata*	Non f
Superb Starling	*Lamprotornis superbus*	Non f
Swamp Flycatcher	*Muscicapa aquatica*	F
Tawny-flanked Prinia	*Prinia subflava*	F
Tree Pipit	*Anthus trivialis*	F
Tropical Boubou	*Laniarius aethopicus*	F
Variable Sunbird	*Cinnyris venustus*	F
Village Weaver	*Ploceus cucullatus*	Non f
Wahlberg's Eagle	*Aquila wahlbergi*	Non f

Western Banded Snake Eagle	*Circaetus cinerascens*	F
Western Marsh Harrier	*Circus aeruginosus*	Non f
Whinchat	*Saxicola rubetra*	F
White-browed Coucal	*Centropus superciliosus*	Non f
White-browed Robin Chat	*Cossypha heuglini*	F
White-browed Scrub Robin	*Cercotrichas leucophrys*	Non f
White-faced Whistling Duck	*Dendrocygna viduata*	Non f
White-throated Bee-eater	*Merops albicollis*	Non f
Winding Cisticola	*Cisticola galactotes*	Non f
Wire-tailed Swallow	*Hirundo smithii*	Non f
Woodland Kingfisher	*Halcyon senegalensis*	Non f
Yellow Wagtail	*Motacilla flava*	Non f
Yellow-backed Weaver	*Ploceus melanocephalus*	Non f
Yellow-fronted Canary	*Crithagra mozambica*	F
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	Non f
Yellow-throated Leaflove	*Chlorocichla flavicollis*	F
Yellow-throated Longclaw	*Macronyx croceus*	Non f

Legend: **FF**-Forest Specialist, **F**-Forest generalist, **f**-Forest visitor, **Non f**-Non forest bird.

Appendix III: Bird species recorded in the Agricultural farmland showing foraging guilds

Common Name	***Scientific Name***	**Feeding Guild**
Red-eyed Dove	*Streptopelia semitorquata*	Frugivore
Rüppell's Starling	*Lamprotornis purpuroptera*	Insectivore
Black-headed Gonolek	*Laniarius erythrogaster*	Granivore
Speckled Mousebird	*Colius striatus*	Frugivore
Sacred Ibis	*Threskiornis aethiopicus*	Omnivore
Cattle Egret	*Bubulcus ibis*	Insectivore
Black Kite	*Milvus migrans*	Raptor
Wire-tailed Swallow	*Hirundo smithii*	Insectivore
African Pied Wagtail	*Motacilla aguimp*	Insectivore
African Thrush	*Turdus pelios*	Insectivore
Red-billed Firefinch	*Lagonosticta senegala*	Granivore
Common Bulbul	*Pycnonotus barbatus*	Frugivore
Bronze Sunbird	*Nectarinia kilimensis*	Nectarinivore
Eurasian Bee-eater	*Merops apiaster*	Insectivore
Common Fiscal	*Lanius collaris*	Insectivore
Fan-tailed Widowbird	*Euplectes axillaris*	Granivore
Hadada Ibis	*Bostrychia hagedash*	Molluscivore
Yellow Wagtail	*Motacilla flava*	Granivore
Yellow-throated Longclaw	*Macronyx croceus*	Insectivore
Red-rumped Swallow	*Cecropis daurica*	Insectivore
African Paradise Flycatcher	*Terpsiphone viridis*	Insectivore
Grey-backed Camaroptera	*Camaroptera brachyura*	Nectarinivore
Lesser Striped Swallow	*Cecropis abyssinica*	Insectivore
Little Swift	*Apus affinis*	Insectivore
Whinchat	*Saxicola rubetra*	Insectivore
White-browed Coucal	*Centropus superciliosus*	Insectivore
Barn Swallow	*Hirundo rustica*	Insectivore
Compact Weaver	*Ploceus superciliosus*	Granivore
African Wattled Plover	*Vanellus senegallus*	Insectivore
Winding Cisticola	*Cisticola galactotes*	Insectivore
Black-headed Heron	*Ardea melanocephala*	Insectivore

Pin-tailed Whydah	*Vidua macroura*	Granivore
White-browed Robin Chat	*Cossypha heuglini*	Insectivore
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	Raptor
Great Sparrowhawk	*Accipiter melanoleucus*	Frugivore
Black-headed Oriole	*Oriolus larvatus*	Frugivore
Grey-headed Sparrow	*Passer griseus*	Granivore
Northern Black Flycatcher	*Melaenornis edolioides*	Insectivore
Blue-spotted Wood Dove	*Turtur afer*	Frugivore
White-throated Bee-eater	*Merops albicollis*	Insectivore
Helmeted Guineafowl	*Numida meleagris*	Omnivore
Grey Crowned Crane	*Balearica regulorum*	Molluscivore
Variable Sunbird	*Cinnyris venustus*	Granivore
Blue-naped Mousebird	*Urocolius macrourus*	Frugivore
Bronze Mannikin	*Spermestes cucculatus*	Granivore
Village Weaver	*Ploceus cucullatus*	Granivore
Superb Starling	*Lamprotornis superbus*	Insectivore
Marabou Stork	*Leptoptilos crumeniferus*	Raptor
Pied Crow	*Corvus albus*	Omnivore
House Sparrow	*Passer domesticus*	Granivore
Western Marsh Harrier	*Circus aeruginosus*	Insectivore
White-faced Whistling Duck	*Dendrocygna viduata*	Insectivore
Common Cuckoo	*Cuculus canorus*	Insectivore
Swamp Flycatcher	*Muscicapa aquatica*	Insectivore
Common Sandpiper	*Actitis hypoleucos*	Insectivore
African Jacana	*Actophilornis africanus*	Insectivore
Holub's Golden Weaver	*Ploceus xanthops*	Granivore
Yellow-backed Weaver	*Ploceus melanocephalus*	Granivore
Grey Heron	*Ardea cinerea*	Raptor
Green Sandpiper	*Tringa ochropus*	Insectivore
African Blue Flycatcher	*Elminia longicauda*	Insectivore
Woodland Kingfisher	*Halcyon senegalensis*	Insectivore
Double-toothed Barbet	*Lybius bidentatus*	Frugivore
Palm-nut Vulture	*Gypohierax angolensis*	Frugivore
Purple-banded Sunbird	*Cinnyris bifasciatus*	Nectarinivore
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*	Granivore
African Green Pigeon	*Treron calvus*	Frugivore

Yellow-throated Leaflove	*Chlorocichla flavicollis*	Insectivore
Spectacled Weaver	*Ploceus ocularis*	Insectivore
Jacobin Cuckoo	*Clamator jacobinus*	Insectivore
Striated Heron	*Butorides striata*	Raptor
Malachite Kingfisher	*Alcedo cristata*	Omnivore
Black-lored Babbler	*Turdoides sharpei*	Insectivore
African Palm Swift	*Cypsiurus parvus*	Insectivore
Black Cuckooshrike	*Campephaga flava*	Insectivore
Red-faced Cisticola	*Cisticola erythrops*	Insectivore
African Firefinch	*Lagonosticta rubricata*	Insectivore
Cardinal Woodpecker	*Dendropicos fuscescens*	Insectivore
Spur-winged Plover	*Vanellus spinosus*	Insectivore
Fawn-coloured Lark	*Mirafra africanoides*	Insectivore
Brown-throated Wattle-eye	*Platysteira cyanea*	Insectivore
Yellow-fronted Canary	*Crithagra mozambica*	Insectivore
Little Egret	*Egretta garzetta*	Raptor
Spotted Flycatcher	*Muscicapa striata*	Insectivore
Western Banded Snake Eagle	*Circaetus cinerascens*	Raptor

Appendix IV: Bird species recorded in the Indigenous shrubs showing their foraging guild

Common Name	***Scientific Name***	Feeding Guild
Red-eyed Dove	*Streptopelia semitorquata*	Frugivore
Speckled Mousebird	*Colius striatus*	Frugivore
African Thrush	*Turdus pelios*	Insectivore
Red-billed Firefinch	*Lagonosticta senegala*	Granivore
Common Bulbul	*Pycnonotus barbatus*	Frugivore
Bronze Sunbird	*Nectarinia kilimensis*	Nectarinivore
Eurasian Bee-eater	*Merops apiaster*	Insectivore
Common Fiscal	*Lanius collaris*	Insectivore
Hadada Ibis	*Bostrychia hagedash*	Molluscivore
Red-rumped Swallow	*Cecropis daurica*	Insectivore
Grey-backed Camaroptera	*Camaroptera brachyura*	Nectarinivore
Lesser Striped Swallow	*Cecropis abyssinica*	Insectivore
Little Swift	*Apus affinis*	Insectivore
White-browed Coucal	*Centropus superciliosus*	Insectivore
Barn Swallow	*Hirundo rustica*	Insectivore
Grey-headed Sparrow	*Passer griseus*	Granivore
Northern Black Flycatcher	*Melaenornis edolioides*	Insectivore
Blue-spotted Wood Dove	*Turtur afer*	Frugivore
White-throated Bee-eater	*Merops albicollis*	Insectivore
Helmeted Guineafowl	*Numida meleagris*	Omnivore
Variable Sunbird	*Cinnyris venustus*	Granivore
Bronze Mannikin	*Spermestes cucculatus*	Granivore
Village Weaver	*Ploceus cucullatus*	Granivore
Green-backed Eremomela	*Eremomela canescens*	Insectivore
Spot-flanked Barbet	*Tricholaema lacrymosa*	Insectivore
Ring-necked Dove	*Streptopelia capicola*	Frugivore
Nubian Woodpecker	*Campethera nubica*	Insectivore
White-browed Coucal	*Centropus superciliosus*	Insectivore
Arrow-marked Babbler	*Turdoides jardineii*	Insectivore
Tree Pipit	*Anthus trivialis*	Insectivore

Common Buzzard	*Buteo buteo*	Omnivore
Mosque Swallow	*Cecropis senegalensis*	Insectivore
Scarlet-chested Sunbird	*Chalcomitra senegalensis*	Nectarinivore
Common Drongo	*Dicrurus adsimilis*	Frugivore
Flappet Lark	*Mirafra rufocinnamomea*	Insectivore
Fischer's Lovebird	*Agapornis fischeri*	Granivore
Black Saw-wing	*Psalidoprocne pristoptera*	Insectivore
Black-crowned Tchagra	*Tchagra senegalus*	Insectivore
Wahlberg's Eagle	*Aquila wahlbergi*	Raptor
Tropical Boubou	*Laniarius aethopicus*	Nectarinivore
Black-headed Gonolek	*Laniarius erythrogaster*	Insectivore
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	Frugivore
Red-headed Weaver	*Anaplectes melanotis*	Granivore
Oriole Finch	*Linurgus olivaceus*	Frugivore
Tawny-flanked Prinia	*Prinia subflava*	Insectivore
African Black-shouldered Kite	*Elanus caeruleus*	Raptor
Klaas's Cuckoo	*Chrysococcyx klaas*	Insectivore
Eastern Grey Plantain-eater	*Crinifer zonurus*	Frugivore
Moustached Grass Warbler	*Melocichla mentalis*	Insectivore
Lesser Honeyguide	*Indicator minor*	Insectivore
Green-headed Sunbird	*Cyanomitra verticalis*	Nectarinivore
Yellow-throated Leaflove	*Chlorocichla flavicollis*	Insectivore
Lilac-breasted Roller	*Coracias caudatus*	Insectivore
Ross's Turaco	*Musophaga rossae*	Frugivore
White-browed Scrub Robin	*Cercotrichas leucophrys*	Insectivore
Red-billed Oxpecker	*Buphagus erythrorhynchus*	Insectivore
Red-throated Wryneck	*Jynx ruficollis*	Insectivore
Steppe Eagle	*Aquila nepalensis*	Raptor
African Harrier Hawk	*Polyboroides typus*	Raptor
Black-headed Batis	*Batis minor*	Insectivore
Meyer's Parrot	*Poicephalus meyeri*	Granivore

Appendix V: Bird species recorded in both habitats

Common Name	***Scientific Name***
African Black-shouldered Kite	*Elanus caeruleus*
African Thrush	*Turdus pelios*
Arrow-marked Babbler	*Turdoides jardineii*
Barn Swallow	*Hirundo rustica*
Black Kite	*Milvus migrans*
Black Saw-wing	*Psalidoprocne pristoptera*
Black-crowned Tchagra	*Tchagra senegalus*
Black-headed Gonolek	*Laniarius erythrogaster*
Black-headed Gonolek	*Laniarius erythrogaster*
Blue-spotted Wood Dove	*Turtur afer*
Bronze Mannikin	*Spermestes cucculatus*
Bronze Sunbird	*Nectarinia kilimensis*
Common Bulbul	*Pycnonotus barbatus*
Common Fiscal	*Lanius collaris*
Eurasian Bee-eater	*Merops apiaster*
Fischer's Lovebird	*Agapornis fischeri*
Grey-backed Camaroptera	*Camaroptera brachyura*
Grey-headed Sparrow	*Passer griseus*
Hadada Ibis	*Bostrychia hagedash*
Helmeted Guineafowl	*Numida meleagris*
Klaas's Cuckoo	*Chrysococcyx klaas*
Lesser Striped Swallow	*Cecropis abyssinica*
Lilac-breasted Roller	*Coracias caudatus*
Little Swift	*Apus affinis*
Moustached Grass Warbler	*Melocichla mentalis*
Northern Black Flycatcher	*Melaenornis edolioides*
Nubian Woodpecker	*Campethera nubica*
Oriole Finch	*Linurgus olivaceus*
Red-billed Firefinch	*Lagonosticta senegala*
Red-cheeked Cordon-bleu	*Uraeginthus bengalus*
Red-rumped Swallow	*Cecropis daurica*
Red-throated Wryneck	*Jynx ruficollis*

Ring-necked Dove	*Streptopelia capicola*
Spot-flanked Barbet	*Tricholaema lacrymosa*
Tropical Boubou	*Laniarius aethopicus*
Variable Sunbird	*Cinnyris venustus*
Village Weaver	*Ploceus cucullatus*
White-browed Coucal	*Centropus superciliosus*
White-browed Coucal	*Centropus superciliosus*
White-throated Bee-eater	*Merops albicollis*

Appendix VI: Indigenous shrubs bird density

Common Name	Scientific Name	Total	Density (Birds/ha)
Little Swift	*Apus affinis*	139	9.83
Common Bulbul	*Pycnonotus barbatus*	65	4.60
Tropical Boubou	*Laniarius aethopicus*	58	4.10
Bronze Mannikin	*Spermestes cucculatus*	22	1.56
Ring-necked Dove	*Streptopelia capicola*	18	1.27
Eurasian Bee-eater	*Merops apiaster*	17	1.20
Bronze Sunbird	*Nectarinia kilimensis*	17	1.20
Grey-backed Camaroptera	*Camaroptera brachyura*	16	1.13
Arrow-marked Babbler	*Turdoides jardineii*	15	1.06
Common Fiscal	*Lanius collaris*	13	0.92
Variable Sunbird	*Cinnyris venustus*	12	0.85
Blue-spotted Wood Dove	*Turtur afer*	10	0.71
Barn Swallow	*Hirundo rustica*	10	0.71
Red-eyed Dove	*Streptopelia semitorquata*	9	0.64
Common Drongo	*Dicrurus adsimilis*	9	0.64
Speckled Mousebird	*Colius striatus*	7	0.49
Black-crowned Tchagra	*Tchagra senegalus*	6	0.42
Common House Martin	*Delichon urbicum*	5	0.35
Hadada Ibis	*Bostrychia hagedash*	5	0.35
Northern Black Flycatcher	*Melaenornis edolioides*	5	0.35
Spot-flanked Barbet	*Tricholaema lacrymosa*	4	0.28
Tawny-flanked Prinia	*Prinia subflava*	4	0.28
White-throated Bee-eater	*Merops albicollis*	4	0.28
White-browed Coucal	*Centropus superciliosus*	4	0.28
African Thrush	*Turdus pelios*	3	0.21
Baglafecht Weaver	*Ploceus baglafecht*	3	0.21
Helmeted Guineafowl	*Numida meleagris*	3	0.21
Lesser Honeyguide	*Indicator minor*	3	0.21
Wahlberg's Eagle	*Aquila wahlbergi*	2	0.14
Yellow-fronted Tinkerbird	*Pogoniulus chrysoconus*	2	0.14

African Harrier Hawk	*Polyboroides typus*	2	0.14
African Paradise Flycatcher	*Terpsiphone viridis*	2	0.14
Blue-naped Mousebird	*Urocolius macrourus*	2	0.14
Crested Francolin	*Francolinus sephaena*	2	0.14
Fischer's Lovebird	*Agapornis fischeri*	2	0.14
Garden Warbler	*Sylvia borin*	2	0.14
Moustached Grass Warbler	*Melocichla mentalis*	2	0.14
Red-rumped Swallow	*Cecropis daurica*	2	0.14
Yellow-billed Oxpecker	*Buphagus africanus*	2	0.14
African Pied Wagtail	*Motacilla aguimp*	2	0.14
Common Buzzard	*Buteo buteo*	2	0.14
Klaas's Cuckoo	*Chrysococcyx klaas*	1	0.07
Red-billed Firefinch	*Lagonosticta senegala*	1	0.07
Red-headed Weaver	*Anaplectes melanotis*	1	0.07
Ross's Turaco	*Musophaga rossae*	1	0.07
Steppe Eagle	*Aquila nepalensis*	1	0.07
Village Weaver	*Ploceus cucullatus*	1	0.07
White-browed Robin Chat	*Cossypha heuglini*	1	0.07
Winding Cisticola	*Cisticola galactotes*	1	0.07
Yellow-throated Longclaw	*Macronyx croceus*	1	0.07
Common Buzzard	*Buteo buteo*	1	0.07
Flappet Lark	*Mirafra rufocinnamomea*	1	0.07
Green-backed Eremomela	*Eremomela canescens*	1	0.07
Grey-headed Sparrow	*Passer griseus*	1	0.07
Klaas's Cuckoo	*Chrysococcyx klaas*	1	0.07
Moustached Grass Warbler	*Melocichla mentalis*	1	0.07
Red-billed Firefinch	*Lagonosticta senegala*	1	0.07
Red-headed Weaver	*Anaplectes melanotis*	1	0.07
Ross's Turaco	*Musophaga rossae*	1	0.07
Winding Cisticola	*Cisticola galactotes*	1	0.07
Yellow-throated Longclaw	*Macronyx croceus*	1	0.07

Appendix VII: Agricultural farmland bird density

Common name	Scientific name	TOTAL	Density (Birds/ha)
Bronze Mannikin	*Spermestes cucculatus*	131	9.26
Little Swift	*Apus affinis*	112	7.92
Common Bulbul	*Pycnonotus barbatus*	58	4.10
Fan-tailed Widowbird	*Euplectes axillaris*	57	4.03
Village Weaver	*Ploceus cucullatus*	51	3.61
Barn Swallow	*Hirundo rustica*	45	3.18
White-throated Bee-eater	*Merops albicollis*	34	2.40
Red-eyed Dove	*Streptopelia semitorquata*	29	2.05
Eurasian Bee-eater	*Merops apiaster*	27	1.91
African Palm Swift	*Cypsiurus parvus*	25	1.77
Lesser Striped Swallow	*Cecropis abyssinica*	22	1.56
White-headed Saw-wing	*Psalidoprocne albiceps*	22	1.56
Common Fiscal	*Lanius collaris*	22	1.56
Ring-necked Dove	*Streptopelia capicola*	17	1.20
Common Waxbill	*Estrilda astrild*	15	1.06
Speckled Mousebird	*Colius striatus*	13	0.92
Hadada Ibis	*Bostrychia hagedash*	11	0.78
Orange-breasted Waxbill	*Amandava subflava*	8	0.57
Bronze Sunbird	*Nectarinia kilimensis*	8	0.57
Whinchat	*Saxicola rubetra*	7	0.49
Winding Cisticola	*Cisticola galactotes*	7	0.49
Blue-spotted Wood Dove	*Turtur afer*	7	0.49
Fischer's Lovebird	*Agapornis fischeri*	6	0.42
Variable Sunbird	*Cinnyris venustus*	6	0.42
Greater Blue-eared Starling	*Lamprotornis chalybaeus*	6	0.42
Grey-backed Camaroptera	*Camaroptera brachyura*	5	0.35
Black-lored Babbler	*Turdoides sharpei*	5	0.35
Yellow Wagtail	*Motacilla flava*	4	0.28
African Wattled Plover	*Vanellus senegallus*	4	0.28
Arrow-marked Babbler	*Turdoides jardineii*	4	0.28

Hamerkop	*Scopus umbretta*	4	0.28
Pied Crow	*Corvus albus*	4	0.28
Plain-backed Pipit	*Anthus leucophrys*	3	0.21
White-browed Coucal	*Centropus superciliosus*	3	0.21
Baglafecht Weaver	*Ploceus baglafecht*	3	0.21
Black Kite	*Milvus migrans*	3	0.21
Black-crowned Tchagra	*Tchagra senegalus*	3	0.21
Black-headed Heron	*Ardea melanocephala*	3	0.21
Cattle Egret	*Bubulcus ibis*	3	0.21
Red-faced Cisticola	*Cisticola erythrops*	3	0.21
Red-rumped Swallow	*Cecropis daurica*	3	0.21
Rüppell's Starling	*Lamprotornis purpuroptera*	3	0.21
White-browed Robin Chat	*Cossypha heuglini*	3	0.21
Yellow-throated Longclaw	*Macronyx croceus*	3	0.21
Black Cuckooshrike	*Campephaga flava*	3	0.21
Black-headed Gonolek	*Laniarius erythrogaster*	3	0.21
Red-throated Wryneck	*Jynx ruficollis*	3	0.21
Speckled Pigeon	*Columba guinea*	3	0.21
Spectacled Weaver	*Ploceus ocularis*	2	0.14
Superb Starling	*Lamprotornis superbus*	2	0.14
Tropical Boubou	*Laniarius aethopicus*	2	0.14
Yellow-fronted Canary	*Crithagra mozambica*	2	0.14
African Black-shouldered Kite	*Elanus caeruleus*	2	0.14
African Green Pigeon	*Treron calvus*	2	0.14
African Paradise Flycatcher	*Terpsiphone viridis*	2	0.14
African Pied Wagtail	*Motacilla aguimp*	2	0.14
African Thrush	*Turdus pelios*	2	0.14
Black-headed Oriole	*Oriolus larvatus*	2	0.14
Brown Snake Eagle	*Circaetus cinereus*	2	0.14
Common Buzzard	*Buteo buteo*	2	0.14
Holub's Golden Weaver	*Ploceus xanthops*	1	0.07
Jacobin Cuckoo	*Clamator jacobinus*	1	0.07
Malachite Kingfisher	*Alcedo cristata*	1	0.07
Moustached Grass Warbler	*Melocichla mentalis*	1	0.07
Purple-banded Sunbird	*Cinnyris bifasciatus*	1	0.07
Spot-flanked Barbet	*Tricholaema lacrymosa*	1	0.07

Spotted Flycatcher	*Muscicapa striata*	1	0.07
Striated Heron	*Butorides striata*	1	0.07
Tawny-flanked Prinia	*Prinia subflava*	1	0.07
Wahlberg's Eagle	*Aquila wahlbergi*	1	0.07
Yellow-throated Leaflove	*Chlorocichla flavicollis*	1	0.07
Malachite Kingfisher	*Alcedo cristata*	1	0.07
Marabou Stork	*Leptoptilos crumeniferus*	1	0.07
Northern Black Flycatcher	*Melaenornis edolioides*	1	0.07
Spotted Flycatcher	*Muscicapa striata*	1	0.07
Tawny-flanked Prinia	*Prinia subflava*	1	0.07
Swamp Flycatcher	*Muscicapa aquatica*	1	0.07
Wattled Plover	*Vanellus senegallus*	1	0.07
Western Banded Snake Eagle	*Circaetus cinerascens*	1	0.07
Western Marsh Harrier	*Circus aeruginosus*	1	0.07
White-faced Whistling Duck	*Dendrocygna viduata*	1	0.07
Woodland Kingfisher	*Halcyon senegalensis*	1	0.07
Yellow Wagtail	*Motacilla flava*	1	0.07
Yellow-backed Weaver	*Ploceus melanocephalus*	1	0.07
Yellow-throated Leaflove	*Chlorocichla flavicollis*	1	0.07

Appendix VIII: Photography gallery

Agroforestry; Photo by Daniel Mokaya

Replacement of indigenous trees with exotic trees; Photo by Daniel Mokaya

Murram excavation; Photo by Daniel Mokaya

Pasture burning; Photo by Daniel Mokaya

Human invasion into the shrubs; Photo by Daniel Mokaya

Transect and point count station setting; Photo by Vincent Otieno

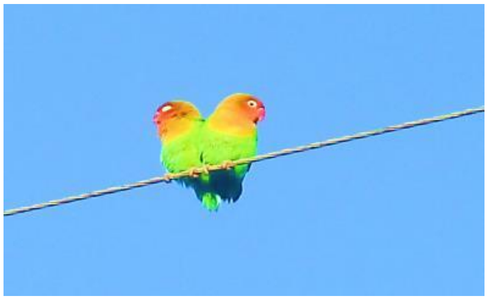
GPS coordinates recording; Photo by Vincent Otieno

Ruppel Starling; Source: Daniel Mokaya, 2018

Grey-crown Crane; Source: Daniel Mokaya, 2018

Great sparrowhawk; source:Mokaya, 2018

Eastern Grey Plantain- eater; Source: Daniel



Fisher's Lovebirds; Source: Mokaya

Common Fiscal; Source: Mokaya, 2018

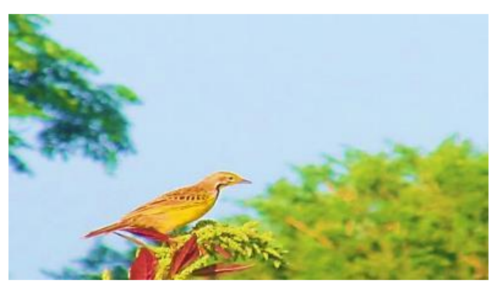
Common Egret; Source: Daniel Mokaya, 2018

African Green Pigeon; Source: Daniel

Black -Headed Heron; Source: Mokaya, 2018

Black-headed Gonoleck; Source: Mokaya, 2018

African Jacana; Source: Daniel Mokaya, 2018



Yellow-throated Longclaw; Source: Mokaya, 2018

Yellow-throated Leaflove; Source: Mokaya, 2018

Woodland Kingfisher; Source: Daniel Mokaya, 2018

White-faced Whistling; Source: Mokaya, 2018

Winding Cisticola; Source: Daniel Mokaya, 2018