COMPARATIVE STUDY OF BIRD GUILDS IN DIFFERENT CROPPING SYSTEMS ON FARM LANDS ADJACENT TO KAKAMEGA FOREST

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NOVEMBER 2011

DECLARATION

I declare that this is my original work and has never been presented for academic award in any other institution of learning.

Signature .... Date..06.Dec.2011........

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This work has been submitted with our approval as supervisors;

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Signature......................... Date...6/12/2011.........................

DEDICATION

This work is dedicated to my parents Alfred and Leokadia whom their love to me will always be remembered and to those who helped me in one way or another to reach where I am today.

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ABSTRACT

Tropical rainforests are characterized by habitat stability and complexity. Hence, the forests support a rich biological diversity, including 40% of all bird species. However, these rain forests have been shrinking due to increasing rate of deforestation, fragmentation, and other forms of resource exploitation. Degradation and loss of rainforests has threatened their rich biological diversity and the life-support systems. However, the rate at which birds are displaced by forest clearing and the potential for birds' conservation on farmlands are not well understood. This study sought to establish the role of farmlands adjacent to tropical rainforests in birds' conservation. The study was carried out for the period of seven months (September 2010-March 2011) in small scale farms lying between two forests (Kakamega main and Kisere) in Kakamega County, Kenya. The objectives were to determine the cropping systems in farmlands adjacent to Kakamega forest determine the spatial and temporal variability of birds' habitats in Kakamega, assess the relative abundance of birds found in different cropping systems in the study area and to determine the variability in the community structure of bird guilds in the study area. Information on crop cover types, crop growth stages and estimates of percentage cover was obtained. Data on bird species composition, diversity, richness and abundance in the identified habitats were collected through timed species counts, conducted in a circular plots of 35m radius. Individual birds were counted, identified and classified into feeding guilds. Their foraging sites were also noted by crop cover and flight height levels present at the sampling sites. Sampling of birds was done twice a week and crop growth stages were evaluated twice a month. Three major habitat types (sugarcane farms without trees, sugarcane farms with trees and farms with mixed crops) were identified. A total of 17,397 birds belonging to 126 species were found in all habitats. Bird species richness was variable among the various cover types while species diversity remained relatively stable (Shannon diversity H'=3.1 and H'=3.5). There was difference (X^2=6, df=5, $p < 0.05$) in number of birds in different bird guilds, insectivorous having the highest number while the nectivorous contained the lowest number. Similarly, the birds showed preference for top height level than the middle and the bottom levels (X^2=3, df=2, $p < 0.05$). Birds utilized various crop stages opportunistically and hence monthly differences were not significant (dmax $P > 0.05$). Farmlands in the study area hosted a rich community of birds, some of which utilized the adjacent tropical rainforest. It was also found that farmlands provided refuge for displaced species and the presence of indigenous trees and fruits appeared to offer favorable feeding and breeding opportunities. Bottom height level was, however, unstable because of the manipulations by the land owners. Nevertheless, this study showed that the mixed farming landscape in Kakamega offered ample potential for birds' conservation provided that key habitats remain stable and are enriched with tree crops.

CHAPTER ONE

INTRODUCTION

1.1 Back ground information

Tropical rain forests receive abundant rainfall year round; have enclosed canopy, complex symbiotic relationships, warm temperatures and high humidity. These are some of the characteristics of the tropical rain forests like Kakamega, which have made them "cradles of diversity". These forests harbour immense and unique biodiversity. In Kakamega alone more than 380 plant species have been recorded in the forest, of which 150 species represent the woody trees, shrubs, and vines (Kenya Indigenous Forest Conservation Programme, 1994).

Rain forests spawn and support big number of biodiversity. Bird species constitute an important component of that biodiversity. However, the rich forest biodiversity is threatened by a wide range of human activities (Primack, 1998). Selective removal of tall trees by human being has negative effects on primates and birds that utilize the forest canopy. Clearing of forested areas for agriculture, settlements or other infrastructural developments cause forest fragmentation which has resulted in open areas between the forests fragments (Gonzalez *et al.*, 1998). The open areas may have isolated bushes or scattered trees growing among crops or pasture for livestock. These open areas have created modified habitats.

The modified natural or agricultural habitats between the forest fragments attract many species of birds. They provide refuge to forest edge bird species that may have been displaced from the original forest and transient species moving between the natural forest blocks or fragments. However, the significance of the farmland habitats to the conservation of birds inhabiting tropical rain forests is not well understood. It is not clear, for instance, how spatial and temporal habitat changes affect habitat use by different bird guilds.

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What birds feed on varies with the species of birds and the habitat. Birds most often feed on fruits, seeds and nectar. Some also eat small animals such as fish, insects, worms and carrion (decayed animal flesh). Some birds are specialists (Feed on only one type of food) others are generalist (Feed on more than one type of food). Knowledge of the bird foraging ecology is one of the keystones in successful management of bird species, communities and ecosystems. The abundance, distribution and availability of food resources are believed to be the principle factors influencing habitat suitability for birds (Lešo and Rudolf, 2007).

1.2 Statement of the problem and justification

The combined influence of both high human populations and poverty in Africa are contributing to an alarming rate of forest loss equal to 5.7 million hectares annually (FAO, 2001). The result of this loss, particularly the loss of tropical rainforests has been associated with the loss of bird species (Primack, 1998). According to Dale, *et. al.* (1998) forest fragmentation results in habitat loss and is responsible for decline in bird species. Kakamega forest being one of the rain forests in East Africa is also suffering and experiencing the same consequences (Kokwaro, 1998). A lot of research work has been done inside the Kakamega forest (Lung, 2009; Kokwaro, 1998; Mann, 1985; Barasa, 2006, Otieno, 2007, Mitchell *et al* 2009,and Oyugi 1998). However, none has studied the importance of farmlands adjacent to the Kakamega forest in the conservation of birds and on how farmlands between forest fragments should be managed for better conservation of the birds. Careful selection of tree species and good management of trees and crops on the farms are needed to optimize farm production and the positive effects on resident bird community. It is also notable that knowledge on farming systems in Kakamega is limited. This study therefore focused on the farming systems on the farmlands adjacent to Kakamega forest and established whether they compliment conservation of wild birds, in adjacent tropical rain forest. To fulfill this, the study determined the types of farmland habitats available to birds, their structure and relative stability over the year, the different bird guilds that utilize those habitats and the frequencies of occupancy

1.3 Main objective

The main objective of the study was to determine the importance of farmland habitats adjacent to Kakamega tropical rain forest in the conservation of wild birds.

1.4 Specific objectives

The specific objectives of this study were:-

1). To determine the cropping systems in farmlands adjacent to Kakamega main and Kisere forests.

2). To determine the spatial and temporal variability in birds' habitats in the farmlands in the study area.

3). To determine the relative abundance of birds found in different cropping systems in Kakamega.

4). To determine the variability in the community structure of bird guilds in the study area

1.5 Research hypothesis

This study was based on the following hypotheses:-

i). Farmlands and adjacent tropical rain forests play complimentary roles in birds conservation

ii). Different cropping systems offer different ecological niches and hence support different bird guilds

iii). The habitat structure and stability directly influence birds' abundance and habitat utilization.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 World tropical rain forests

Tropical rain forests are the big forests located between the latitudes 22.5°North and South. They are characterized by tall trees, warm climate and lots of rainfall which may rain more than 2.54 cm every day in some of the forests. Tropical rain forests of the world include Amazon in South America, Queensland in Australia, Borneo lowland in Asia, Congo in Africa and Madagascar lowland (Allby, 1999).

Since the tropical rainforests are the most diverse ecosystems on earth, are biological hotspots that contain about 80% of the world's known biodiversity (Reuters, 2008). Rain forests are natural reservoirs of genetic diversity; support biodiversity, by providing habitat for wildlife (Science Daily, 2007). The forests are important in regulating global weather and maintaining regular rainfall, while buffering against floods, drought and erosion. They store vast quantity of carbon, while producing significant amount of oxygen. For this reason, the rain forests are also termed as “lungs of our planet” (Broeker, 2006). Historically, utilization of forest products from tropical rain forest including timber fuel wood, medicines, water and cultivable land have played a key role in human societies (Ferrez, 2009).

Despite their greatest values, tropical rainforests are being destroyed by human at a very high rate wherever they are. Commercial logging is the single largest cause of destruction both directly and indirectly. Other activities include clearing land for grazing and subsistence farming (Lung, 2009). Clearing of the main tropical rain forests has caused forest fragmentation resulting in smaller forest patches separated by non-forest land (Lung and Schaab, 2006).

2.2 Kakamega tropical rain forest

From geological, biological and historical evidences, being a mid-altitude forest (1400-1700m) in western Kenya, Kakamega forest is believed to have been a continous forest with Guineo-Congolian rain forests of west and central Africa (Lung, 2009). However, due to clearing of forests and grasslands by human some thousands years back, western Kenya forest was separated from the main Congo forest. Apart from Bantu, there was much clearing of forest in this region by British colonialists during the construction of the trans-African railroad (Mitchell, 2004). Later on in 1933, Kakamega forest was declared a national forest and boundaries were clearly set (Kokwaro, 1988). By that time Kakamega forest was a single forest covering approximately 24,000 hectares. At the beginning of the 21st century the forest was reduced in size to about 15,000 hectares. The forest was separated from all other forests by fragmentation into numerous smaller patches (Lung, 2009). Kakamega forest currently consists of a large forest block and six forest fragments (Peters *et al.* 2009). The main forest block is approximately 8,245 hectares (excluding natural glades) and forest fragments range in size from 65 ha to 1,370 ha. The fragments are separated from the main forest block by 1.3-9.4 km of non forest areas and from each other by 0.2–9.4 km (Brooks et al. 1999; Peters *et al.*, 2009). Kakamega tropical rainforest has been severely fragmented by human encroachment (Otieno, 2007). The signs of this encroachment are actually what are seen in areas surrounding the Kakamega forest as mixture of cattle pastures and agricultural fields surrounding the forest (Gonzalez *et al.*, 1998).

2.3 Effects of forest fragmentation on biodiversity

Forest fragmentation results in small isolated forest patches which are separated by non-forest land. According to Lung (2009), reduction in size of the forest and isolation results in reduced population, changes in genetic variability, and reduced fitness of wildlife species which can lead to extinction. This idea is supported by Dale *et al.*, (1999) who said "Forest species were obviously affected when habitat is lost but they may also go extinct if remaining forest fragments were too small to support viable populations. In addition, small forest fragments will be subjected to larger edge effects on many species. Edge effects include changes in abiotic conditions some distance into forest, such as increased amounts of sunlight, higher wind speeds and larger fluctuations in temperature and humidity."

There is no doubt about a great loss of plant and animal species resulting from tropical rain forests' destruction. Many species of different life forms are driven into extinction every day in the world's tropical rainforests (Pimm and Askins 1995). Economic activities such as logging, cattle ranching, and oil drilling have contributed to the loss of millions of acres of tropical rainforest (Primack, 1998).

2.4 Effects of forest fragmentation on bird species

The increasing rate of tropical deforestation is the major threat to global bird diversity (Rukosawa and Askins, 2002). Decline in forest birds has been reported in different parts of the world such as Japan (Endo, 1993; Higuchi and Morishita-1999) and North America (Pimm and Askins, 1995). Forest fragmentations in their breeding areas and habitat loss have been mentioned as the major causes of this decline (Askins *et al.*, 1990; Rabinson *et al.*, 1995).

2.5 Ecological functions of birds in tropical rain forests.

The importance of birds ranges from ecological, social to economical functions, which explain the need for their conservation. Through predation, birds are very important in tropical rainforest, as they enhance continuous flow of energy and nutrients throughout the ecosystem and a trophic relationship among the units of the communities (Mukherejee *at al.*, 2007). Through decomposition of their droppings and other waste products, birds provide the basic food stuff for the communities at appropriate trophic level in the tropical rainforest ecosystems (Gere, 1983). As frugivorous or granivorous birds defecate, they drop seeds away from the parent plants and therefore act as seed dispersers. Therefore birds are important in rainforests as they contribute to the forest regeneration process (Howe, 1986). Some birds such as sunbirds and humming birds are flower pollinators (Orthophillus). They maintain sexual reproduction in higher plants hence increasing diversity and better chance of survival in tropical rainforests (Alfredo, *et al.*, 2004).

Other birds such as Bee-Eaters (*Merops apiaster)*, Flycatchers, Bat Hawk (*Macheiramphus alcinus*) and Cattle Egrets (*Bubulus ibis*)feed on insects, mice and other reptiles; hence birds can be used as biological control agents (Haward, 1967). Birds also serve as some of the best environmental indicators. The periodical presence or absence of certain bird species is related to changes in environmental conditions. For instance, the presence of fruits and flowers, which occur during rainy seasons, would always attract nectar and seed feeders just like carcass would attract members of the vulture family (Boening and Bauer, 1996).

2.6 The role of birds in farmlands.

Forest fragmentation results in habitat loss for different animal species including wild birds (Dale *et. al.*, 1998). However, the farm lands between forest fragments provide all types of food needed by birds. They provide grains for granivorous birds, insects for insectivorous, fruits for frugivorous, fish and rodents for predators (carnivorous), and also provide nectar for nectivorous birds (Barasa, 2006). These farmlands have modified habitats which act as refuges on which birds run to, after being displaced from the original forests.

Animals kept in farmland areas also attract some birds such as Cattle Egrets *(Bubulcus ibis)*, Red-billed Oxpecker *(Buphagus erythrorhynchus*), Fishers' Starling *(Spereo fischeri*) and African pied Wagtail (*Motacilla aguimp*) which live in association with cattle and other domestic animals and also with moving vehicles such as tractors. The birds appear to exploit small animals flushed by moving animals or mobile machines and hence are easier to detect and/or capture. This provides birds with easy access to abundance of food resource on farmlands (Seedikkoya *et al.*, 2005).

Farmlands also provide shelter, protection, and food to the birds; while the birds help to recycle the nutrients, control pests, pollinate plant crops, and help in plant dispersion hence; the two, birds and farmlands are complimentary to each other in maintaining the new ecosystem existing between the forest fragments (Loiselle and Blake, 2002).

2.7 Compatibility of agriculture and birds conservation

Due to the needs of expanding human populations and the agricultural economies of many tropical countries, tropical forests are increasingly becoming fragments in agricultural landscapes (Kirika, 2005). This means that fragmentation and disturbance are, and will continue to be threats to the protected rainforests with their biodiversity (Temple and Wilcox, 1986). The type of farming practiced in areas between the forest fragments can save biodiversity from extinction. Of importance to observe is the practice of agro-forestry, in which trees or shrubs are intentionally planted or spared from felling within agricultural systems, or non-timber forest products are cultured in forest settings (Lung, 2009). Agro-forestry incorporates several tree species with crops into a given land area and creates a more complex habitat that can support a wider variety of birds, insects, and other animals.

Biodiversity in agro-forestry systems is typically higher than in conventional agricultural systems (Uezu *at al.,* 2008). Rapid growth in human population in the tropics in recent decades has led to increased demand for agricultural land to produce food, resulting in loss of natural habitats and biodiversity (Otieno, 2007). Nevertheless, conservation of birds and agriculture can be complimented: biodiversity performs ecosystem services to farmlands, including pollination, seed-dispersal, nutrient cycling, and genetic exchange, while agricultural landscapes offer foraging and dispersal opportunities to birds' degraded habitats (Heath and Rayment, 2001).

This study aimed to investigate if the farmland habitats between Kakamega main forest and Kisere are available and used by birds. If the habitats are available to birds are they available all the year around or not. It also aimed to find out if different cropping systems and types of crops in different farms in the area affect the availability, of birds in terms of their numbers and species richness.

CHAPTER THREE

3.0 STUDY AREA MATERIALS AND METHODS

3.1 Study area

3.1.1 Description of the study area.

This study was conducted on farmlands adjacent to two blocks of tropical rain forest, in Kakamega county, western Kenya, between September 2010 to March 2011. The two blocks of forests were Kisere occupying an area of 500 ha (Tsingalia and Kassily, 2009) and Kakamega main forest block with an area of 8,600 ha (Brooks *et al.*, 1999) (Fig. 1) The two forest blocks are separated by about 2 km of densely populated agricultural land (Chism and Cords, 1998). The two blocks were selected due to their variability in cropping systems that separate them.

Kakamega forest lies between latitudes 00°08'30.5'' N and 00°22'12.5'' N and longitudes 34°46'08.0'' E and 34°57'26.5''E at an altitude range of 1,500 to 1,700 m. From the 150 km remote Rift Valley it is separated by Cherangani highlands in the North, and the Mau escarpment in the South (Ntale, 2008). It is one of the few tropical rain forests remaining in Africa.

The spectacular Kakamega main forest together with the adjacent Kisere forest was gazetted as Kakamega Forest National Reserve in 1986. This reserve acts as a habitat to a great number of plant and animal species. It has about 380 plant and 350 bird species, as well as mammals like porcupines, pangolins, otters, civets, antelopes, bush pigs and scaly-tailed squirrels (Lung, 2009).

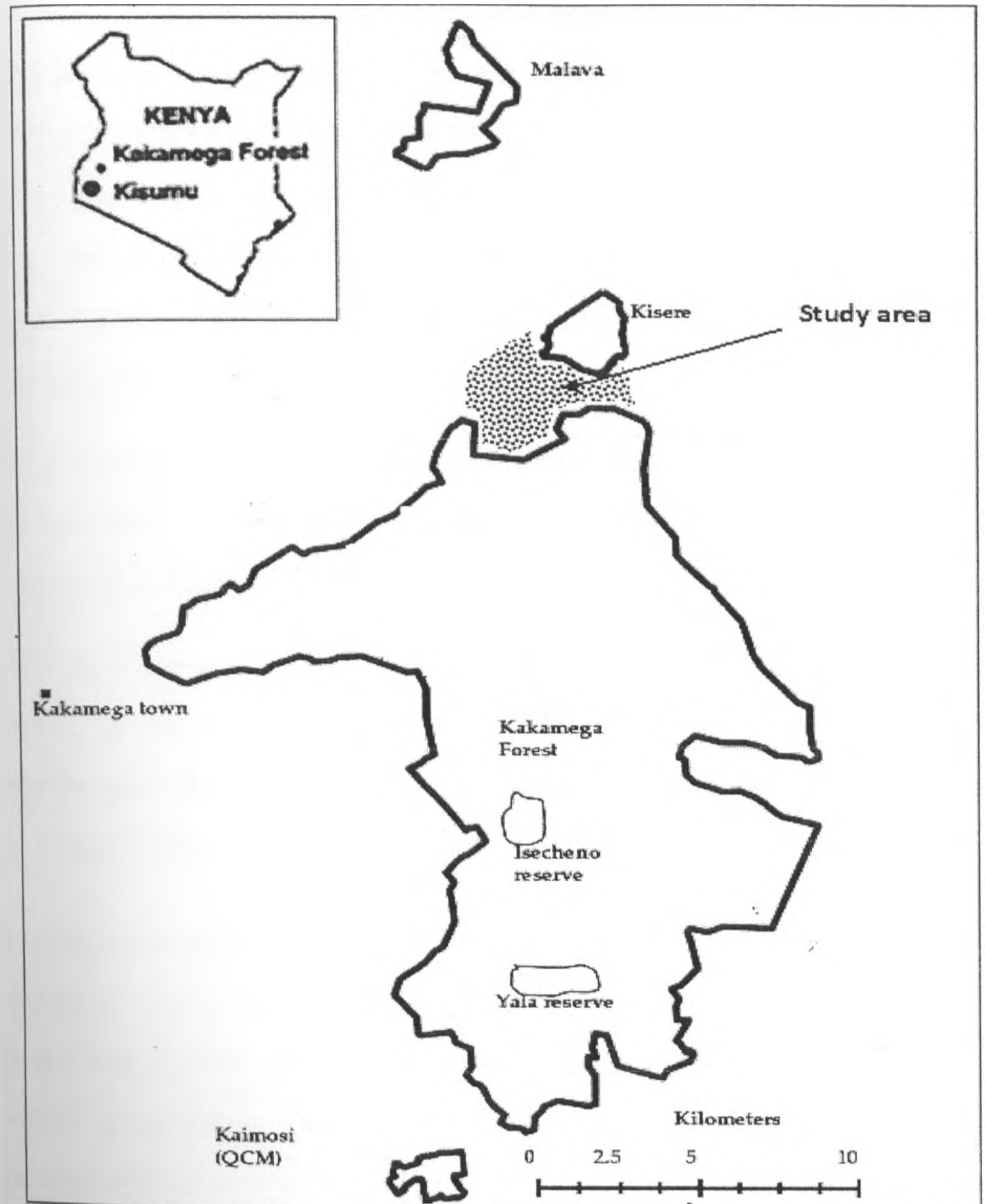

Figure 1: Location of the study area between Kisere and Kakamega forests Inset is the map of Kenya showing the location of Kakamega forest. (Lung and Schaab, 2002)

The forests are placed in one of the world's most densely populated rural areas with mean population density of 600 persons /km^2 (Blackett, 1994). Most part of the land in this area is intensely used for subsistence agriculture. Family farms range approximately from 1 to 2 ha, and are owned by individual farmers. The major cash crops grown include tea, sugar cane and coffee, largely at small scale while crops for subsistence agriculture include maize, beans, pulses, bananas, sweet potatoes, millet, cassava and other root crops (Export processing zone authority, 2005.)

Due to continually increasing population numbers, the pressure on the forests is growing. For the local people, the forests play an important role in satisfying their daily needs e.g. fire wood, house building material, source of water, honey and medicinal herbs (Kokwaro, 1988).

In 1933, Kakamega forest was still a single forest, allowing birds and primates to move freely in the forest (Lung, 2009). Since the blocks have been separated from each other and from the main block by the farmlands, some birds and primates extend their foraging area to the farmlands where they interact with humans and occupy semi-permanent habitats.

3.1.2 Climate of the study area

Kakamega forest is situated in a fairly wet area of Kenya with an average annual rainfall ranging from 1,200mm and 2,100 mm per year (Emerton, 1994). The rainfall is binomial, with the two wet seasons falling in March to June and August to November (Fig. 2). In 1963 Zimmerman (1972) recorded over 3,500 mm annual rainfall and since then rainfall in the area has been declining possibly due to the effects of deforestation (Kokwaro, 1988). Mean monthly maximum temperature ranges from 18-29 degrees centigrade while diurnal temperatures range from minimum of 10.6 – 27.7 degrees centigrade (Kokwaro, 1988; Muriuki and Tsingalia, 1990).

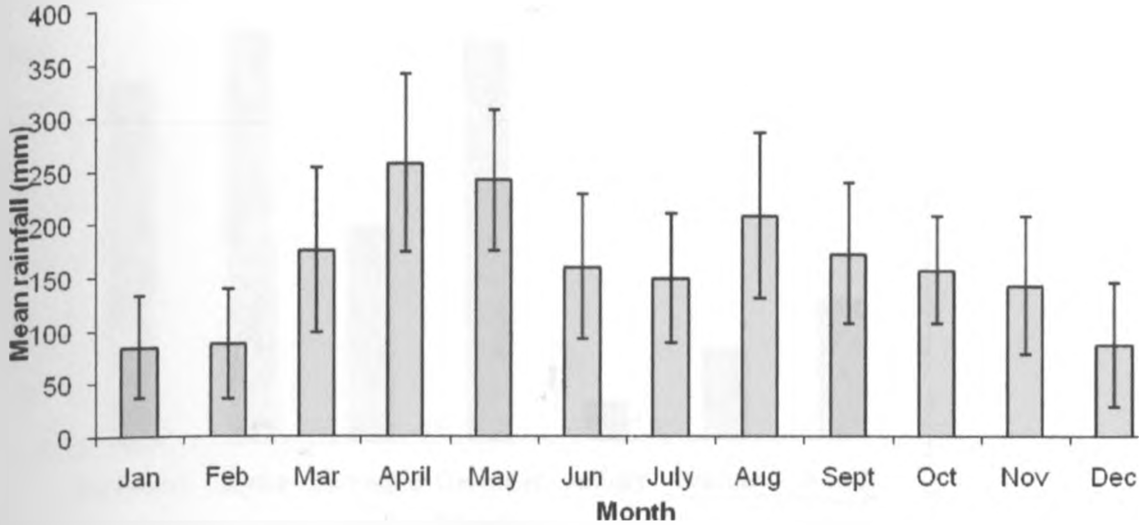

Figure 2: Mean monthly rainfall for Kakamega area for the period of 31 years (1979-2010). (Source: Kakamega meteorological office) NB: Error bars represent calculated confidence intervals

Although there was rainfall throughout the study period, the rainfall amount was not equal in all moths. The large amount of rainfall was experienced in September, October and December. February and January received very little amount of rain; these two were almost dry months during the period of study (Fig. 3 as shown in the thesis). With October experiencing the highest amount of rain during the data collection period, could be one of the indications of changing in rainfall pattern in the area. The mean monthly rainfall for the period of 31 years was calculated to be 159mm. During the study period no month exceeded the 159mm amount of rainfall. Due to this the data collected during the study were not compared in terms of seasonality but were compared from one month to another.

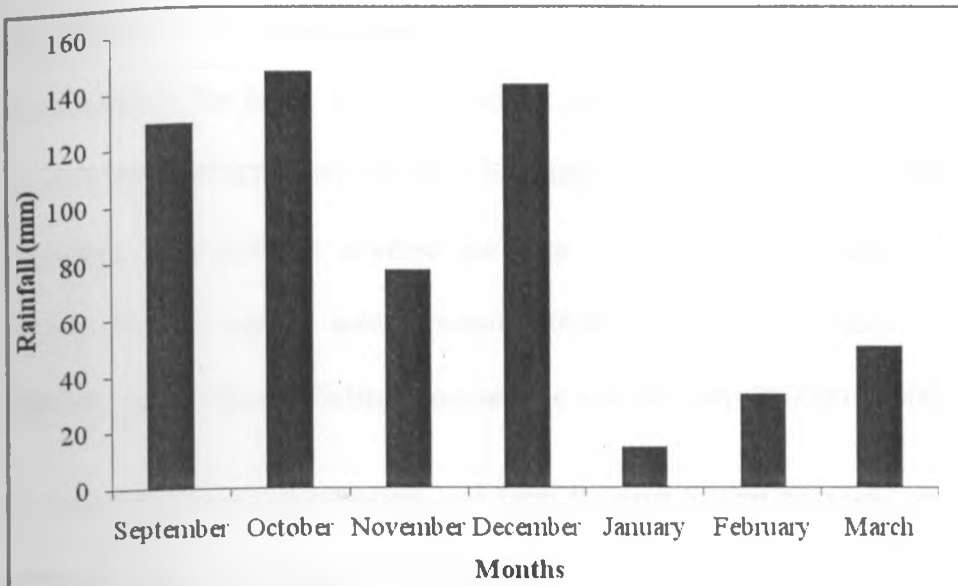

Figure 3 : Monthly rainfall for Kakamega area during the study period

(Source: Kakamega Meteorological Office - Sept 2010- Mar 2011)

3.2 Materials and methods

3.2.1 Selection of study sites

The land in the study area was used for different purposes with approximately 97% used for crop farming, 2% for homesteads and 1% used for pastures. The selection of study sites was based on farming systems, type of crops and presence or absence of trees in the farms. Three types of habitats were identified in farmlands between Kakamega main and Kisere forests. These habitats were sugarcane farms with trees, sugarcane farms without trees and mixed crop farms with trees.

On the map and by use of GIS computer software, the study area was divided into six equal parts by the north south grid references as indicated in fig 4. In each part, formed by two grid references, small farms of different habitat types were present randomly. First selection was to get the farms that qualified to form the sampling sites. For the farm to be selected for data collection, there was an agreement with the farmer, the farm was at least 200 m away from the main forest (to reduce edge effect), was to be 100 m away from another sampling point (to minimize double counting), and was also to be 100 m away from the main road (to avoid disturbances). No farms were selected for sampling in the Eastern part of the study area as farmers declined with their farms to be sampled. Hence the work could only be done in four divisions. First division covered the area 705000-706000 (North south grid references), second division was the area between 706000-707000, third division was between 707000-708000, and the fourth division covered the area between 708000-709000 as shown in fig.4

In the second phase of selection, one farm for each habitat type was randomly selected from each part formed by the grid references. From each division of the study area, three farms of different habitat types were obtained, making a total of twelve farms (Fig. 3). The farms in the division were selected by applying stratified random sampling method. First, the farms were identified according to their habitat type in each division, and then within each habitat farms were selected randomly.

In each selected farm and at each sampling point, a circular plot (Fig. 5) was established and the coordinates of its centre were noted from the GPS. In this establishment, data collection on trees, birds and crops were conducted.

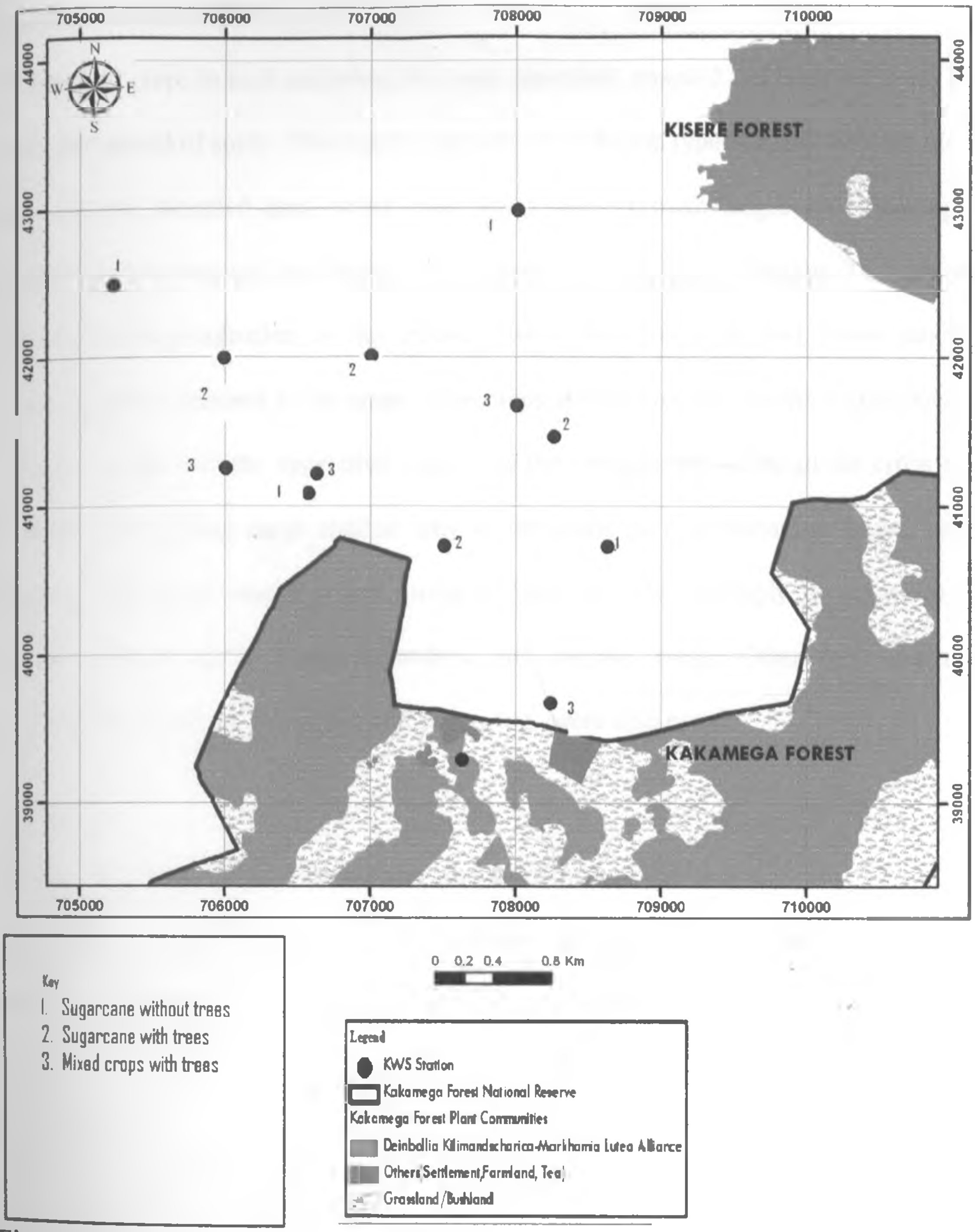

Figure 4 : Map of the study area showing twelve randomly selected sampling sites

3.2.2 Assessment of habitat characteristics.

The types of crops in each sampling plot were identified, counted and recorded twice a week during the period of study. The stages of growth of each crop type in each sampling plot were observed and recorded once every two weeks. Four growth stages (germinating stage, vegetative, flowering and the fruiting) were recognized for data collection. The germinating stage included germination of the crop till when the crop plant had about four leaves. Flowering phase referred to the stage when crops started booting. Between germinating and flowering stages was the vegetative stage. The three stages applied to all the crops studied. However, the fruiting stage applied only to the crops such as tomatoes, beans, cowpeas, bananas, maize and pepper which produced fruits but did not apply to sugarcane, sweet potatoes, Napier grass, Kale, corianders, and cassava crops. Other farm management practices like weeding, harvesting and harrowing were also noted.

3.2.3 Assessment of birds' abundance and distribution.

The point count method was used to gather data and information on birds in selected study sites. A circular sampling design of 35 m radius was used (Fig. 5).

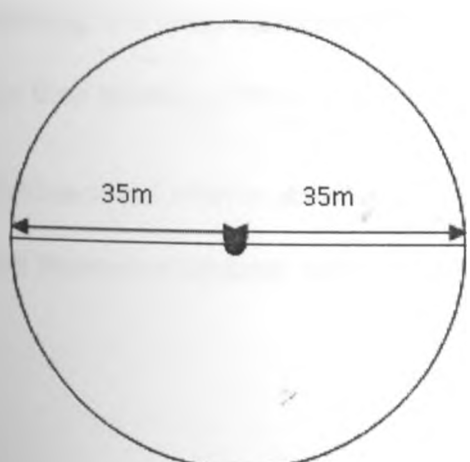

Figure 5 : Circular sampling plot used for data collection

Each sampling point therefore had an area of 0.38465 hectare (3846.5 meter squares). A transect line of length equal to the diameter of each circular plot was set up. At the mid-point of each circle and along the transect line, two people stood facing in the opposite directions (back-to-back) so as to ensure that each person had a clear view of the study site at an angle of 180 degree of the circle. At this point and at a fixed position, information on all the birds seen or heard was recorded within a period of 15 minutes. The information collected included the species name, species number, and their activities as described by (Bibby *et al.*, 1992). The common (English) and scientific names together with the feeding guilds (Birds of Kenya and Nothern Tanzania) Zimmerman *et al* (1999).

Flight height, on which the birds were, during data collection were also recorded. Three height levels; bottom, middle and top were considered (Barasa, 2006). Bottom level was estimated from ground level to one meter high, middle level from 1m to 3m high and top level was from a height of 3m and above. Each sampling plot was sampled twice a week for birds counting from 7am to 10.30 am when birds were active. No data was collected in the afternoons due to heavy rains experienced most of the days. Data was also not collected during fog and burning of crop stubble or grass as this could affect birds' behavior and visibility. Care was also taken not to disturb the birds during data collection so as to avoid double counting. For every data collection, the first five minutes were used to let birds settle and resume their normal activities in the area as described by Khurshid (2004).

Birds' abundance and relative abundance were used to compare the birds in the three habitat types while Kormorov-Smirnov test was used to compare the birds' distribution in different habitats.

3.2.4 Habitat availability

Habitat availability (the proportion of the total study area occupied by each habitat) was derived from about 400 ha of the total study area as described by Chism and Cords (1998). The three habitats were sugarcane farms without trees which covered about 120 ha, sugarcane farms with trees which occupied an area of about 200 ha and mixed crops with trees which covered about 80 ha of the total study area.

3.2.5 Species richness, evenness and diversity

Species richness is the number of species observed in a particular habitat. For birds' diversity in different habitat types Shannon-index of diversity was calculated as described by Zar, 1996.

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i) \qquad \text{.................................Equation 1}$$

Where;

H'=Shannon-Wiener diversity index

k=Number of categories

P_i = The proportion of observation found in category *i*

n= The sample size

f_i = The number of observations in category *i*

$P_i = f_i / n$;

Typically the value of the index ranges from 1.5 (low species richness and evenness) to 3.5 (high species evenness and richness) (Glane, 2003).

The species evenness was obtained as described by Zar, 1996 .

$H'_{max} = \log k$ ....Equation 2.

Where H'_{max}= Maximum possible diversity for a set of data consisting of k categories

$J' = H'/H'_{max}$..Equation 3.

Where;

J' = Species evenness

H'= Shannon-Wiener diversity index

Species richness as described by Zar, 1996

$$S_{max} = \alpha \log_{e(1+N/\alpha)}$$ ....Equation 4

Where:

S_{max} = Maximum possible number of species that can be observed in a habitat.

N = the number of individuals sampled

α= Species diversity

3.2.6 Bird guilds and height levels

The birds' feeding guilds in the study area were grouped into insectivorous, granivorous, carnivorous, frugivorous, omnivorous and nectivorous. The guilds observed were compared in terms of their numbers in each guild and in each habitat type. To find the most preferred height level, the number of birds observed in each height level was recorded.

3.2.7 Species habitat use overlap.

Niche overlap is the extent to which two species require similar resources. The resource can be space (habitat), food or other resources. Habitat use overlap is the part of niche overlap where two species use the same habitat as one of their resource. This may course special competition among the community members of the area. Frequency of occupancy matters in terms of habitat overlap. The species with low number of visits in the area may have no effects on space competition as they spend most of their time to other habitats. Those with high number of visits in the area are likely to be residing in the area. These are the ones who likely to compete for space in the area as they spend most of their time in the particular area. The species with very high number of frequency (occurrence) during the study period were taken as indicator of space competition in the study area. The proportion of the number of occurrence of indicator species in each habitat was used to calculate their habitat utilization patterns as described by Colwel and Futuyama (1971) (Equation 3).

$C=1-0.5(\Sigma_i |Pxi-Pyi|)$------------------------------------Equation 5.

Where P=Species proportion

X and y are the species in habitat i

Pxi = proportion of species x found in habit i

Pyi = proportion of species y found in habitat i

To get P the number of occurrence of species (x or y) in habitat i was divided by the total number of occurrence of that species in all habitats.

C=habitat overlap,

C measures the proportional similarity between species in their habitat utilization patterns. It ranges from 0 (No overlap) to 1 (complete overlap).The equation above is also knows as Shannon's information theory.

3.2.8 Monthly variability in birds' abundance.

Birds were compared in terms of their individual numbers from one month to another during the study period. This datum was used to find out if there was a significant difference in number of birds from one month to another.

3.2.9 Data analysis

Data analysis was performed using SPSS statistical software version 16. Shannon-winner index was used to determine the birds' diversity in different habitats. Kolmogov-Smirnov test was used to test birds' distribution and Chi Square was used to compare the abundance in birds' guilds and in different canopy levels. Habitat overlap was evaluated using Shannon's information theory.

CHAPTER FOUR

4.0 RESULTS

4.1 Habitat availability

Within farming systems, it was found that sugarcane farms with trees covered the largest area (200 ha), followed by sugarcane farms without trees which covered (120 ha) while farms with mixed crops covered the least area (80 ha). On the basis of these proportions the available habitats for birds in the study area were estimated as shown in table 1. Coverage of mixed crops varied unpredictably as a result of farming activities and farmer preferences; however the cover types with sugarcane remained relatively stable.

Table 1: Habitat types, area studied and habitat availability

Habitat	Total area studied (ha)	% Habitat availability
Sugarcane farms without trees	120	30
Sugarcane farms with trees	200	50
Mixed crops with trees	80	20
Total	**400**	**100**

4.2 Birds' abundance and distribution

A total of 17, 397 birds belonging to 126 different species were recorded during the study. This represented 34.3% of the 367 species documented in and around Kakamega forest (Lung, 2009). Birds were distributed in all habitats studied or cover types but were not uniformly distributed in the three habitats, Kormorov-Smirnov test dmax=966, p>0.05 (X^2= 3.0, df=2, p>0.05) . The biggest number of birds was found in mixed crop farms followed by the sugarcane farms with trees. The lowest number of birds was recorded in sugarcane without tree farms (Table 2).

Table 2: Birds abundance and Relative abundance in different habitat types

Habitat	Birds abundance	Relative abundance (%)
Sugarcane farms without trees	4833	28
Sugarcane farms with trees	6134	35
Mixed crops with trees	6430	37
Total	**17397**	**100**

4.3 Species richness, evenness and diversity

The 3 to 3.5 values of Shannon H' which were obtained, indicate that all three habitats had high species evenness and richness. Both the diversity index H' and evenness were generally similar in all habitat types (Table 3).

The three habitats shared the bird species but overall mixed crop farms and sugarcane farms with trees, supported higher numbers of each of the bird species compared to the sugarcane farms without trees during the study period.

Of 215 maximum possible number of bird species in sugarcane farms without trees only 34% were observed. In sugarcane farms with tree, of 298 maximum possible bird species only

36% were observed while in mixed crops with 287 maximum possible bird species only 36% were observed.

Table 3: Species richness, evenness and diversity

	Sugarcane farms without trees	**Sugarcane farms with trees**	**Mixed crops**
Shannon diversity index H’	3.143	3.543	3.565
Evenness	0.305	0.326	0.347
Observed number of bird species (*S*)	76	106	102
Maximum possible number of species (S_{max})	215	298	287

4.4 Crop diversity

Small-scale farms in the study area were planted with a wide range of food crops and cash crops (Table 4). This high diversity of crops provided valuable niches for feeding and nesting of birds. The crops hosted insects on foliage and worms on the soil. The birds also fed on the flowers, pods, fruits and leaves.

Table 4: Crops grown on farms between Kakamega and Kisere forests in western Kenya

Types of crops				
Grains	**Root crops**	**Fruits**	**Vegetables**	**Commercial crops**
Maize	Sweet potatoes	Bananas	Coriander	Sugarcane
Millet	Irish potatoes	Guava	Kales	Tea
Sorghum	Arrow roots	Pawpaw	Pepper	Coffee
			Onions	Napier grass
			Tomatoes	
			Cabbage	
			Spinach	
			Black night shed	
			Spider herb	

In all the 12 farms sampled, sugarcane was the most dominant crop and therefore it had the highest percentage (34%) of frequency among the crops encountered, followed by bananas (13%) and cassava (9.4%) in that order. Tomatoes and coriander were the least grown crops in the area as represented by the low percentages 0.6% and 0.5% respectively (Fig. 6).

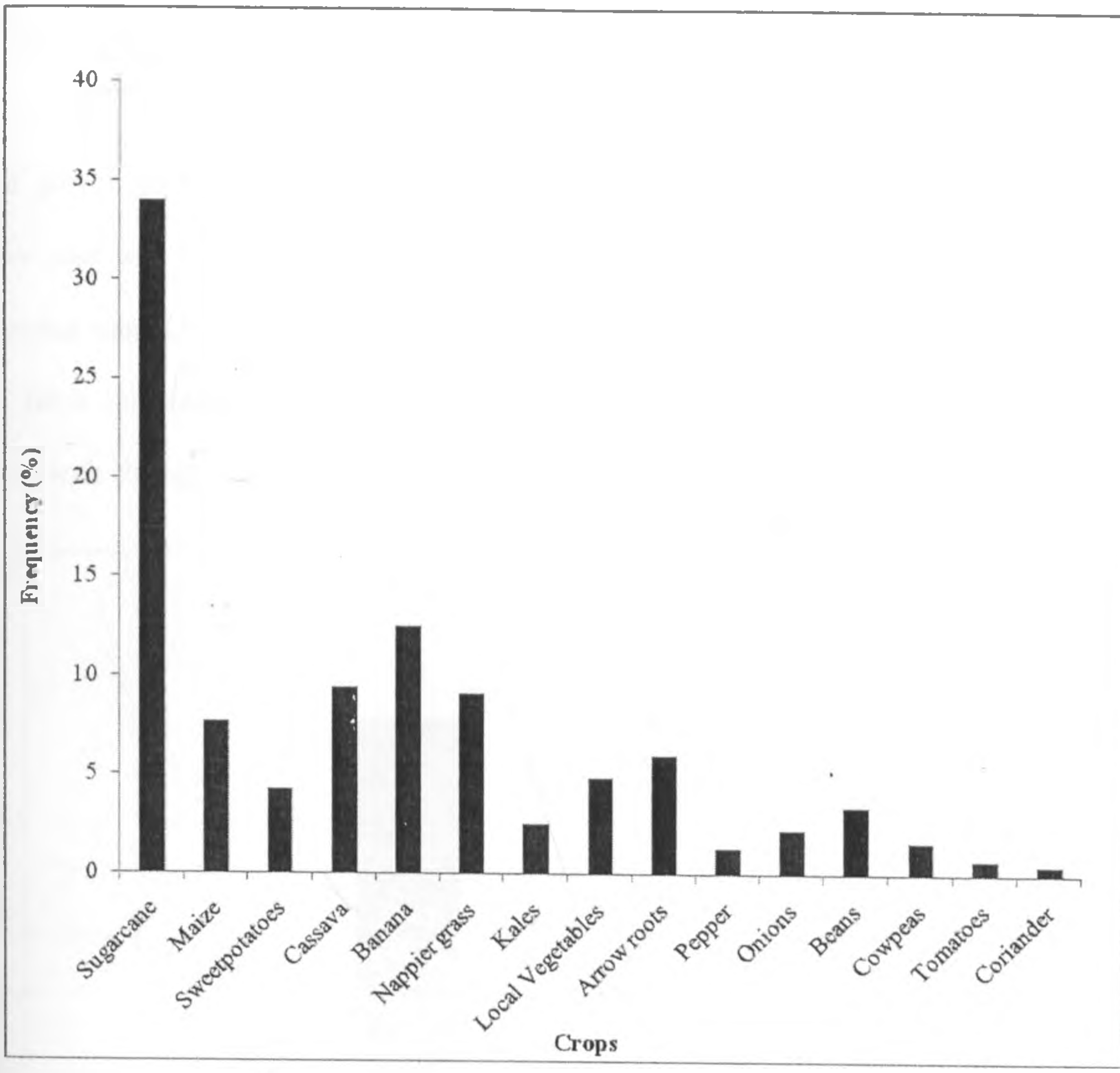

Figure 6: Frequency of occurance of various crops in the small scaled farms adjacent to Kakamega and Kisere forests, in western Kenya.

4.5 Crop growth stages

Different growth stages of crops were recorded during the study as shown in fig 7. The vegetative stage was the most prominent (60.4%), followed by the germinating stage (14.7%) and flowering stage (14.2%). The flowering stage was the least encountered as recorded only 10.7%. Birds inhabiting the farmlands adjacent to Kakamega forest appeared to change abundance with changes in growth stages of crops.

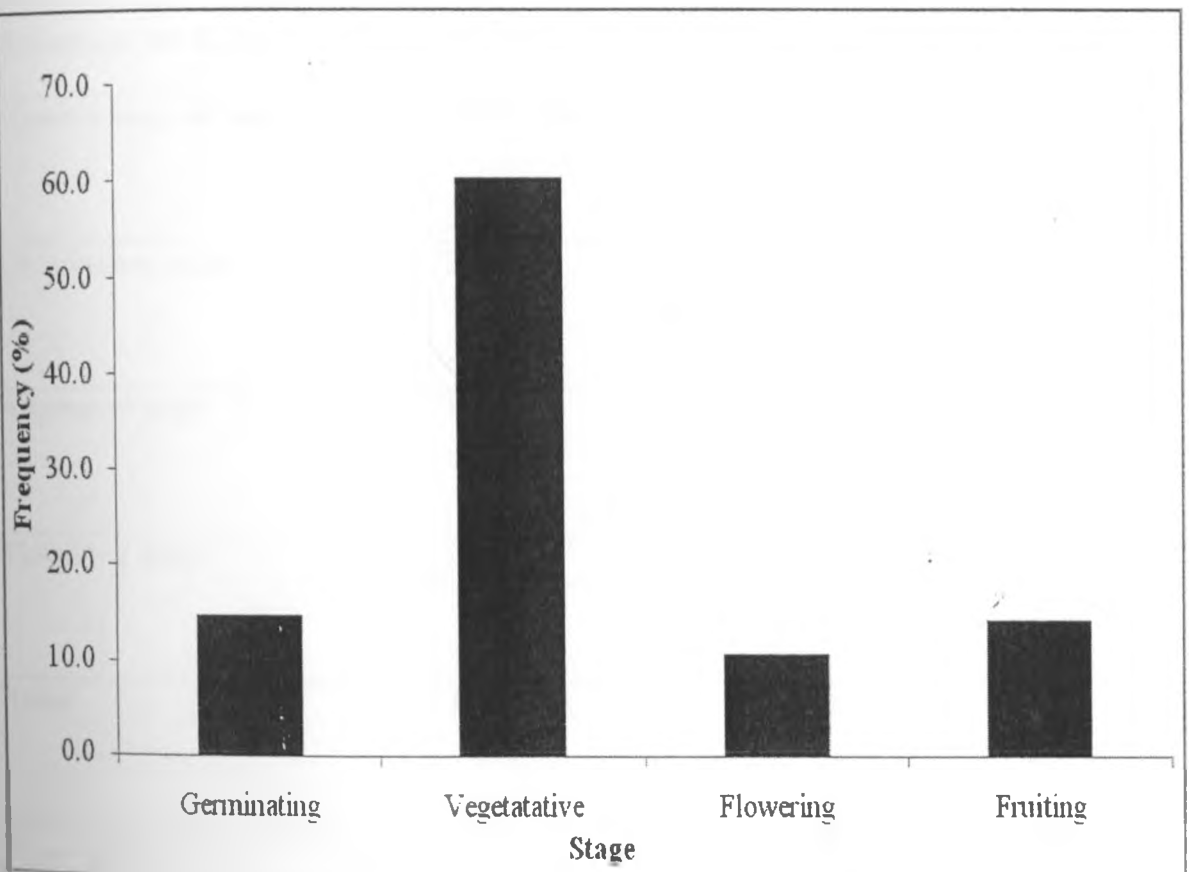

Figure 7: Growth stages of different crops in small scaled farms between Kakamega and Kisere forests, western Kenya.

Variation in birds' abundance was assessed in farms planted with sugarcane (which was the dominant crop) at different growth stages. This study found that all sugarcane growth stages were used by birds; however, the birds were not equally distributed in all growth stages of sugarcane. The vegetative growth of sugarcane recorded the highest number of birds (42.85%). Flowering stage recorded 36.17% while the germinating stage which recorded the least number of birds had 20.97% (Table 5). Statistically there was no significant difference (dmax, $P > 0.05$).in the number of birds at different sugarcane growth stages.

Table 5: Birds abundance in different growth stages of sugarcane crop in farmlands between Kakamega and Kisere forests in western Kenya

Growth stage of sugarcane	Birds abundance	Percentage (%)
Germinating stage	2,300	20.97
Vegetative stage	4,700	42.86
Flowering stage.	3,967	36.17
Total	**10,967**	**100**

4.6 Bird guilds observed in the study area

The feeding guilds identified during the study period were insectivorous, granivorous, carnivorous, frugivorous, omnivorous and nectivorous. The percentage number of birds observed in different feeding guilds is illustrated in fig 8. The number of birds varied significantly among different feeding guilds in the study area (X^2=6, df =5, $p < 0.05$). The largest number of birds observed was the insectivorous (49%), followed by the granivorous (22%). Frugivorous recorded 13%, omnivorous 8% and Carnivorous recorded 6%. Nectivorous recorded the lowest number of birds which was only 3%

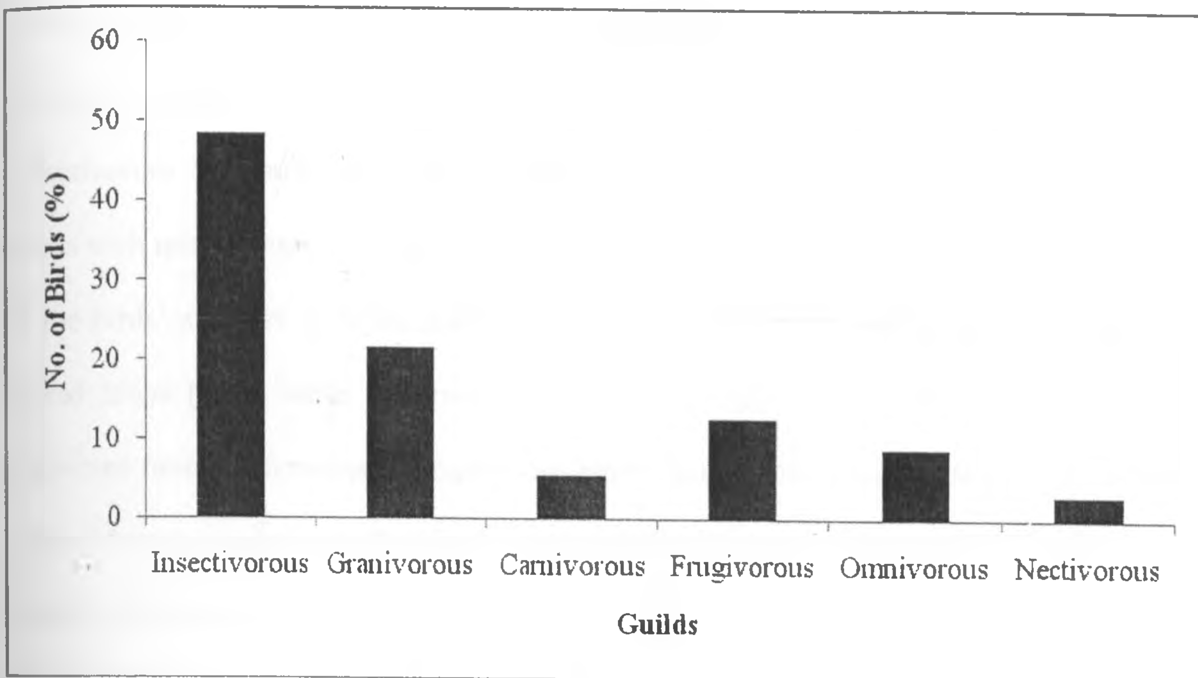

Figure 8: Number of birds in feeding guilds in farmlands adjacent to Kakamega and Kisere forests in western Kenya.

4.7 Guilds in different habitats

All the feeding guilds observed during the study were present in all the habitat types. Fig 9 illustrates the number of birds in different feeding guilds, in each habitat type, as observed during the study. Although in all farm habitats the insectivorous guild had the highest numbers of birds, the sugarcane farms with trees recorded the highest number (55%) of insectivorous than other farm habitats. Sugarcane farms without trees recorded 52% while farms with mixed crops recorded 41%. The granivorous guild was the second group in terms of the birds' numbers in all the habitats and the highest number was recorded in farms with mixed crops (23%) while the lowest percentage (20%) of granivorous was observed in sugarcane farms without trees. Frugivorous represented the third highest feeding guild in two habitat farms; sugarcane with trees and in farms with mixed crops. However; the largest number of frugivorous was recorded in farms with mixed crops (17%), while the lowest number (6%) was recorded in sugarcane farms without trees.

The largest number of omnivorous (10%) was recorded in mixed crop farms habitats. In sugarcane farms without trees omnivorous recorded were 9% and the least was in sugarcane farms with trees (7%). For Carnivorous, the highest number was recorded in mixed crop farms (6%), while both sugarcane farms with trees and sugar cane farms without trees recorded 5% each. In all the three habitat types, nectivorous were the least recorded.

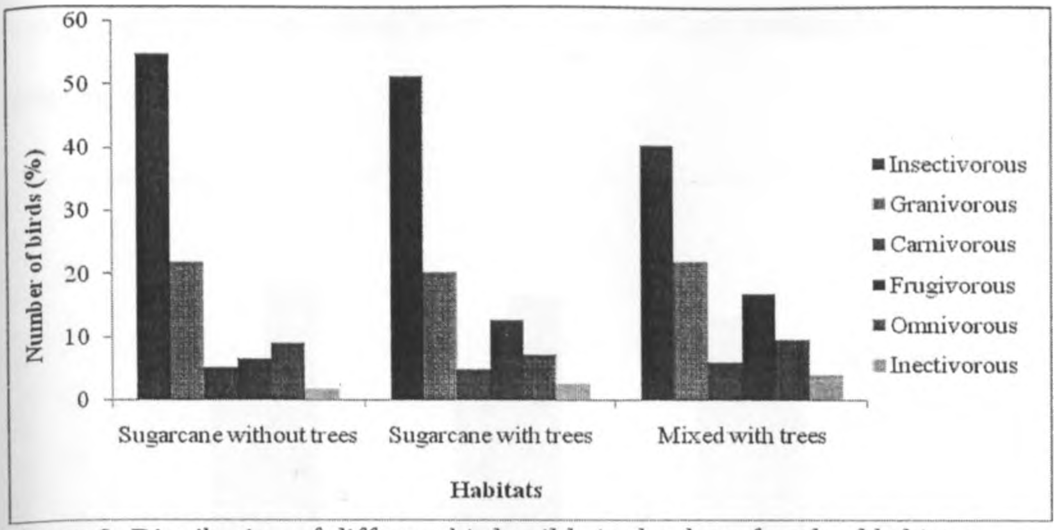

Figure 9: Distribution of different bird guilds in the three farmland habitats

4.8 Height levels in the study area.

The current study found that height levels played a major role in birds' habitation. There were significant differences ($X^2 = 3$, df = 2, $P < 0.05$) in height level utilization in the area, with the top height being the most birds (57%) preferred followed by the middle height level (39%). The least number of birds (4%) was observed in the bottom height level (Fig 10).

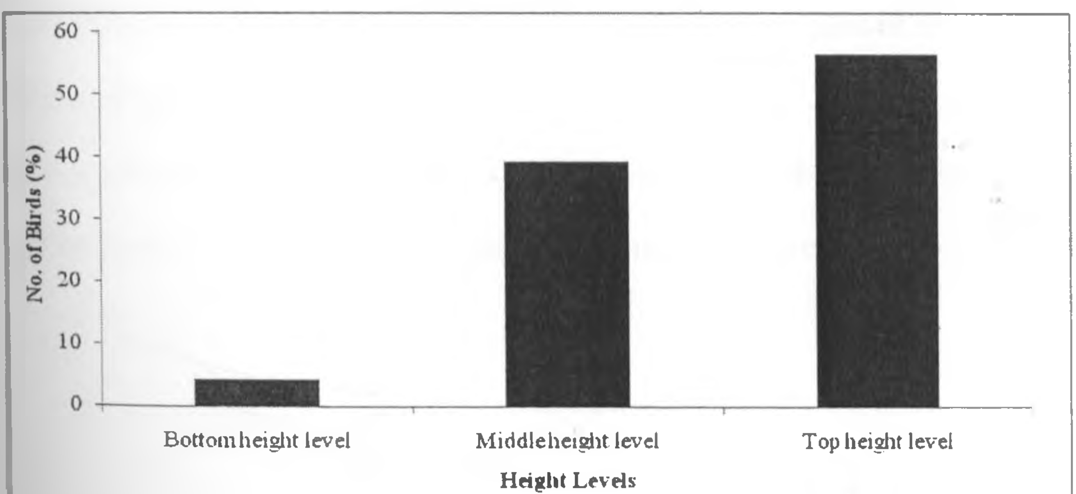

Figure 10: Number of birds in different flight height in farmlands adjacent to Kakamega forest, Western Kenya

4.9 Effect of height levels on birds habitation

Habitation by birds by height levels showed mixed results. In farms with sugarcane but without trees and farms with sugarcane and trees, birds preferred top height level while for farms with mixed crops birds preferred occupying the middle height level (Fig 11). The results also showed that bottom height level was the least preferred by birds in all categories of farms.

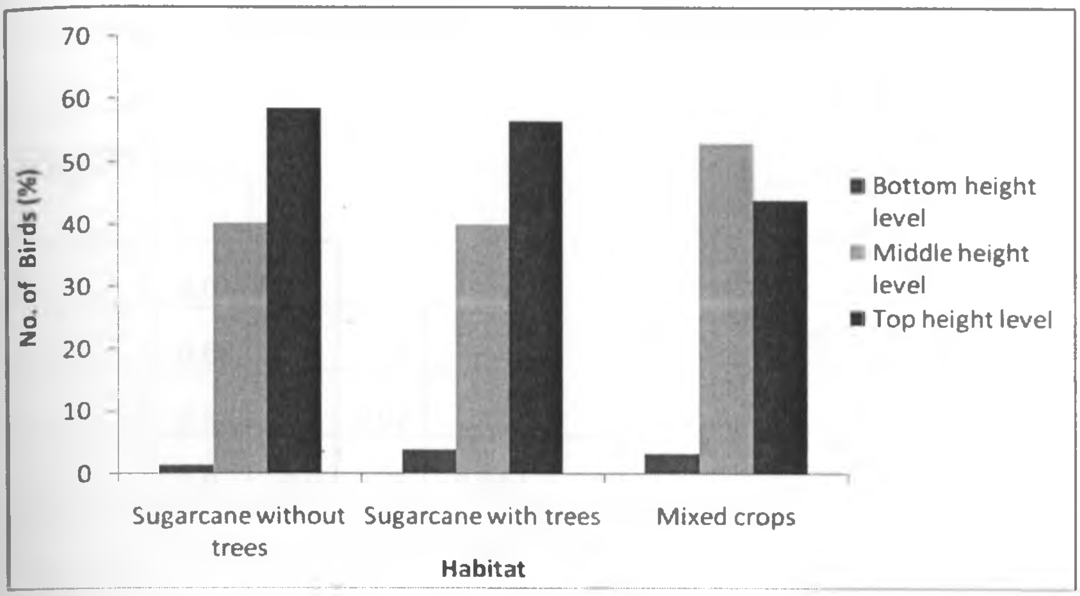

Figure 11: Birds distribution in three height levels in the three farmland habitats between Kakamega and kisere forests, Western Kenya

4.10 Overlap in habitat utilization by birds.

The results obtained from the proportional similarity between pairs of species in their habitat utilization patterns are shown in table 6. Complete habitat overlap (1) was observed in members of the same species while partial habitat overlap ($0<X<1$) was observed in all the bird species. No zero (0) values (which indicates no habitat overlap) were observed.

Table 6: Proportions of habitat utilization by birds in farmlands adjacent to Kakamega forest, western Kenya.

The values in the table are the habitat overlaps calculated using the equation 3.

SPECIES										
a	1									
b	0.01	1								
c	0.66	0.68	1							
d	0.8	0.96	0.02	1						
e	0.9	0.9	0.75	0.94	1					
f	0.01	0.46	0.75	0.88	0.01	1				
g	0.94	0.96	0.73	0.95	0.96	0.9	1			
h	0.66	0.64	0.32	0.62	0.58	0.56	0.03	1		
i	0.96	0.97	0.7	0.93	0.91	0.89	0.85	0.62	1	
j	0.77	0.78	0.86	0.78	0.85	0.76	0.68	0.42	0.0 1	1
SPECIES	a	b	c	d	e	f	g	h	i	j

Key for species; Key for species;

a=Barn Swallow

b=Black and white Mannikin

c=Common Bulbul

d=Black saw-wing Swallow

e=Speckled Mouse Bird

f=Eurasian Bee eater

g=Yellow fronted Canary

h=White Stock

i=Ring necked Dove

j=Yellow white eye.

Sixteen percent of the specie pairs involved showed low ($0.01 \leq C \leq 0.5$) habitat overlaps (Table 7). These showed tendencies to segregate and feed separately. Eighty four percent pairs reported almost complete overlap $0.5 \leq C \leq 1.00$. These showed high tendency of foraging together though their diet may have been different.

Table 7: Frequency and percentages of habitat overlaps, among different bird species in farmlands between Kakamega and Kisere forest, western Kenya.

Class of habitat overlap values obtained	**Frequency**	**Relative frequency (%)**
0.01-0.25	6	11
0.26-0.50	3	5
0.51-0.75	13	24
0.76-1.00	33	60
Total	55	100

4.11 Monthly variability in birds' abundance

Birds' abundance was recorded in all months during the study period. The month of November recorded the highest number of birds (16.9%), followed by October (15.74%) and December (15.59%), and January which recorded 15.46% respectively. February recorded 13.87% while March recorded 11.48%. The least number of birds was recorded in September (10.85%). Generally there was no significant difference (X^2=2.9, df=6, $P > 0.05$) in number of birds from one month to another during the period of study.

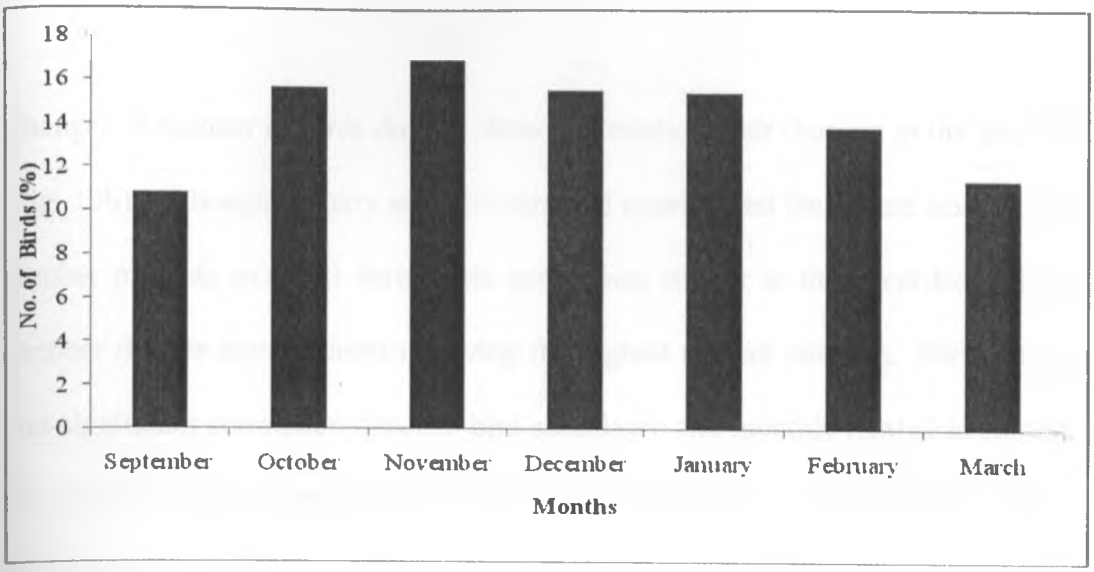

Figure 12: Monthly distribution of bids (September 2010-March 2011) in farmlands adjacent to Kakamega forest western Kenya.

4.12 Rainfall patterns

During the study period, the month of October received the highest amount of rainfall (147.4mm) followed by December (142.9 mm) and September (129.6 mm). January February and March received among the lowest rainfall amounts (14.4mm, 33.1mm and 50mm respectively) during data collection period (Fig 13a).

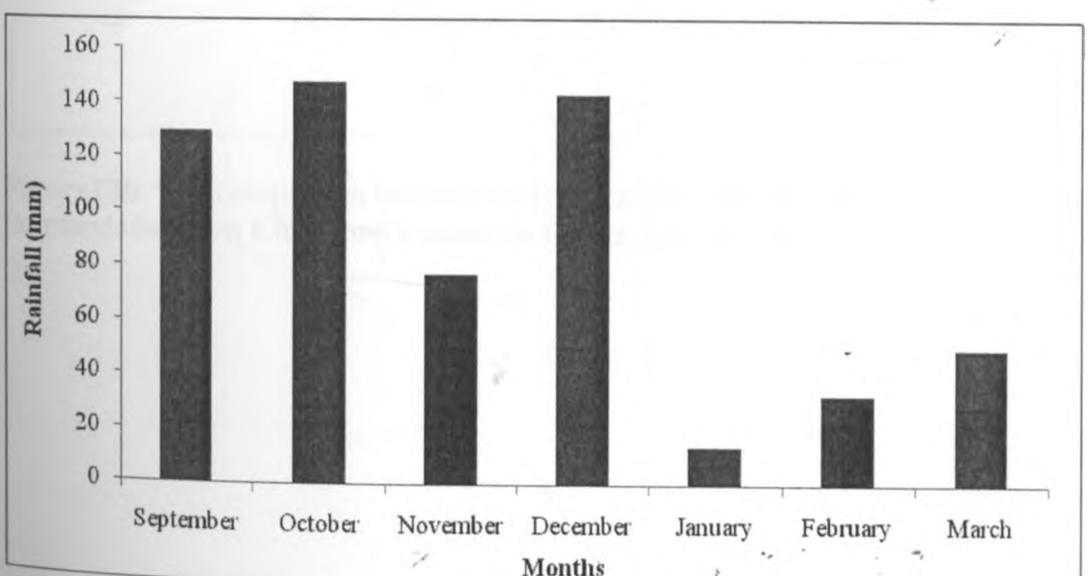

Figure 13a:Monthly rainfall (in percentages) for Kakamega forest during the study period (Sept 2010-March 2011).

Changes in number of birds did not show any relation with changes in the amount of rainfall (Fig. 13b). Although January and February had experienced the lowest amount of rainfall, the number of birds recorded during this period was similar to that recorded in December and October despite these months receiving the highest rainfall amounts. There was positive but non-significant correlation between bird abundance and monthly rainfall in Kakamega during the period of study (Pearson Correlation r = 0.037, n = 7, P>0.05). These results indicated that monthly changes in rainfall had very little effects on the abundance of birds in the study area.

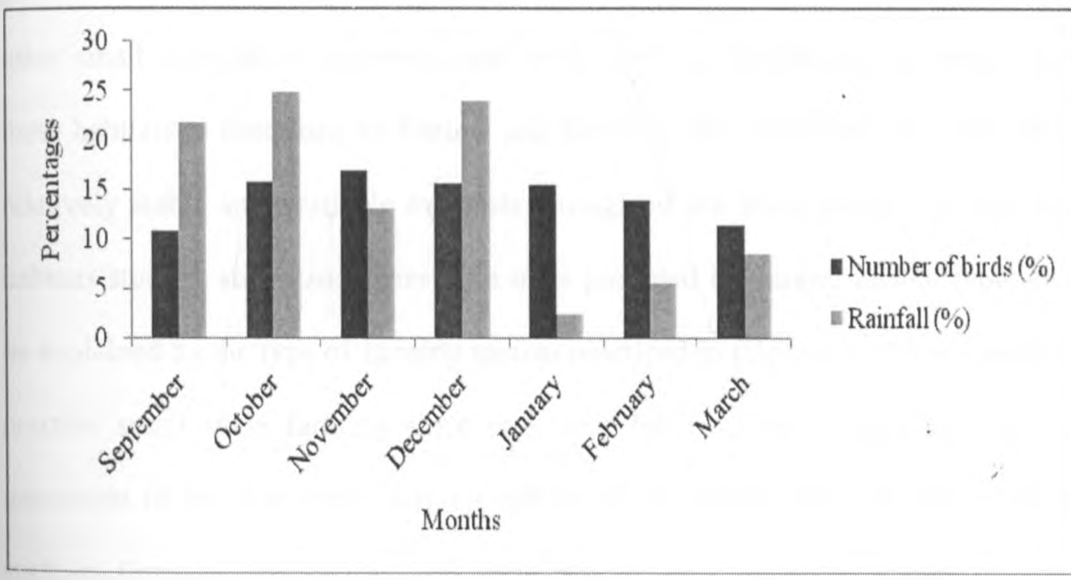

Figure13b: The comparison between birds' abundance and rainfall amount in farmlands between Kisere and Kakamega forests,western Kenya.

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Discussion

5.1.1 Habitat availability

Different crop cover types in the study area provided habitat availability for birds. The three farmland habitat types studied were important for provision of food, nesting, perching, and protection for birds. The sugarcane cover provided bushy kind of habitat which was suitable for birds nesting, and hiding. Sugarcane is also used as source of food (insects, aphids, and other small animals) by different birds hence the high biodiversity of birds experienced in these habitats as described by Ehrlich and Raven (1964). Furthermore, sugarcane cover was relatively stable and available for birds throughout the study period. Of the three types of habitats studied, sugarcane farms with trees provided the largest habitat type and this could be explained by the type of farming system practiced in this region. Most farmers in the area practice small scale farming since they rely fully on their farms for their living. The gazetment of the Kakamega forest hindered many people from accessing forest resources such as firewood and timber and these people were forced to engage in agro- forestry (Kokwaro, 1988). However, most birds tend to prefer farms with mixed crops compared to farms with sugarcane as a mono-crop (with or without trees). Farms planted with mixed crops provided a wide range of habitats for birds to nest, perch, and feed (Stolton and Geier, 2000). As coverage of mixed crops varied unpredictably as a result of farming activities and farmer preferences, different crops planted made this habitat to be available to different birds' species, which fed on a wide diversity of crops. These habitats provided a wide range of birds' requirements throughout the study period.

5.1.2 Birds abundance and Distribution

There were differences in number of birds in the three habitat types. These differences could be attributed to the differences in types of crops, presence or absence of trees, and other biodiversity present in the habitats. All these affected the food recourse availability and accessibility as well as nesting sites as described by Anord (2003).

In the farms with mixed crops, the high number of individual birds could be attributed to the different kinds of crops with their higher nutritional values, which did not only attract the large number of birds, but also attracted other small animals like insects which in turn attracted more birds to the habitat. Presence of trees in these farms and in sugarcane farms with trees attracted the high number of birds in these habitats compared to the farm habitat without trees. According to Uezu and Beyer (2008), trees are the stepping stones as birds fly from one farm to another and also from one forest block to another. Trees offer the nesting habitats at different heights and also regulate micro-climates which in turn generate micro-habitats. These micro-habitats influence the movement and habitation of different birds and other organisms (Bolwig *et,al.*, 2004). The lowest number of birds in the sugarcane farms without trees can be associated with lack of trees in this habitat. The birds' requirements that are provided by trees were unavailable in this habitat and therefore the birds that specifically depended on such requirements may have migrated to other habitats.

5.1.3 Species richness, evenness and diversity

The fact that the three farmlands gave almost high and similar birds' diversity indices means that all habitats not only recorded the big number of species, but also meant that the individuals were distributed equitably among these species. (Roth *et al.*, 1994). Similar diversity and evenness levels among the three farmlands was indication that all the three habitats were suitable as birds habitats; that birds were moving from one farm to another and that they did not colonize particular farm lands. That was also the reason for the three farmlands to record almost similar values of evenness. However; birds' movement is controlled by many factors, among them the availability of food, shelter, breeding habits, presence or absence of predators, and the capacity of birds to fly long distances (Magurran, 2004).

5.1.4 Field crops

From the current study it was found that, sugarcane formed the bulk (75%) of all the crops grown in the area. This could be explained by the high rainfall, high temperatures, the tropical hot conditions and well drained soils found in this area, as suitable conditions for the sugarcane crop growing. The mid-altitude position of the area is another suitable attribute for successful sugarcane establishment in this area (Bull, 2000). Apart from continuous canopy at maturity stage, sugarcane formed another habitat of the stems which were very tightly and closely packed together. This could have increased ecological niches for the bird species and their food; hence more diversity in the area. The effect of modified niches and high bird diversity could be further explained by the fact that sugarcane flowers are anemorphilous and therefore most of these birds could not be attributed to the presence or absence of sugarcane flowers. This characteristic was disadvantages to nectivorous birds in the area (Moore and Nuss, 1987).

The fruits like banana, pawpaw and tomatoes crops produced flowers, nectar and fruits, for birds and other animals in the area. The root crops like cassava, arrow roots, and sweet potatoes provided food for nematodes and other small animals as they fed on their leaves and roots. They also provided anti-predator cover for ground foraging birds and other small animals. The grains crops like maize produced the grains for granivorous birds to feed on directly hence more granivorous birds were found in farms with mixed crops. Vegetables provided good microhabitat cover for birds, insects, worms, aphids and other animals to live, feed and hide. All these factors made the mixed crop habitat to have high number of birds compared to other habitats.

5.1.5 Crop stages

Farmlands provide a wide range of variation in birds' habitats. Important sources of this variation include different canopies and crop vegetation structure (Holmes and Sherry, 2001). As one of the main influences on habitat structure, growth stages of crops can have a profound effect on bird assemblages (Brawn *et al.* 2001).

Of all the cropping stages, vegetative stage was the most dominant during the study. The reason for this was that most farms had sugarcane which was at its vegetative stage during the data collection period (In sugarcane farming this stage is known as grand growth phase). It is the most important phase of the sugarcane growth when the actual cane formation, elongation, and the yield build up occurs (Ramesh, 1986) and this is why this stage of growth takes a long period of about five to eight months. The high number of birds in the vegetative stage of sugarcane could be attributed to specific features associated with this growth stage of sugarcane (Giese and Cuthbert, 2003). The specific features include vegetation beneath the sugarcane plants, which provides good habitat for the lower canopy foraging bird species. The vegetative stage also provides suitable microhabitat for small animals on which birds come to feed on.

In the entire sampling period, flowering stage was the lowest in all farms sampled and this could be explained by the sugarcane harvesting which normally occurs before flowering. According to Bull, (2000) flowering would lead to the reduction in sugarcane weight as a result of reduction of the sugar content. This could be linked to the low diversity of birds and other animals which depend on flowers directly or indirectly.

In all the sugarcane growth stages, germinating stage recorded the lowest number of birds. According to Wilson *et al* (2006), the birds recorded in this stage are mainly pre-canopy closure, typically of open habitat and are usually specialized. Such birds require special conservation concern. At germinating stage most land is bare and the sun light hits the ground directly making it dry and unsuitable for many life forms. The birds had no place to hide, nest or rest hence the low number of birds recorded during this growth stage.

5.1.6 Feeding guilds

The feeding guilds identified during the study showed that insectivorous birds represented the highest percentage. The high number of insectivorous birds in all habitats was associated with the large number of insects present in this area as described by Lung, (2009). Being in tropical areas, the study area has a lot of plant diversity and many insects feed on these plants. As a result there is plenty of food for insectivorous birds in the area, which explains their large numbers compared to other groups of guilds in the area.

The granivorous, frugivorous and omnivorous birds were low in numbers, compared to insectivorous in all the three habitat types. The low number of these birds could be linked to their antagonistic relationship with farmers. The three types of birds are pests of the crops; hence man has kept their population low by application of pesticides, bird scare or use of other deterrent activities such as trapping to kill them or destruction of their nests (Dhindsa and Saini, 1994). During the data collection period food for granivorous and frugivorous was not plenty in the farmlands. Many crops recorded were not in fruiting growth stages to give out fruits, and seed. Farmers also, would not allow the wild plants in their farms to reach the stage of giving out fruits or seeds before they weed them out (Butler at el., 2007).This are another reason for the granivorous and frugivorous to be low in number compared to insectivorous.

Animals like snakes, frogs, rodents and scorpions which are fed on by carnivorous birds, are currently threatened by man as he encroaches into their habitats. Some of these animals are used by man as food, medicine, for superstitious activities and even for illegal trade (Silva *et. al.*, 2009).Invertebrates densities may be an order of magnitude low on farmland due to combined effects of mechanical damage during ploughing and loss of insulating vegetation (Atkinson *et. al.*, 2002). Decline in number of these animals affected the population of carnivorous birds in the farmlands.

Equally, the low number of nectivorous birds in the area can be explained by the types of crops and flowers, mode of pollination of the flowers, and the stage of crop growth recorded during the data collection period. The low levels of flowering plants could have deterred nectivorous birds from visiting the farms and pushed the birds to the forests where more diversity of flora was found (Barasa, 2006). Many of the crops recorded were non-nectar producing plants (such as sugarcane and maize); if they were nectar producing crops, may be their stage of growth was not at flowering (like the vegetative stage) and if they were at their flowering stage there were not birds pollinated flowers. According to Rodriguez and Santamaria (2004), for a flower to be pollinated by birds it should be large in size for birds to perch on; should produce a lot of nectar and bright colored (Usually red) for birds to recognize their presence.

5.1.7 Effect of height levels on birds' habitation

The height from ground in farmlands differ in many ways, including temperature, amount of sunlight they receive, the wetness of the environment and types of life forms inhabiting these strata. Birds use different height levels from the ground in several ways: for shelter, for nesting and for food (Barasa, 2006). Many birds have specific niches, either feeding on the bottom, in the middle, or in the top height level. Birds also have specific nesting preferences, with some birds preferring to nest up high, others in lower flight level and some in the middle level (Svein *et al.*, 2000).

In this study all the three height levels were exploited by birds. However, there was differential use of these height levels with most birds preferring the top and middle height levels, while only few preferred bottom height. The high number of birds in the middle and the top flight height could be attributed to the vegetation structure in the study area. The leafy environment and high amount of sunlight at the top height attracted many birds, insects, arachnids, and reptiles. The understory layer in the middle height level is a home of insects, lizards and snakes which also attracted the high number of birds in this level (Lowman and Wittman, 1996). The bottom level on the other hand receives very little amount of sunlight compared to the upper and middle flight heights. Only organisms that are adapted to low light can live in this height level (Pigdon, 2004) and this could be explained for the few birds found in this height level. The low number of birds in the bottom level in such farms could also be caused by, sugarcane leave mosaic that tightens the packaging at the bottom level in such a way that, many birds could not fly freely and as a result, they preferred the top height level where they could fly easily .The low number of birds in the bottom level in the mixed farms, could be attributed to the different activities performed by farmers like, ploughing, harrowing, weeding, which were disturbing the birds. There were neither stable places for nesting nor hiding for birds in bottom level in mixed crops farms.

Another reason for low number of birds in the bottom level could be the application of artificial fertilizers used by farmers which killed some organisms and also created unpleasant environment to birds and other organisms. (Michael *et al*, 2002) Due to this birds could have run to the other height level where the effect of the fertilizers was somehow low compared to that on the ground level.

5.1.8 The overlap in the utilization of habitats by birds.

Habitat overlap may result in space competition among members of the same species (Intraspecific competition) or of different species (Interspecific competition). According to the competitive exclusion principle, two species that use the same resource, in the same way, at the same time and space can not coexist (Hardin, 1960) and that they must diverge from each other in order for the two to coexist. In this case, birds use the available habitats differently in order to utilize limited resource and minimize competition for them to coexist.

In this study, there was complete habitat overlap between members of the same species. This is because the birds used the same type of resources and therefore visited the same habitat at the same time. According to Fry (2001), to avoid space competition while visiting the same habitat(s) in the area, birds used different canopy levels. Another mechanism which birds with complete habitat overlap use to avoid space competition is to visit the same habitat at different times of the day.

In this study, zero value which indicates no habitat overlap between two species in the area was not obtained. This was the indication that there was a general overlap in all birds' categories, suggesting that most birds shared at least two habitats among the three habitats. Zero overlap could occur between two species in which each one was visiting a particular habitat, which was not visited by the other species at all.

The other values of habitat overlap indicated that different species shared habitats according to availability and ability to compete. Some species used different resources in a variety of microhabitats as one of the mechanisms of avoiding space competition between members of different species. Another mechanism of avoiding space competition is for various birds species to adjust feeding strategies (as the Galapagos Finches did) to changing habitat conditions. This is the mechanism which was given by Charles Darwin as an important proof of the evolution theory (Grant, 2006)

5.1.9 Monthly variability in Birds' abundance

The variation in amount of rainfall from one moth to another, during the sampling period did not affect the number of birds. This can be attributed to the worm temperatures, rainfall throughout the year and drained soil types which encouraged plant and animal diversity in the study area (Lung, 2009) as explained earlier. These abiotic characteristics of the area lead to the availability of food for birds in the area all the year round. According to Bauer *et al.* (2006) food availability is the underlying process for birds' movement from one area to another. Presence of food in the area all the time caused birds not to migrate to other area from one month to another during the data collection period.

5.2 Conclusions and Recommendations

5.2.1 Conclusions

This study aimed to provide better understanding of the complimentary role of farmland habitats and adjacent tropical rain forests in the conservation of wild birds. The large number of birds (126 species) observed during the study period proved that the farmlands are very important in wild birds' conservation. The birds use these areas to feed, nest, perch, and to fly over. The farm lands between forests fragmentations are modified homes for disturbed birds from the original forests.

The study also found that the farmlands complement with conservation of wild birds. The farming methods in the area were friendly to birds conservation with only few modifications needed to be made. Continued farming of sugarcane as a monoculture in the area will eliminate the nectivorous birds from the area, hence reduction in birds' richness and diversity. The findings of this study were that mixed farming encouraged more bird guilds hence this type of farming should be encouraged for better management and conservation of birds. The study also found that farms with trees had large number of birds compared to the farms without trees hence agro-forestry should be encouraged.

Other biodiversity in farmlands apart from crops such as reptiles and amphibians are of great importance for birds' conservation in the area as they provide food for carnivorous birds. Wild plants in these farms provide fruits, grains, nesting sites, shelter, and protection. Any action of removing them completely from farms will affect the presence of birds especially in farms with sugarcane.

Overall it was found that the continued conversion of farms from mixed to monoculture is one of the reasons for the decline of birds especially the nectivorous. Also the over-reliance of farmers on sugarcane for commercial purpose has resulted to loss of traditional crops which supported a diversity of birds.

5.2.2 Recommendations

Based on results of this study, the following are suggestions for management actions that may mitigate loss of birds' biodiversity.

- With continuing climate change and increase in human population, there is need for more studies to be conducted on farmlands to find better ways of managing these areas, for the purpose of conserving not only birds but also other wild lives.

- Farmers should be encouraged to conserve all other life forms in their farms apart from their crops. Deforestation without planting of trees, frequent fire outbreaks in the abandoned farms or as a way of clearing their farms after harvesting should be discouraged.

- Management guidelines that govern the rules present on activities that directly threaten birds, such as the deliberate killing or capturing of birds, the destruction of their nests, taking of their eggs and trading in live or dead birds should be put into action and emphasized more.

- Public awareness through public barazas, seminars and workshops should be encouraged. More education is still needed for farmers for the purpose of wildlife conservation.

- Farmers' behavior or understanding towards the biodiversity around them apart from their crops is very important for birds' life conservation in the area.

- Mixed crop type of farming should be encouraged in the area, not only for the purpose of wild birds' conservation, but also for hunger and poverty eradication in the area.

REFERENCES

Alfredo,V., Dupont,L.,& Olesen,M.(2004).Birds-flower interactions in the Mecaronesian island.*J.Biogeogr*, **31**:1945-1953.

Allaby, M. (1999). *Biomes of the world*. Oxford, Anndromedia Limited.

Anord, G. (2003). Birds' species richness and abundance in Wandoo woodland and in trees plantation on farmlands at Baker's Hill,Western Australia. *Emu*, **103**: 259-269.

Askins, R.A., Lynch., & Greenberg (1990). Population decline in migratory birds in eastern North America. *Current Orthology*. **7**:1-57.

Atkinson, P.W., Fuller, R.J, & Vickery, J. A. (2002). Large- scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales. *Ecography*, **25**:466-480.

Barasa, F.M (2006). Bird species richness and abundance in different forest types of Kakamega forest, Western Kenya. Master of Science Thesis, Nairobi University, Kenya.

Bauer S., Madsen J. & Klaassen M. 2006. Intake rates, stochasticity, or onset of spring – what aspects of food availability affect spring migration patterns in Pink-footed Geese *Anser brachyrhynchus*? *Ardea*, **94(3)**: 555–566.

Bibby, C.J., Burges, N. D. & Hill, D. A. (1992). *Bird census technique*. London, Academic Press.

Blackett, H.L. (1994). Forest Inventory Report No.3. Kakamega Forest Department. /KIFCON, Nairobi Kenya.

Boening-Gaese, K. & Bauer, H.-G. (1996). Changes of Species Abundance, Distribution and Diversity in a Central European Bird Community. *Conservation Biology*, **10**:175-187.

Bolwig, S., Mushabe. D., Nkuutu, D.P., Pomeroy, D., & Tushabe. H. (2004). Biodiversity in Uganda's Farming Systems in Relation to Agricultural Intensification. *Research report submitted to the Strategic Criteria for Rural Investment in Productive programe, Uganda. International Food Policy Research Institute, Washington D. C. and Makerere University Institute of Environment and Natural Resources, Kampala.*

Brawn, J. D., Robinson, S.K. & Thompson, F.R. 2001. The role of disturbance in the ecology and conservation of birds. *Ann. Rev. Eco. System*, **32**: 251–276.

Broeker, W.S. (2006). Breathing easy, Et tu, O2. Columbia University, http://www.columbia.edu/cu/21stC/issue-2.1/broecker.htm.

Brooks, T. M, Pimm, S. L & Oyugi, J. O (1999). Time lag between deforestation and bird extinction in tropical forest fragments. *Conservation Biology*, **13**:1140-1150.

Bull,T.(2000). The sugarcane plant. *Bureau of Sugar Experimental Stations*, Indooroopily. Australia.

Butler, S. J., Vickery, J. A., & Norris, K., (2007). Farmland Biodiversity and Footprint of Agriculture. Science **315**: 381-384.

Chism, J. B. & Cords, M. (1998). De Brazza's Monkeys *Cercopithescus neglectus* in the Kisere National Reserve, Kenya. *African Primates*, **3**: 18-22.

Colwell, K.R., & Futuyma, J.D. (1971). On the measurement of niche breath and habitat overlap .*Department of ecology and evolution*, State university of New York, Stony Brook.

Cordell, H.K., & Herbert, N. K. (2002). The popularity of birding is still growing. *Birding*, **34**: 54-59.

Dale, S., Mork, K., Solgang, R., & Plumtre, A. J., (1998). Edge Effects on the Understory Bird community in a Logged Forest in Uganda. *Conservation biology*. **14**: 265-276.

Dhindsa, S. M., & Saini, K. H., (1994). Agricultural ornithology: an Indian perspective. Biosciences, **19 (4):**391-402.

Ehrlich, R.P., & Raven, H.P., (1964). Butterflies and plants. *Evolution*, **18**:586 - 608

Endo, K. (1993). Natsudori no uta wa ima? Sanseido ,Tokyo.

Emerton, L. (1994). Utilization of Kakamega forest reserve by adjacent households. KIFCON Social-Economic Report, Karura, Kenya, *Forest department*.

FAO. (2001). Food & Agriculture Organization – AFRICOVER Project: Kenya Land Cover. www.africover.org.

Ferrez, S. (2009). Using indicators of deforestation and land-use dynamics to support Conservation strategies: A case study of central Rondônia, Brazil. *Forest Ecology and Management*, **257**: 1586-1595.

Fry, H. (2001). "Family Meropidae (Bee-eaters)". *Mousebirds to Hornbills*. Barcelona: Lynx Edicions. pp. 286–325.

Gere, G. (1983). The role of birds in matter and energy flow of ecosystem. *Puszta*, **1**:10.

Glane, D.(2003). Space, Time and Life. *Biogeography*, **12**:400-409.

Giese, C.L.A. & Cuthbert, F.J. 2003. Influence of surrounding vegetation on woodpecker nest tree selection in oak forests of the UpperMidwest, USA. Forest *Ecol. Manage*. **79**: 523–534.

Gonzalez, J. G., Guevara,S. & Sosa,V.J. (1998). Bat-and Bird-Generated Seed Rains at Isolated Trees in Pastures in a Tropical Rainforest. *Conservation biology,* **14**:1693-1703

Grant, P.R. (2006). Darwin's Finches, Decent with modification and Natural selection. *Science,* **313**: 224-226.

Hardin, G. (1960). The Competitive Exclusion Principle. *Science,* **131**: 1292-1297.

Haward, E.W. (1967). Biological control of vertebrate pests. University of Calfonia, Lincoln.

Heath, M. & Rayment, M. (2001). Using data to develop biodiversity indicators for agriculture. Zurish, Switzerland.

Higuchi, H.& Morishita, E. (1999). Population Declines of Tropical Migratory Birds in Japan. *Manazuru marine Laboratory for Science Education,* **12**:51-59

Holmes, R.T. & Sherry, T.W. (2001). Thirty-year bird population trends in an unfragmented temperate deciduous forest: Importance of habitat change. *Auk* , **118**: 589–609.

Howe, H.F. (1986). Seed dispersal by fruit-eating birds and mammals. In: *Seed Dispersal* (ed. Murray DR), pp 123-189. New York, Academic Press.

Kenya Authority Processing Zone (2005). Athi river, Kenya.

Kenya Indigenous Forest Conservation Programme (1994). Kakamega Forest: Nairobi, Kenya, Forest Dept.

Kirika, M. J. (2005). Forest fragmentation effects on avian frugivores and Implications on seed dispersal and regeneration in Kakamega forest. Western Kenya. M.Sc., Thesis, Nairobi University, Kenya.

Khurshid, S. N. (2004). Ecological studies of waterfowl of Karachi coast. Masters of Zoology thesis, university of Karachi, Pakistan.

Kokwaro, J. O. (1988). Conservation status of the Kakamega forest in Kenya: the easternmost relic of the equatorial rain forests of Africa. *Monographs in Systematic Botany Missouri Botanical Gardens,* **25**:471-489.

Leso, P. & Rudolf, K. (2007). A comparison of three different approaches for the classification of bird foraging guilds: an effect of leaf phenophase. *Forest Protection and Wildlife Management,* **56(1):** 51–70.

Loiselle, B. A. & J. G. Blake. (2002). *Potential consequences of extinction of frugivorous birds for shrubs of a tropical wet forest. Ecology, Evolution and Conservation.* Oxford, UK, CABI Publishing.

Lowman, D.M & Wittman, K.P. (1996). Forest canopies: methods, hypothesis and future directions. *Ecological systems,* **27**:55-81.

Lung, M. (2009). An Analysis of Fragmentation Effects in Kakamega Forest in Relation to Reforestation Benefits: Working Paper. Eco2librium LLC.

Lung, T. & Schaab, G. 2002: Change-detection in western Kenya – the documentation of fragmentation and disturbance for kakamega forest and associated forest areas by means of remotely-sensed imagery. Department of Geoinformation, Karlsruhe University of applied science. Karlsruhe, Germany.

Lung, T. & Schaab, G. (2006). Assessing fragmentation and disturbance of west Kenyan rainforests by means of remotely sensed time series data and landscape metrics. *Afr J Ecology,* **44**:491-506.

Mann, C.F. (1985). An Avifaunal study in Kakamega Forest, Kenya, with a particular reference to species diversity, weight, and molt. *Ostrich*, **56**:236-262.

Magurran, A. E. (2004). Measuring biological diversity. Oxford, UK, Blackwell.

McDonald, Glen, M., (2003). *Biogeography: Space, Time and Life.* New York, John Wiley & Sons inc.

Michael, L., Bruce, G & Marcot. R. (2002). Wildlife and habitat relationships: Concepts and applications. Island press, USA.

Mitchell, N. (2004). BIOTA East Report #1: Exploitation and disturbance history of Kakamega Forest, western Kenya. Germany, TIB Hannover.

Mitchell, N., Schaab, G& Wagele J.W 2009.Kakamega forest ecosystem. An introduction to the natural history of human context. Biota report 5.

Moore, P. & Nuss, K.(1987). Flowering and flower synchronization. *Sugarcane improvement through breeding.* New York, Elsevier.

Mukherejee, A., Wilske, B. & Borad, K. (2007). The role of birds in matter and energy flow in the ecosystem. *The Raffles bulletin of zoology*, **55(1):**191-194.

Muriuki, J. W., and Tsingalia, M. H. (1990). A new population of de Brazza's monkey in Kenya.*Oryx*,**24**:157-162

Ntale, F.K. (2008). Institutional Dilemmas in Tropical Resource management. Dr.phl dissertation der Universität Leipzig. Forest Dept., Nairobi. Kenya

Otieno, N. E. (2007). Factors Influencing Diversity and Abundance of Farmland Birds Around Kakamega Forest in Kenya. Unpublished M.Sc., Thesis. Nairobi University, Kenya.

Oyugi, O. J.1988. Ecological forest fragmentation and avian population changes in Kakamega forest. M phil. Thesis, Moi University.

Peters, M. K., Fischer, G., Schaab, G., & Draemer, M. (2009). Species compensation maintains abundance and raid rates of African swarm-raiding army ants in rainforest fragments. *Biological Conservation* **142**:668-675.

Pigdon, K. (2004). Rainforest birds. United Kingdom, Horwitz garden limited.

Pimm, S.L., & Askins, R.A (1995). Forest losses predict bird extinction in eastern North America. Proceedings of the National Academy of Sciences of the U.S.A. **92**:9343-9347.

Primack, R.B. (1993). *Essentials of conservation biology*. 1st Edition Sunderland, Mass: Sinauer association.

Primack, R. B. (1998). *Essentials of conservation biology*. 2nd Edition. Sunderland Sinaur,

Ramesh, P. (1986). Sugarcane growth stages *.Agronomy and crop Science*, **185**:83-89.

Reuters, 20 June (2008), U.N. calls on Asian nations to end deforestation.

Robinson, S. K., Thompson, T. M., Donovan, D.R., & Faaborg, J.(1995). Regional forest fragmentation and the nesting success of migratory birds. Science **267**:1987-1990.

Rodriguez, M. & Santamaria, L. (2004) .Why are so many bird pollinated flowers red? *Evolution*, **2(10)**: 350-378

Roth, D. S., I. Perfecto, and B. Rathcke. 1994. The effects of management systems on ground-foraging ant diversity in Costa Rica. *Ecological Applications* **4(3)**:423-436.

Rukosawa, R. & Askins, A .R. (2003). Effects of Habitat Fragmentation on Birds in Deciduous Forest in Japan. *Conservation Biology*, **17**: 695-707.

Science Daily, August 14, 2007. Rainforest Biodiversity Shows Differing Patterns

Science Daily, August 14, 2007. Rainforest Biodiversity Shows Differing Patterns

Seedikkoya, K., Azeez, P.A. & Shukkur, E.A. A., (2005). Cattle Egret *Bubulus ibis* Habitat use and Association with cattle. *Forktail*, **21**:174-176.

Silva, P. J., Tolan, J. & Jones. W., (2009). LIFE and Europe's reptiles and amphibians: Conservation in practice. European Commission (Life Unit). ISBN 978-92-79-12567-6. Doi: 10.2779/48925.

Stolton, S. & Geier, B. (2000). Relationship between Biodiversity and Organic agriculture: Defining policies and approaches for sustainable agriculture. www.equillibriumresearch.com .

Svein, D., Kjetil, M., Rune, S. & Andrew, J. P. (2000). Edge effects on Understory Bird Community in a Logged forest in Uganda. *Conservation Biology*, ***14**:265-* 276.

Temple, S.A., & Wilcox, A.B. (1986). Predicting effects of habitat parchness and fragmentation. *Verner, J. Morrison, M.L. and C. J. Ralpha, (Eds,* University of Wisconsin press Modison, pp 261-262.

Tsingalia, H. M. & Kassily, F. N. (2009). The Origins Kakamega Forest Grassland: A critical Review. Masinde Muliro University, Kakamega. *Biological sciences,* **27(2):**129-135.

Uezu, A ., Beyer, D.D, & Metzger, P. J. (2008). Can agro forest woodlots work as stepping stones for birds in the Atlantic forest region? *Biodiversity and Conservation.,* **17(8):**1907-1922.

Wilson, W. R., Pithon, J., & Gittings, T., (2006). Effects of growth stages and tree species composition on breeding bird assemblages of plantation forest. *Bird study,* **53**:225-236.

Zar, J. H. (1996). *Biostatistical Analysis.*3rd edition. London, Prentice-Hall.

Zimmerman, D., Turner, A., & Pearson, D. (1999). *Birds of Kenya and Northern Tanzania*. London, Christopher Helm.

Zimmerman, D. A. (1972). The avifauna of Kakamega Forest, Western Kenya, Including bird population study. *Bulletin of American Museum of National History.*, **149**: 259-339.

APPENDECIES

Appendix 1: Birds species observed during the study period (September 2010-March 2011).Names (English or scientific) follow Zimmerman *et al* 1999.

English name	Scientific name
African blue Flycatcher	*Elmina longicauda teresita*
African Citril	*Serinus citrinelloides*
African blue/pale/ashy grey Flycatcher	*Muscicapa caerulescence*
African Dusky Flycatcher	*Muscicapa adusta*
African Emerald Cuckoo	*Chysococcyx c. cupreus*
African Firefinch	*Lagonosticta rubricata*
African Green Pigeon	*Treron calva*
African Grey Flycatcher	*Bradormis microrhynchus*
African Harrier Hawk	*Polyboroides t. typus*
African Pied Wagtail	*Motacilla aguimp vidua*
African Pygm Kingfisher	*Ispidina picta*
African Thrush	*Turdus palios centralis*
Angola Swallow	*Hirundo angolesins*
Augur Buzzard	*Buteo a. augur*
Baglafetch Weaver	*Ploceus baglafetch*
Bandade Snake Eagle	*Circaetus cinerascens*
Barn Swallow	*Hirundo r. rustica*
Black Bishop	*Euplectes gierowii*
Blackcap	*Sylvia atricapilla*
Black-and-white- casqued Hornbill	*Bycanistes subcylindricus*
Black- headed/Village Weaver	*Ploceus cucullatus*
Black-lored Babbler	*Turdoides sharpei*
Black-and-white/ Jacobin Cuckoo	*Oxylophus jacobinus*
Black -and-white Mannikin	*Lonchura bicolar*
Black-billed Barbet	*Lybius guifsobalito*
Black- crowned Tchagra	*Tchagra s. senegala*
Black-crowned Waxbill	*Estrilda n. nonnula*
Black-headed Heron	*Ardea melanocephala*
Black Kite	*Milvus migrans*
Black Saw/rough -wing-Swallow	*Psalidoprocne holomelas*
Blue-spotted Wood-Dove	*Turtur afer*
Bocage's Shrike	*Melaconotus bocagei jacson*
Bronze Sunbird	*Nectarinia k. kilimensis*
Brown Babbler	*Turdoides plebejus cinereus*
Brown-backed Scrub-Robin	*Cercotrichas hartlaubi*
Brown-crowned Tchagra	*Tchagra autralis*
Brown Parrot	*Poicephalus meyeri*
Cardinal Woodpecker	*Dentropicos fulscescens*
Chubb's Cisticola	*Cisticola chubbi*
Cinnamon-chested Bee -eater	*Merops oreobates*

Common Bulbul	*Pycnonotus barbatus*
Common Fiscal (Fiscal Shrike)	*Lanius collaris humeralis*
Common House Martin	*Delichon u. urbica*
Common Stonechat	*Saxicola torquata axillaris*
Common Wattle -eye	*Platysteira cyanea nyansae*
Common Waxbill	*Estrilda astrild*
Crowned Hornbill	*Torcus alboterminatus*
Diederik Cuckoo	*Chrysococcyx caprius*
Double-toothed Barbet	*Lybius bidentatus aequatorialis*
Eastern Grey Plantain-eater	*Crinifer zonurus*
Eurasian Bee-eater	*Merops apiaster*
Fischer's Lovebird	*Agapornis fischeri*
Francollins	*Francollins spp*
Grassland Pipit	*Anthus cinnamomeus*
Great Sparrowhawk	*Accipiter melanoleucus*
Green-headed Surnbird	*Nectarinia verticalis*
Green-throated Sunbird	*Nectarinia rubescens*
Grey-backed Cameroptera	*Cameroptera brachyura*
Grey Crowned Crane	*Balearica regulorum*
Grey- headed Negrofinch	*Nigrita canicapilla*
Grey- headed Sparrow	*Passer griceus*
Grey Woodpecker	*Dentropicos goertae*
Grosbeak-Weaver	*Amblyospiza albifrons*
Hadada / Hadeda Ibis	*Bostrychia hagedash*
Hamerkop	*Scopus u. umbretta*
Helmeted Guineafowl	*Numida meleagris*
Isabelline Wheater	*Oenanthe isabellina*
Joyful Greenbul	*Chlorocichla laetissima*
Klaas's Cuckoo	*Chrysococcyx klaas*
L'esser Honeyguide	*Indicator minor teitensis*
Lesser Striped Swallow	*Hirundo abyssinica*
Little Swift	*Apus a. affinis*
Macknnon's Fiskal	*Lanius mackinnoni*
Mosque Swallow	*Hirundo senegalensia*
Long-crested Eagle	*Lophaetus occipitalis*
Nothern Black Flycatcher	*Melaenornis edolioides*
Nothern Double-collared Sunbird	*Nectarinia preussi kikuyuensis*
Nubian Woodpecker	*Compethera nubica*
Olivaceous Warbler	*Hippolais pallid elaeica*
Pale Flycatcher	*Bradornis pallidus*
Pied Crow	*Corvus albus*
Pin- tailed Whyda	*Vidua macroura*
Purple Starling	*Lamprotarnis pupureus*
Red-billed Firefinch	*Lagonosticta segegala ruberrima*
Red- cheeked Cordon-bleu	*Uraeginthus bengalus*
Red-chested Cuckoo	*Cuculus solitaries*

Red-headed Lovebird	*Agapornis pullarius ugandae*
Red-winged-Starling	*Onychognathus morio*
Ring-necked Dove	*Streptopelia capicola*
Ross's Turaco	*Musophaga rossae*
Scarlet-chested Sunbird	*Nectarinia senegalensis*
Senegal Coucal	*Centropus s. senegalensis*
Snowy-crowned Robin-Chat	*Cossypha niveicapilla*
Speckled Mousebird	*Colius striatus*
Speke's Weaver	*Ploceus spekei*
Spotted Morning Thrush	*Cichladusa guttata*
Singing Cisticola	*Cisticola cantans*
Tambourine Dove	*Turtur tympanistria*
Tawny-flanked Prinia	*Prinia subflava*
Tropical Boubou	*Laniarius aethiopicus*
Variable Sunbird	*Nectarinia venusta*
Vieillot's Black Weaver	*Ploceus n. niggerimus*
Violet-backed Starling	*Cinnyricinclus leocogaster*
Whistiling Cisticola	*Cisticola latelaris antinorii*
White headed saw-wing Swallow	*Psalidoprocne a.albiceps*
White-browed Robbin-chat	*Gossypha heuglini*
White-chinned Prinia	*Prinia leucopogon*
White-eyed Slaty Flycatcher	*Melaenornis fischeri*
White Stork	*Ciconia ciconia*
Willow Warbler	*Phylloscopus trochilus*
Wire-tailed Swallow	*Hirundo s. smithii*
Woodland Kingfisher	*Halcyon senegalensis*
Yellow Wagtail	*Motacilla flava*
Yellow- fronted Canary	*Serinus mozambicus*
Yellow-mantled Widowbird	*Euplectes macrourus*
Yellow-rumped Tinkerbird	*Progoniulus bilineatus*
Yellow- spotted Barbet	*Buccanodoa d. duchaillui*
Yellow-throated Leaf-love	*Chlorocichla flavicollis*
Yellow-throated Longclaw	*Macronyx croceus*
Yellow White-eye	*Zosterops senegalensis*

Appendix 2. Crop species observed in the study area

Local names	Scientific names
Nduma	*Culcasia sp.* Engl.
Bananas	*Musa sapientum* L.
Beans	*Phaseolus vulgaris* L.
Black night shade	*Solanum nigrum* L.
Cabbage	*Brassica oleracea var.oleracea* L.
Coffee	*Coffea arabica* L.
Coriander	*Coriandrum sativum* L.
Cowpeas	*Vigna unguiculata* (L.) Walp.
Guava	*Psidium guajava* L.
Irish potato	*Solanum tuberosum* L.
Kales	*Brassica oleraceae var.botrytis* .
Maize	*Zea mays* L.
Millet	*Eleusine coracana* (L.) Gaertn.
Nappier grass	*Pennisetum purpureum* Rich.
Onions	*Allium cepa* L.
Pawpaw	*Carica papaya* L.
Pepper	*Capsicum frutescens* L.
Sorghum	*Sorghum vulgare* Pers.
Spider herb	*Gynandropsis gynandra* (L.)Briq.
Spinach	*Spinacia oleracea* L.
Sugarcane	*Saccharum officinarum* L.
Tea	*Camellia sinensis* (L.)Kuntze
Tomatoes	*Lycopersicon esculentum* Mill.

Appendix 3: GPS points used as central points in sampling sites on the map

Divisions	GPS points	Habitat type for the sampling site.
1	705228,42488	Sugarcane without trees
	706001,41255	Mixed crops with trees
	706000,42000	Sugarcane with trees
2	706631,41218	Mixed crops with trees
	706571,41086	Sugarcane with trees
	707000,42000	Sugarcane without trees
3	707506,40735	Sugarcane without trees
	708003,41676	Sugarcane with trees
	708000,43000	Mixed crops with trees
4	708238,39677	Sugarcane without trees
	708629,40728	Mixed crops with trees
	708495,40710	Sugarcane with trees

Appendix 4: Ten bird species and the proportions used to calculating habitat overlap in farmlands between Kakamega and Kisere forests.

Species name	habitat1	habitat 2	habitat 3	frequencies
Barn Swallow	220	219	216	655
	0.33587 8	0.33435 1	0.32977 1	
Black and white Mannikin	187	198	201	586
	0.31911 3	0.33788 4	0.34300 3	
Common Bulbul		221	215	436
	0	0.50688 1	0.49311 9	
Black saw-wing Swallow	130	124	156	410
	0.31707 3	0.30243 9	0.38048 8	
Speckled Mouse bird	95	120	158	373
	0.25469 2	0.32171 6	0.42359 2	
Eurasian Bee eater	101	171	133	405
	0.24938 3	0.42222 2	0.32839 5	
Yellow fronted Canary	128	160	178	466
	0.27467 8	0.34334 8	0.38197 4	
White Stock	210	100		310
	0.67741 9	0.32258 1	0	
Ring necked Dove	92	115	102	309
	0.29773 5	0.37216 8	0.33009 7	
Yellow white eye	31	114	163	308
	0.10064 9	0.37013	0.52922 1	

Key for appendix 3.

Habitat 1= Sugarcane without trees

Habitat 2=Sugarcane farms with tree

Habitat 3=mixed crops with trees.

Appendix 5: Different trees recorded in farmlands in Kakamega during the study Period.

Scientific names
Albizia grandibracteata
Blighia unijugata
Bridelia micrantha
Carica papaya
Celtis africana
Citrus sinensis
Cordia africana
Cupressus lusitanica
Diospyros abyssinica
Eucalyptus saligna
Ficus thoninngii
Ficus lutea
Ficus vallis-choudea
Grevillea robusta
Groton marostachyus
Harungana madagascariensis
Leucaena spp.
Mangifera indica
Markhamia lutea