DIVERSITY AND ABUNDANCE OF BEE POLLINATORS VISITING HEDGEROW PLANTS IN THE FARMLANDS BORDERING KAKAMEGA FOREST

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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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To my wife Wambui and children Christine, Dennis and Kevin

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA – Analysis of Variance

BIOTA - Biodiversity Monitoring Transect Analysis in Africa.

°C – Degrees Centigrade

E.A. – East Africa

Ha -Hectare

KARI- Kenya Agricultural Research Institute

Km – Kilometre

LSD – Least Significance Difference

m – Metre

MOA – Ministry of Agriculture

MOALD – Ministry of Agriculture and Livestock Development

m/s – Metre per second

mm – Millimetres

NARL- National Agricultural Research Laboratories

NMK – National Museums of Kenya

p.a. – Per annum

RH – Relative Humidity

SPSS – Statistical Software for Social Scientists.

ABSTRACT

The study was carried out in Kakamega farmland, north of the Kakamega forest, from October 2008 to March 2009, in order to determine the diversity and abundance of bee pollinators that forage on flowers in the hedgerows, and the major bee plant species. Fourty hedgerow transects measuring 50m each were selected and marked in the farmland. Five land use categories i.e, forest, roads, sugarcane, grazing and maize/beans production were used as a criteria for transect selection, hedgerow plant composition was also considered. Each of the transect was sampled twice a month for the bees visiting the flowers from October 2008 to March 2009. During sampling all the bees foraging on the flowers of the plants in the hedgerow were recorded, together with the plant species visited. Each sampling took 40 minutes. All the bees that could not be identified on site were captured using standard sweepnets, kept in killing jars and labelled with a code. Later the bees were pined in the insect pinning boxes for identification at the NMK. Similarly, specimen of the plants that could not be identified were collected and labelled with similar codes for further identification. The results indicate a significant variation both in bee diversity and abundance across the five land uses. A total of 82 bee species belonging to three families, i.e. Apidae, Megachilidae and Halictidae were recorded on hedgerow flowers. Apidae was the most diverse family having 42 bee species with *Apis mellifera* being the most frequent visitor. The megachilidae and halictidae families had 20 species each. *Xylocopa* species mostly visited *Justicia flava, Caesalpinia decapetala* and *solanum incanum* plants while most *Meliponula* species visited *Tithonia diversifolia* flowers.The plant species/family in the hedges had significant variation both in the number of bee species (diversity) and individuals (abundance) for all the bees except Megachilidae. The most important bee resource plants in the hedgerows based on the number of indviduals that visited the flowers are in the Acanthaceae family represented by *Justicia flava, Asystasia gangtica and Acanthus pubescens,* Asteraceae family represented by the species *Tithonia diversifolia, Craessocephallum vitellinum and Aspillia mossambicensis* and the species *Caesalpinia decapetala* in the Fabaceae family. From the results obtained from this study it can be concluded that hedgerow plants play an important role in providing food resources (nectar and pollen) for various species of bee pollinators, and can be used for their conservation in the farmland.

CHAPTER 1

1: INTRODUCTION

1.1 Background Information

Food security is a high priority in many developing countries like Kenya. Most of these countries have put in place various programmes whose objective is to increase food production in order to ensure food security to their people. This is in line with the United Nations Millennium Development Goal No.1 (MDG 1), which aims to reduce extreme hunger and poverty by half by the year 2015. In these countries efforts in increasing food production and improving food security have, over the years, been directed to almost all production inputs except pollination. For many years crop pollination has been taken for granted and indeed not in any way associated with the improvement of crop yields. However, there is evidence that insufficient pollination results in low yields (Kasina *et al.*, 2009a). Pollination is an important agricultural input, just as other inputs like seed, fertilizers, machinnery, pesticides and herbicides. These inputs have also been given priority in policy formulation and the importance of pollination in agricultural production has been underscored.

Pollination is an ecosystem service that involves the transfer of pollen grains from the anthers of the male floral organ (stamen) to the stigma- the receptive surface of the pistil (female floral organ) either of the same or another flower or plant of the same species. Once the pollen gets into contact with the stigma, one of the pollen cells germinates and forms the pollen tube through which the male nuclei necessary for fertlilization moves to the ovules. This precedes fertilization of the ovules and seed formation, making pollination a critical precursor to sexual reproduction in plants (Kasina *et al.*, 2009a). Biotic pollination is important for agricultural production. Indeed, animals provide pollination services for over three-quarters of the staple crop plants that feed human kind and for 90% of all flowering plants in the world (Ingram *et al.*, 1996). About a third of all food and other wild plants would not exist without pollinators. Bees are the most important insect pollinators, pollinating about 75% of the most cultivated crops. Other pollinators include: flies (19%), bats (7%), wasps (5%), beetles (5%), birds (4%), butterflies (4%) and moths (Maheshwari, 2003). This is because any one bee is likely to visit only flowers of the same plant species on a single foraging trip. As a result, all insects managed for crop pollination are bees, with honey bee (*Apis mellifera*) being the most widely used. It has been observed that pollinators and pollination are very crucial in the functioning of almost all terrestrial ecosystems and are indicators of biodiversity loss (Kearns *et al.*, 1998). It is therefore evident that without pollinator service ecosystems, humans, animals and plants would lose their life support.

Agricultural intensification and the use of modern production technologies have greatly reduced the number of bees and other wild pollinating animals (Kremen *et al.*, 2002). The main food resources for the bees (nectar and pollen) are obtained from flowers of different plant species. Bees also require plants for other purposes such as nesting material, hiding, resting, protection and mating. Undisturbed habitats provide the most suitable environments for different bee species as they have enough dead logs, leaves, holes left by wood-boring beetles, tree cavities, pithy hollow plant stems, abundant rodent burrows, soils with suitable texture, vegetation cover and mositure (Cane, 2001). Human activities have disturbed or modified the habitats resulting in reduction in bee species and abundance (Richards and Kevan, 2002).

In agricultural production systems habitat modification may include fragmentation of the habitats such as forests, establishment of monocultures especially of non-nectar bearing cereals that replace native forage, overgrazing, land/vegetation clearing, irrigation and mechanical cultivation (Plate 1).

Plate 1: Sugarcane cultivation (a monoculture) (pink arrow) in the farmland adjacent to the Kakamega forest (yellow arrow)

Introduction of allien species, such as honey bees may lead to competition and displacement of the indigenous bee species (Cane, 2001). Moreover, certain crop management practices such as spraying of pesticides, herbicides or smoking kill or repel foraging bees, especially when applied during the flowering period when bee activity is at the peak (Kearns *et al.,* 1998). There is therefore need for a deliberate effort in incorporating strategies that will preserve suitable habitats for bees and other pollinators in the agricultural production systems. One of the important strategies that may be applied in conservation of bee pollinators in the farm landscapes is the use of hedgerows (Banaszak, 1992)

1.2 Problem statement

High diversity of bee species has been recorded in the Kakamega forest and the sorrounding farmlands (Gikungu, 2006). However, due to continued disturbance resulting mainly from the intensification of farming activities in the area, the future of this diversity and thus provision of sufficient pollination to crops in the agricultural landscape cannot be guaranteed (Biota, 2004). Nevertheless, the farming system can be managed in such a way that the habitats for the bees and other pollinators are provided and maintained. There is therefore need for a deliberate effort in incorporating bee conservation strategies in the agricultural production systems. Use of hedgerows has been identified as one of the strategies that can be used in bee pollinators conservation in Kakamega farmlands (Kasina *et al.*, 2009b). However, studies in the use of hedgerows for conservation of bees and other pollinators have been done in developed countires such as United Kingdom (Matheson, 1994) and Poland (Banaszak, 1992). No such studies have been done in Kenya and the information genereated from such studies cannot be transfered to developing countries due to differences in ecology. Moreover the pollinators may differ from one region to another. This study aims to bridge this information gap and elucidate the use of hedgerows in the conservation of bee pollinators in the Kakamega farmlands.

1.3 Justification

Most developing countries, Kenya included, do not have managed pollinator services and depend on wild pollinators to provide the pollination service (feral pollination) (Kasina *et al.*, 2009a). Most of the pollination studies have been conducted in the developed countries, where the high input agriculture relies mainly on managed bees for pollination, in line with research findings that indicate the pollination requirements of specific crops (Kasina *et al.*, 2009a). Very few such studies have been done in developing countries like Kenya. In the low input farming practised in most developing countries, production inputs such as seed, soil fertility, fertilizers, water and crop protection products have been given priority in policy formulation, while the importance of pollination in crop production has been ignored. Research has also been biased in favour of the other production factors, almost masking the role of polllination (Free, 1999). There is therefore need to improve and increase the knowledge available on the pollination service as an important input in agricultural production, and to develop appropriate conservation strategies.

Bees have been shown to be the most important among the insect pollinators (Maheshwari, 2003). However, modern agricultural production technologies and other land use systems have continued to disturb and/or modify the pollinator habitats, resulting in the reduction of bee species and their populations. Farmers in Kakamega region do not manage bees for pollination of their crops but unconsciously depend on the pollination service from the nearby habitats. Studies done in Kakamega forest (Gikungu, 2006) reported a high diversity of bee species in the forest (243 species) and its environs visiting flowers. However, due to the continued fragmentation of the forest and intensification of agricultural activities in the sorrounding farmlands, the pollination service provided by the forest is threatened (Biota, 2004). Live fences or hedgerows have been found to be a unique feature in many farmlands in Kenya, especially the study area, Kakamega region. The hedgerows are rich in different plant species and if well managed could form areas of floral and structural diversity that can provide temporal and spatial needs of different bee species, by ensuring through-out the year availability of forage, especially when the crops are off-season. Management of these hedgerows is one of the strategies that can be used to enhance bee population and species diversity. This will improve crop pollination leading to increased crop yields. The purpose of the study is therefore to investigate and establish the role played by the hedgerows as one of the strategies in the conservation of bees in Kakamega farmlands that can also be applied in other areas with similar farming practices. The research will endevour to give solutions and recommendations on the use and management of hedgerows, as a cost effective and multi-purpose strategy, for the on-farm conservation of polliantors that is available to the farmers. The information obtained in the study may be useful in policy formulation for the conservation of bee pollinators, for increased crop productivity, not only in the study area but also in other areas with similar agroecosystems.

1.4 Objectives

Overall objective

To evaluate hedgerows as a management strategy for the conservation of bee pollinators in the farmland adjacent to Kakamega forest

Specific objectives:

1 To determine the species composition and abundance of bee pollinators visiting hedgerow plants in farmlands adjacent to Kakamega forest

2 To identify the major bee resource plant species in the hedgerows in the farmlands adjacent to Kakamega forest

1.5 Research questions

(i) Does the presence of hedgerows in the farmland act as restoration/conservation sites for bee pollinators?

(ii) What plant species are found and/or grown along the hedgerows?

(iii) Which bee species visit flowers in the hedgerows?

(iv) How abundant are the bee species in the hedgerows?

(v) What are the most important bee resource plant species in the hedgerows?

(vi) Does land use system in the farmlands affect bee diversity and abundance?

(vii) Does the weather parameters (temperature and wind speed) affect the bees foraging activties in the hedgerows.

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CHAPTER 2

2: LITERATURE REVIEW

2.1 Pollination service

The pollination of flowering plants is one of the important life-support services provided by biological processes in the ecosystem. This service ensures continuity and sustainability of the biodiversity in the ecosystem. Without pollination by animals, most flowering plants would not reproduce sexually; this would result in loss of food and other plant products necessary for human and animal life (Kearns *et al.,* 1998). More and better quality seeds usually develop when a large number of pollen grains are transfered and sufficient pollination is achieved. Seeds in turn stimulate sorrounding ovary tissues to develop such that, a fruit with many seeds, for example, will be larger than one with fewer seeds. In this way, good pollination improves not only seed set but also fruit yield. Many plants cannot set seeds or fruits without fertilization and in turn fertilization cannot occur before the pollen comes into contact with the stigma (pollination). This plant-pollininator interaction is essential for the survival of both natural ecosystems and agroecosystems.

2.2 Economic value of pollination service

The ecosystem services provided by pollinators include pollination of agricultural crops and wild plants. One measure of the immense value of ecosystem services is monetary value. However, it is difficult to estimate the monetary value of pollination in both agricultural crops and the natural plant communities, most attempts to estimate the economic value of pollination have therefore focused on agricultural production. An annual global value of pollination has been placed at US$ 120 billion (Constanza, 1997). Richards (1993) estimated the value of pollination service for the global agriculture to be US$ 200 billion while in USA alone the value of pollination has been reported to vary between US$ 4.5 and US$ 18.9 from 1960s to 1980s. (Morse and Calderone, 2001). The value of pollination by the honey bee has been reported to be US$ 321 million annually in the U.K. (Carreck and Williams, 1998) and to vary from US$ 0.5 billion to US$ 1.4 billion in Australia (Gordon and Davis, 2003). The economic importance of pollination, and its aesthetic and ethical values, makes it clear that the conservation of pollination systems is an important priority.

2.3 Role of pollinators in Agriculture and the ecosystem

Biotic pollination is important for the production of agricultural goods and in the ecosystem. Animals, including insects, pollinate over three quarters of the staple crops that feed human kind, and over 90% of all flowering plants in the world (Buchman and Nabhan, 1996; Maheshwari, 2003). It is also estimated that about a third of all the total human diet in the developed countries is derived from insect pollinated plants and the proportion is also considerable in the other countries (Goulson, 2003). About a third of all our food and other wild plants would not exist without pollinators (Maheshwari, 2003). The degree of dependence on insect pollination varies widely with different crops (Table 1). Pollinators have been cited as crucial for the functioning of almost all ecosystems (Kevan, 1999). They can be used as bioindicators to monitor ecosystem health and envronmental stress brought about by factors such as introduced competitors, diseases, parasites, preditors, chemical pollution and habitat modification (Kevan, 1999). Honeybees, for example, have been used to assess atmospheric and other types of pollution in the environments in which they are kept.

Table 1: Degree of dependence of selected crops on insect pollination

Crop	Crop insect dependence	Expected % crop loss estimate
Apple	1.0	80
Asparagus	1.0	90
Avocado	1.0	20
Carrot seed	1.0	90
Cabbage seed	1.0	60
Cotton seed	0.2	30
Cucumber	0.9	60
Soybean	0.1	10
Sunflower	1.0	80
Water melon	0.7	40

Value 0.1 – 1.0 is the scale of increasing crop dependence on insect for cross pollination(William, 1994; Southwick and Southwick, 1992)

Recent studies show that bee pollination not only enhances the yield of most crops in the farmlands but also improves the quality of the produce, consequently improving food security and farm incomes (Kasina *et al.*, 2009, Nderitu *et al.*, 2008). A study by Kasina *et al (* 2009b) in the Kakamega farmlands, Western Kenya, indicates that although some crops can produce without bee pollination, increase in yield due to pollination in the crops investigated ranged from 25% to 99%. The success of pollination in many agricultural systems depends on pollinators' diversity, abundance, pollen load, frequency of visitation, and flower consistency (Banaszak, 1983). . Diversity is crucial as it helps to reduce the risk that may arise due to lack of a pollinator during the critical period of crop flowering.

2.4 Bees as pollinators of agricultural crops

Records show that 90% of world food supplies are contributed by 82 commodities that can be assigned to plant species and by 28 general commodities that cannot be assigned to particular species (Buchman and Nabhan, 1996). Bees pollinate 63 (77%) of the 82 species commodities and are the most important known pollinators for at least 39 (48%). Moreover, many crops of commercial importance such as pear, apple, coffee, sunflower, melon, avocado, mango, cucumber, alfalfa and turnip rely on insect pollination for reproduction. The overall value of bee pollination becomes clearer when we put together all the bee-pollinated food plants and also consider the large quantities of agricultural products processed and converted into animal feeds and ultimately to meat, milk, egg, and other livestock products (Gordon and Davis, 2003; Barclay and Moffet, 1984). For the animal pollinated agricultural crops, bees are the most important pollinators worldwide. However, only 15% of the world's crops are pollinated by the managed bee species such as *A. mellifera,* while the rest are pollinated by un-managed solitary bees and other animals (Ingram et al, 1996). Moreover, only a few plantations keep and manage *A. mellifera* colonies for the pollination purpose; this in most cases is done without determining the most effective pollinator for the crops grown (Goulson, 2003). In Kenya, for example, some large coffee and horticultural farms have started bee keeping projects where honeybees are kept to supplement pollination of their crops (Kasina *et al.*, 2009). However, this is done without evaluating whether honeybees are effective pollinators of the crops grown.

2.5 Land management for bee conservation

Among the 25,000 bee species documented worldwide, only 3,000 are found in sub-Saharan Africa (O'Toole and Raw, 1991). In Kenya, 243 bee species have been recorded in Kakamega forest and the surrounding open land (Gikungu, 2006). According to the U.S Department of

Agriculture, the world faces an impending "pollination crisis" due to the alarming rate at which both managed and wild pollinators are disappearing (Ingram *et al.*, 1996). The decline is as a result of anthropogenic activities, among which agricultural intensification has been cited as the key threat to bees (Kremen *et al.*, 2002). Activities such as fragmentation of the forest, mechanical cultivation, land/vegetation clearing, establishment of monocultures, burning/smoking, overgrazing and use of pesticide continue to threaten the bee diversity (Richards and Kevan, 2002; Kearns *et al.*, 1998). Conservation of bee habitat may be the best means of reversing the declining trend in pollinator populations. In many parts of the world, this may mean conservation of human-made habitats, some of which prove to be good substitutes for threatened or destroyed natural habitats (Klemm, 2004). However, it is possible to improve these practices so as to take consideration of the bee requirements. Agricultural practices such as minimum tillage, safe and appropriate use of pesticides, crop diversification, use of hedgerows and maitaining natural habitats can be useful in conserving the bee populations. Although studies show that most of the farmers in the Kakamega farmlands (60%) do not use chemical pesticides to control crop pests (Kasina *et al.*, 2009b), those who do were found to be using chemicals such as pyrethroids and carbamates that are not only toxic to bees but also highly persistent in the environment.

2.6 Hedgerows and bees

Hedgerows are narrow dynamic bands of woody vegetation and the associated organisms that seperate fields (Forman and Baudry, 2005). They are usually perceived as the background in an agricultural landscape, largely unnoticed and unstudied. However, in many agricultural landscapes the hedgerows are interconnected to form a functional network (Forman and Baudry, 2005). According to Forman and Godron (2000), three predorminant types of hedgerows origins are recognised, these are planted, spontaneus and remnant. Evidence suggests that hedgerows perform more than 20 diverse functions and roles that are of economic and ecological significance to the farmer and the general society. These include, provision of property boundaries, protection and privacy, woodfuel and timber, plant products such as fruits and vegetables, windbreaks, fencing to keep livestock in or out of field, pollarded fodder for livestock, microhabitats for the conservation of numerous organisms, reduction of water erosion through runoff and the consequent nutrients loss, creation of microclimates suitable to crops, animals and homesteads. In addition infrastructures such as roads, ditches, canals and parks can be protected using hedgerows. Hedgerows also play a critical role in the aesthetics of the agicultural landscape. Many hedgerow fauna studies show high species diversity, apparently due to the heterogeneous micro-habitat that they create (Forman and Baudry, 2005). This high species diversity was found to apply to the invertebrates as well as the vertebrates, with hymenoptera and diptera being the most abundant. Insect diversity in the hedgerow was also found to exceed that of bean field and pasture and to correlate to various flora attributes. For example, species of plant bugs (Miridae) was directly correlated with the number of hedgerow plant species in France (Forman and Baudry, 2005).

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CHAPTER 3

3: DIVERSITY AND ABUNDANCE OF BEE SPECIES IN THE MAJOR BEE RESOURCE PLANTS IN THE FARMLAND HEDGEROWS ADJACENT TO KAKAMEGA FOREST .

3.1 Introduction

It is estimated that about a third of all the total human diet in the developed countries is derived from insect pollinated plants and the proportion is also high in the developing countires (Maheshwari, 2003). Among the insect pollinators, bees are the most important pollinating 77% of the 82 commodities from which human food is derived (Buchman and Nabhan, 1996). Out of the 25,000 bee species documented worldwide, only 3,000 are found in sub-Saharan Africa (O' Toole and Raw, 1991). In Kenya 243 bee species have been recorded in Kakamega forest and the surrounding open land (Gikungu, 2006). However, anthropogenic activities continue to threaten the sustainability of the bee diversity with agricultural intensification cited as the key threat to the bee populations (Kremen *et al.*, 2002). Bees and other pollinators need to be nurtured by providing suitable environments for them within the ecosystem. Bee populations can be enhanced if the agro-ecosystems are managed with the bee requirements in mind. There is therefore need to incorporate suitable conservation strategies, such as the management of hedgerows, into the farming activities, to ensure sustainability of this important service.

In many agricultural landscapes hedgerows provide heterogeneous plant structure and are interconnected to form a functional network (Forman and Godron, 2000). One of the hedgerows studied indicated a high species diversity of invertebrates as well as the vertebrates, with hymenoptera and diptera being the most abundant (Forman and Baudry, 2005). Insect diversity in the hedgerow was also found to exceed that of bean field and pasture and to correlate to various flora attributes. Hedgerows have been found to be a common feature of the study area, Kakamega farmlands, that form an important interconectivity with the forest (Kasina *et al.*, 2009b). The hedgerows have a wide range of trees, shrubs and herbs that flower at diffeerent times of the year and are mainly managed through trimming and weeding (Kasina *et al.*, 2009a). Farmers in this area use the hedgerows as live fences to mark farm boundaries, as a source of fuel and medicinal plants, and as fodder for their livestock. Management of these hedgerows has also been identified as one of the strategy that can be used to enhance bee population and diversity in the Kakamega farmlands, resulting in increased crop yields (Kasina *et al.*, 2009a). Proper management of these hedgerows could ensure that foraging resources are available to the bees throughout the year, especially when crops are off-season. The objective of this study was therefore to assess the bee diversity and abundance in the hedgerows and elucidate their use as a management strategy for the conservation of bee pollinators in the farmlands sorrounding Kakamega forest.

3.2 Materials and methods

3.2.1 Study area

The study was conducted in Ileho division of the Kakamega North District in Western Province. The area is located in the northern part of the Kakamega forest. The area has rich agricultural soils and receives plenty of rain (over 1500 mm p.a.) which is well distributed throughout the year with two rainfall peaks, one in April/May (long rains) and September/ November (short rains)(MOA, 2006). The mean monthly temperature ranges from 11°C to

29°C with the average being 29°C. The climate and soil attributes make the area suitable for farming, and is classified as one of the high potential areas in agricutural production in Kenya (Jaetzold and Schimdt, 2006). Most of the inhabitants are small scale crops and livestock farmers, with small land sizes ranging from 0.2 ha to 0.7ha (Greiner, 1991). Sugarcane is the main cash crop in the area, other crops grown include: vegetables, fruits, and a variety of staple crops such as maize and beans. Most of these crops require biotic pollination and would strongly be affected by any decline of pollinators (Kasina *et al.*, 2009b).

3.2.2 Sampling

Fourty (40) hedgerows transects each measuring 50m long, and making a total lenght of 2.0Km were sampled. The hedgerows were grouped into five categories based on the plant composition and the adjacent land use system. The land uses include sugarcane production, maize/beans production, access roads, grazing and forest. The land use management activities were expected to influence diversity and abundance of bees visiting hedgerow flowers. Belt transect sampling method was used, as it gives more data on the abundance of species present along the transect and relative density of the individual species than the line transect. This involved making field observation for the flower visiting bees to a distance of one metre on both sides of the total length of each hedgerow, taking an average of 40 minutes on each transect. Each site was sampled twice a month for six months from October 2008 to March 2009. Sampling was done between 9.00 am and 2.00 pm. Weather parameters (wind speed in m/s) and temperature in ^{O}C)) and hedgerow characteristics (width in m), flower colour and flower morphology) were recorded during sampling. During sampling, all the foraging bees in each hedgerow transect were observed, all the species found reaching either the anthers or stigmas were counted and recorded using the method used by Gikungu (2006). All the bee species recorded visiting flowers in the hedgerows were grouped into eight categories. Field observation was limited to a maximum foraging height of 3m of the hedge. For identification, samples of bees observed were captured using sweeping nets and a code was assigned to each sample. The plant species whose flowers the bee was found visiting were identified. Where the plant could not be easily identified on site, a specimen was taken, assigned the same code as the visiting bees and preserved for further identification at the University of Nairobi. The bee samples captured were preserved and pinned in insect boxes for further identification at the National Museums of Kenya (NMK).

3.2.3 Data Collection and analysis

Just before sampling was started the width and height of all the transects were recorded. During sampling the following data was recorded: names and numbers of all the bee species that visited and foraged on the plants in the hedgerows, names of all the plant species (with open flowers) found in the hedgerows, the total number, colour and morphology of open flowers. In addition weather parameters such as temperature (^{o}C) and wind speed (m/s) were recorded using a portable weather recording device. The data collected was organised in Microsoft Excel and subjected to the Analysis of Variance (ANOVA) using SPSS 12.0 statistical software and means seperated using standard error (S.E) at 5% level of significance. Linear Regression analysis was done to determine the effect of hedgerow characteristics and weather parameters on the bees foraging activities on the hedgerows.

3.3 Results

3.3.1 Bee diversity and abundance in the hedgerows

A total of 82 bee species belonging to three families (Apidae, Megachilidae and Halictidae) and 24 genera were observed and recorded on hedgrow flowers of the farmland sorrounding Kakamega forest (Table 2).

Table 2: A list of the bee species in each family in the hedgerows

Apidae	**Halictidae**
Apis mellifera	*Lasioglossum sp.1*
Amigella aff langi	*Lasioglossum sp.2*
Amigella (megamigella sp.1)	*Lasioglossum sp.3*
Allodape interrruptus	*Lasioglossum sp.4*
Braunsapis luapulana	*Lasioglossum sp.*
Braunsapis foveata	*Lipotriches sp.1*
Braunsapis sp.	*Lipotriches sp.2*
Ceratina ericia	*Lipotriches sp.3*
Ceratina sp.1	*Nomia viridiciata*
Ceratina sp.2	*Nomia sp.1*
Ceratina sp.3	*Patellapis sp.*
Ceratina sp.4	*Patellapis sp.3*
Ceratina sp.5	*Patellapis (Zonalictus sp.1)*
Ceratina sp.6	*Patellapis (Zonalictus sp.2)*

Ceratina sp.7

Ctenoplectra antinorii

Ctenoplectra polita

Ctenoplectra albolibata

Ctenoplectra politula

Hypotrigona gribodoi

Meliponula bocandei

Meliponula lendiana

Meliponula ferruginea

Pleibena hilolebrandti

Tetraloniella sp.

Thyreus interruptus

Thyreus sp.

Xylocopa acraensis

Xylocopa calens

Xylocopa incostans

Xylocopa flavorufa

Xylocopa nigrita

Xylocopa imatator

Xylocopa? albifrons

Xylocopa koptorsoma

Xylocopa (Koptorsoma sp.1)

Xylocopa torrida

Pseudapsis sp.

Pseudapsis sp.1

Pseudapsis sp.2

Seladonia sp.

Thrinchostoma torridum

Thrinchostoma (New species)

Megachilidae

Euapsis sp.1

Euapsis sp.2

Heriades sp.

Heriades sp.1

Heriades sp.2

Heriades sp.3

Pseudanthidium sp.

Megachile sp.1

Megachile sp.2

Megachile sp.3

Megachile sp.4

Megachile sp.5

Megachile sp.6

Megachile sp.7

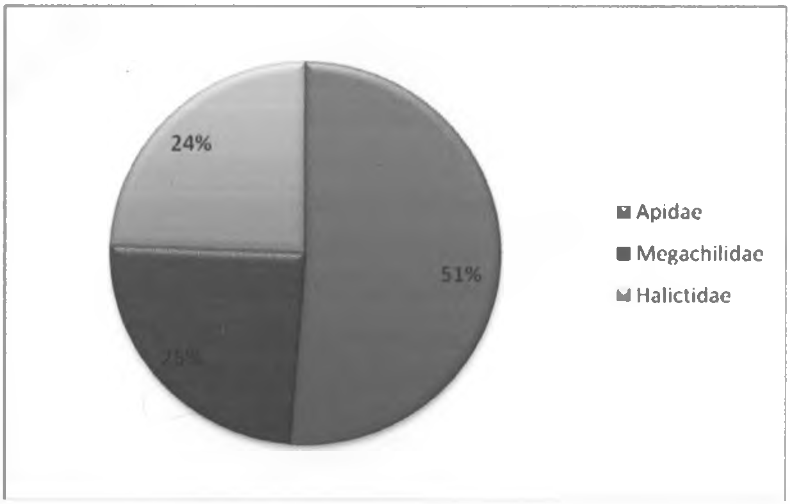
Megachile sp.8

Megachile felina

Xylocopa (Xylomellisa sp.1)	*Megachile rufipes*
Xylocopa sp.1	*Megachile bituberculata*
Xylocopa sp.2	*Megachile ithanoptera*
Xylocopa sp.3	*Megachile? gratiosa*
Xylocopa sp.4	

The most diverse bee family was Apidae represented by 42 species (51.2%) in 13 genera, followed by Halictidae (7 genera and 20 species) and Megachilidae (4 genera and 20 species) (Figure 1).

Figure1: Family distribution of bee species on the hedgerows in the Kakamega farmlands



The genus *Xylocopa* had the highest number of species (15) followed by Megachile with 13 species. Two parasitic species in the genus *Thyreus*, with only four individuals, were also recorded. A list of the common bee pollinators and the frequency of occurence is shown in table 3. The most abundant bee species on the hedgerow flowers was *Apis mellifera* with a frequency of 46.9% and a total of 2897 bee individuals followed by *Xylocopa calens* with a frequency of 17.5% and 524 individuals (plate 2).

Table 3: Frequency of occurrence and the number of individuals of the various bee categories in the hedgerows for the six months

Bee Category	**Frequency (%)**	**No.of individauls**
Apis mellifera	46.9	2897
Xylocopa calens	17.5	524
Melliponula bocandei	14.3	1089
Xylocopa nigrita	4.4	127
Xylocopa[1]	2.8	51
Apidae[2]	7.2	128
Megachilidae[3]	2.6	43
Halictidae[4]	4.1	73
*Thyreus**	0.1	4

Xylocopa[1] - 5 species in Xylocopa genus. Apidae[2]- 22 species in Apidae family
Megachilidae[3] – 20 species in Megachilidae family. Halictidae[4]- 20 species in Halictidae family
*Thyreus** - 2 parasitic bee species in the genus *Thyreus*

Apis mellifera

Xylocopa incostans

Xylocopa flavorufa

Xylocopa calens

Xylocopa nigrita

Thyreus interruptus

Meliponula bocandei

Megachile bituberculata

Plate 2: Common bee pollinators observed visiting flowers in the hedgerows.

3.3.2 Relationship between number of bee individuals and hedgerow flowers .

There was a significant ($P<0.05$) positive correlation between the number of hedgerow flowers and the number of bee individuals recorded on the hedgerows (Table 4).

Table 4: Relationship between the number of hedgerow flowers and the number of bee individuals on the hedgerows.

	Number of flowers	Number bee individuals
Number of flowers	1.00	0.194**
Number bee individuals	0.194**	1.00

** Correlation is significant at 0.01 level (two tailed)

The highest number of bees on the hedgerow flowers was recorded in the month of December and the lowest in the month of January (Figure 2), these two months had the highest and lowest number of hedgerow flowers respectively.

Figure 2: Monthly fluctuations of the bee numbers and hedgerow flowers in the six months.

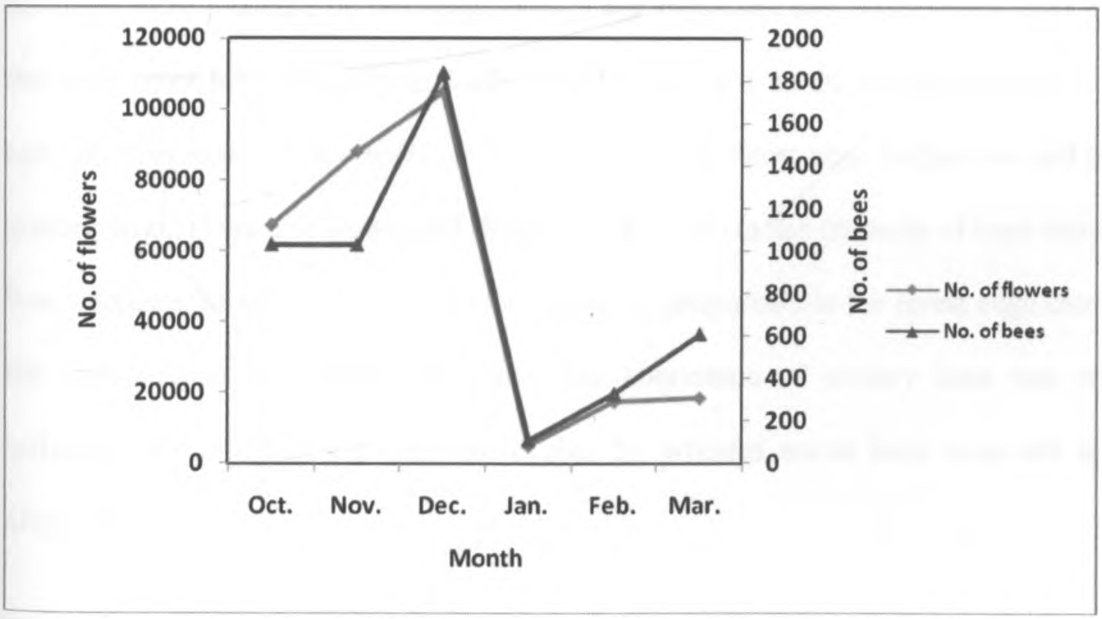



Plate 3: Roadside hedgerow

3.3.3 Effect of land use on the number of bee species and individuals.

There was significant difference ($P<0.05$) in the number of bees recorded in the five land use particularly for *X. nigrita* and *M. bocandei.* (Table 5). However, the type of land use did not significantly ($P>0.05$) affect the number of *A. mellifera, X. calens,* Apidae , *Xylocopa,* Megachilidae, and Halictidae. However, although there was no significant difference, more *A. mellifera* were recorded on the hedgerows in the sugarcane and maize/beans land uses than in the other three land uses. More *X. nigrita* were recorded on the roadside hedgerows than the rest, whereas more *M. bocandei* were recorded on the forest edge hedgerows and the least on grazing land. There was significant difference ($P<0.05$) in the diversity of bees recorded in the five land uses. More species were recorded on the hedgerows in the forest edge category while the least was in the grazing land use. The abundance of solitary bees was significantly influenced ($P<0.05$) by the land use (Table 5), whereas social bees were not significantly affected.

Table 5: Mean number of bee individuals on hedgerow flowers under different land use categories

Land use	**Bee Category**								**No. of species**	**No. of bee individuals**	
	A.mellifera	*X.calens*	*X.nigrita*	*Xylocopa*[1]	*M.bocandei*	*Apidae*[2]	*Megachilidae*[3]	*Halictidae*[4]		Social bees*	Solitary bees
Forest edge	2.22	0.49	0.17	0.07	2.23	0.17	0.07	0.12	1.54	4.46	1.07
Roadside	2.43	0.54	0.16	0.02	0.67	0.13	0.03	0.06	1.22	3.12	0.93
Sugarcane	2.72	0.50	0.05	0.06	0.54	0.13	0.04	0.06	1.25	3.27	0.82
Grazing	2.58	0.34	0.09	0.04	0.51	0.07	0.02	0.05	1.20	3.09	0.61
Maize/Beans	2.60	0.42	0.11	0.03	1.10	0.09	0.03	0.05	1.25	3.70	0.72
mean	2.53	0.46	0.11	0.04	0.95	0.12	0.04	0.06	1.28	3.48	0.82
S.E.	0.099	0.032	0.018	0.008	0.090	0.012	0.006	0.008	0.021	0.140	0.040
p-value	0.283	0.340	0.024	0.275	0.000	0.082	0.183	0.099	0.000	0.054	0.002

* Social bees - *Apis mellifera* and *Meliponula spp*. Solitary bees – all other bees.

3.3.4 Bee visitation on the hedgerow flowers.

There was significant variation (P<0.05) in the number of bee individuals (abundance) that foraged on the flowers of different plant families/species in the hedgerows, for all the bee, except Megachilidae (Table 6).

Table 6: Mean number of bees in the different plant families in the hedgerows

Plant family	Bees							
	A.mellifera	X.calens	X.nigrita	Xylocopa[1]	M.bocandei	Apidae[2]	Megachilidae[3]	Halictic
Acanthaceae	3.53	0.75	0.12	0.05	0.21	0.07	0.03	0.0
Asteraceae	2.25	0.14	0.02	0.01	1.85	0.24	0.06	0.13
Fabaceae	0.070	0.80	0.64	0.14	3.90	0.06	0.05	0.05
Verbanaceae	3.10	0.13	0.00	0.05	0.16	0.07	0.02	0.00
Compositae	3.20	0.07	0.00	0.00	0.81	0.06	0.01	0.04
Convolvulaceae	2.72	0.05	0.00	0.00	0.00	0.05	0.00	0.00
Solanaceae	0.57	1.31	0.07	0.12	0.07	0.10	0.05	0.00
Myrtaceae	3.76	0.76	0.06	0.18	0.00	0.00	0.00	0.00
Cucurbitaceae	0.00	0.00	0.00	0.00	0.36	0.93	0.00	0.29
Lamiaceae	1.16	0.12	0.00	0.00	0.40	0.16	0.20	0.16
Malvaceae	3.07	0.00	0.00	0.00	0.87	0.00	0.00	0.00
Sterculiaceae	3.75	0.00	0.00	0.00	0.17	0.00	0.00	0.00
Grand mean	2.53	0.46	0.11	0.04	0.95	0.12	0.04	0.06
S.E.	0.099	0.032	0.018	0.008	0.090	0.012	0.007	0.00
p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.088	0.00

Similarly the plant effect on the number of individuals of both the social and solitary bees was significant (P<0.05). Variation in the number of bee species on the plants was also significant (P<0.05) (Table 7).

Table 7: Mean number of bee species and mean number of social and solitary bee individuals in the different plant families in the hedgerows

Plant family	No. of bee Species	No. of individuals	
		Social bees	Solitary bees
Acanthaceae	1.39	3.75	1.08
Asteraceae	1.36	4.10	0.58
Fabaceae	1.71	4.61	1.73
Verbanaceae	1.11	3.26	0.21
Compositae	1.16	4.01	0.19
Convolvulaceae	1.03	2.72	0.10
Solanaceae	1.21	0.69	1.60
Myrtaceae	1.18	3.76	1.00
Cucurbitaceae	1.29	0.43	1.14
Lamiaceae	1.00	1.56	0.60
Malvaceae	1.20	3.93	0.00
Sterculiaceae	1.08	3.92	0.00
Grand mean	1.28	3.49	0.82
S.E.	0.021	0.140	0.040
p-value	0.000	0.000	0.000

The family Fabaceae had the highest bee diversity while Lamiaceae had the lowest. The plant families had significant ($P< 0.05$) effect on the abundance on both the social and solitary bees, with the Fabaceae family having the highest number of both bee groups. The Lamiaceae family had the least number of social bees while no solitary bees were recorded on plants in the Malvaceae and sterculiaceae families.

Plant species belonging to a total of 12 families were visited by the bees in the hedgerows. The family Acanthaceae had the highest number of bees (Figure 3), with *Justicia flava* (see also Plate 4), *A.gangetica, A. pubescens* being important species. This was followed by the family Asteraceae with important species such as *Tithonia diversifolia*, *C. Vitellinum* and *A. mossambiscensis* and Fabaceae family represented by *Caesalpinia decapetala* (Table 8). Figure

3 shows the distribution of the bee individuals on the seven most important plant families in the hedgerows.

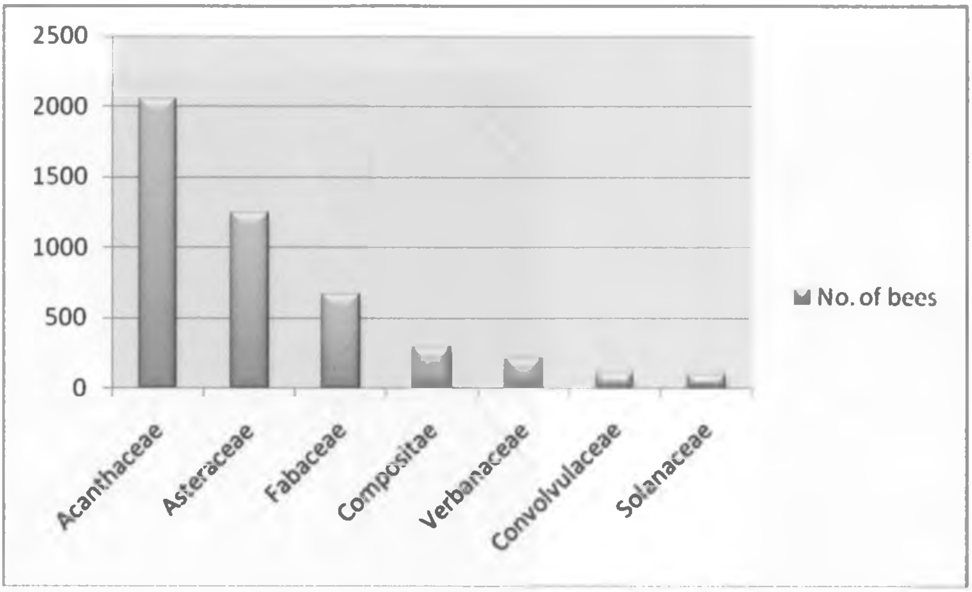


Figure 3: Number of bee species on the seven major plant families in the hedgerows

Plate 4: Some of the important bee resource plants in the hedgerows.

Justicia flava

Tithonia diversifolia

Caesapinia decapetala

Aspillia mossambicensis

Plate 5: A flower of *Mormodica foetida (pink arrow):* a common climber in the hedgerows

The species and families of all the plants observed in the hedgerows and the number of bee species and individuals that foraged on them is given in Table 8.

Table 8: A list of the important bee resource plants in the hedgerows and bee species diveristy and abundance on them

Plant		No.of bee species	No. of individuals individuals
Family	**Species**		
Acanthaceae	*J. flava*	41	1025
Asteraceae	*T.diversifolia*	18	744
Acanthaceae	*A.gangetica*	12	663
Fabaceae	*C.decapetela*	24	657
Acanthaceae	*A.pubescens*	13	358
Asteraceae	*C.vitellinum*	32	226
Verbanaceae	*L.camara*	6	207
Compositae	*S.syringifolius*	6	173
Asteraceae	*A.massambicensis*	18	131
Asteraceae	*B.pilosa*	9	119
Compositae	*B.fusca*	11	117
Convolvulaceae	*Ipomea spp.*	7	110
Solanaceae	*S.incanum*	9	96
Myrtaceae	*P.guajava*	6	70
Malvaceae	*Hibiscus spp.*	5	61
Sterculiaceae	*D.burgensea*	5	47
Lamiaceae	*O.hadiens*	13	38
Curcbitaceae	*M.foetida*	12	22
Asteraceae	*V.auriculifera*	12	21
Lamiaceae	*L.deflexa*	2	12
Myrtaceae	*Eucalyptus spp.*	1	11
Verbanaceae	*S.jamaicensis*	7	6
Lamiaceae	*P.longipes*	8	3
Verbanaceae	*L.trifolia*	6	2
Lamiaceae	*P.barbatus*	1	2
Asteraceae	*C.sarcobasis*	1	1
Acanthaceae	*T.alata*	6	1

3.3.5 Effect of the number of hedgerow flowers on bees

The number of bees visiting hedgerow flowers was significantly (P<0.05) influenced by the number of flowers. This was observed for *A. mellifera,* Apidae , *M. bocandei* and Halictidae (Table 9).

Table 9: Mean number of bee species and individuals in hedgerows with different number of open flowers

Io. of owers	Bee Category								No. of species	No. of bee individuals	
	A.mellifera	*X.calens*	*X.nigrita*	Xylocopa[1]	M.bocandei	Apidae[2]	Megachilidae[3]	Halictidae[4]		Social bees	Solitar bees
) – 200	1.48	0.42	0.08	0.06	0.62	0.16	0.04	0.13	1.20	2.11	0.86
) – 400	3.12	0.50	0.14	0.04	1.25	0.10	0.05	0.01	1.37	4.38	0.85
) – 600	2.90	0.45	0.14	0.02	0.93	0.06	0.02	0.02	1.28	4.60	0.72
) – 800	3.68	0.49	0.02	0.00	1.76	0.04	0.02	0.02	1.33	4.65	0.59
mean	2.53	0.46	0.11	0.04	0.95	0.12	0.04	0.06	1.28	3.48	0.82
	0.099	0.032	0.018	0.008	0.090	0.012	0.006	0.008	0.021	0.140	0.040
alue	0.000	0.625	0.219	0.212	0.006	0.005	0.577	0.000	0.000	0.000	0.123

More *A. mellifera* (Plate 6) were recorded in the hedgerows having the highest number of flowers (600- 800) while the least was recorded in hedgerows with the least flowers (0 -200). Similarly the highest number of *M. bocandei* was recorded in hedgerows with 600- 800 flowers. In addition the number of flowers significantly influenced (P<0.05) the number of species that foraged on the plants in the hedgerows (P<0.05). The number of social bees that visited the flowers increased with increasing number of flowers. There was no significant effect of flowers (P>0.05) on solitary bees. (Table 9).

Plate 6. Honey bee (*A. mellifera*) (red arrow) foraging on *Lantana Camara* flowers in the hedgerow

3.3.6 Effect of hedgerow characteristics and weather parameters on bees

Weather parameters (temperature and wind speed) and hedgerow characteristics (width, flower colour and morphology) had significant ($P<0.05$) influence on the number of bees that visited hedgerow plants (Table 10). Temperature had significant effect on solitary bees while wind speed had significant influence only on *A. mellifera*. The hedgerow width only affected *A. mellifera* whereas flower colour significantly affected the abundance of solitary bees in the hedgerows. The flower morphology (open or tubular) affected the numbers of all the bees except *M. bocandei*.

Table 10: Regression analysis of the weather and hedgerow parameters on various bees

Parameter	Bee category									
	A. mellifera		*M. bocandei*		*X. calens*		Social bees		Solitary bees	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.
Temperature	-0.003	0.910	0.011	0.707	-0.055	0.049	0.004	0.882	-0.055	0.0451
Wind speed	0.060	0.042	0.011	0.697	0.025	0.370	0.051	0.086	0.029	0.306
H. width	0.021	0.470	0.037	0.214	0.033	0.243	0.041	0.162	0.046	0.103
F. colour	0.042	0.217	0.132	0.000	0.348	0.000	0.055	0.104	0.364	0.000
F.morphology	0.068	0.043	0.040	0.230	0.235	0.000	0.075	0.026	0.233	0.000

β - coefficient, Sig. – significance
F. - flower, H.- Hedgerow

3.4 Discussion

The bee pollinators recorded visiting hedgerow flowers in the study belonged to three families that were also reported by Gikungu (2006) in an earlier study in Kakamega forest and the sorrounding farmlands. The ranking of the families (Apidae, Halictidae and Megachilidae) according to the number of bee species, was also similar to that reported by Gikungu (2006). This would suggest that the plants in the hedgerows in the farms provide a resource connectivity with the forest. Bees of these three families were also recorded as important pollinators of various crops grown in the farmlands (Kasina *et al.*, 2009b), for example *X. Calens* and *Halictus spp.* pollinated tomato flowers. The most frequent visitor on the hedgerow (*A. mellifera*) was also recorded as having the highest number of individuals in earlier study on crop pollination in the farmlands (Kasina *et al.*, 2009b). This suggests that hedgerow flowers probably suppliment crops in providing resources for the bees in the farmlands. The number of soliatry bees were found to be low on the hedgerow plants, again similar to the low population reported on crops reported by (Kasina *et al.*, 2009a).

The land use in the farmlands had significant effect on the number of bee species that visited the hedgerows. This can be attributed to the different land management practices which not only affect the growth, establishment and flowering pattern of plants in the hedgerows but also the interfere with bees' foraging activities. This confirms that human activities, especially in the agricultural landscape, result in modification of bee habitats (Richards and Kevan, 2002) with possible decline in diversity and abundance of bees and other pollinators. This could be due to low farmer knowledge on bees and their importance in agriculture as noted by (Kasina *et al.*, 2009a). There is therefore need for the farmers to be aware of the bee requirements and their economic benefit so that they may incoporate them into their farm management activities. For example, pruning or cutting down the hedgerow plants is a common practice in the study area that reduces the flower density in the hedgerows, especially when carried out when the plants are in flower. However, land use affected the abundance of only two bee species (*X. nigrita* and *M. bocandei*). This is probably because *X. nigrit*a are large bees that preferred foraging on hedgerows with well established plants such as *Caesalpinia decapetala*, that were mainly on the forest edge and roadside hedgerows. Similarly most *M. bocandei* visited the well established *Tithonia diversifolia* plants on the roadside and forest edge hedgerows. The land sizes in the study area are small and bees can conveniently move from one land use to the other, this may explain why land use did not significantly affect most of the bee species. Moreover, the hegderow plant structure was not very different in the land uses which were considered.

The plant species in the hedgerows affected both the number of species and individuals of bees that foraged on the hedgerows. This could be attributed to the fact that the foraging behaviour of bees are dependent on characteristics such as the bee's body structure and energy requirement and plant characteristics such as flower morphology and resources offered (Michener, 2000). A bee with a short proboscis, for example, will not be able to get nectar from a deep flower and would thus not forage on plants with such flower morphology (Michener, 2000). This may explain why more bees visited flowers with open flower morphology than those with the tubular morphology. Plants with porricidal (tubular) anthers such as *Solanum incanum* were visited by bees that are able to buzz pollinate such as *X. calens*. Plants belonging to the Acanthaceae family such as *Justicia flava, Asystasia gangetica and Aspillia mossambicensis* (Asteraceae) were found to be important bee resource plants in the farmlands. These were also recorded as important bee resource plants by Gikungu (2006) in the Kakamega forest and the sorrounding farmlands. The number of open flowers in a hedgerow, at the time of sampling, had significant effect on both the number of bee species and the number of social bees that visited the flowers, but no effect was shown on the solitary bees. This is probably because social bees such as *A. mellifera* have the obligation of feeding their young ones in the colony. They thus prefer to visit flower patches with a high flower density where they are likely to collect enough nectar and pollen to meet this requirement (Corbert and Osborne, 2002). *A. mellifera* is also known for its flower consistency.

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CHAPTER 4

4: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 Discussion

The study found that the hedgerow plants offer important resources to the bee pollinators and can therefore be used as part of the strategy for the restoration/conservation of the pollinators in the farmland. This is in agreement with Forman and Baundry (2005) and Klemm (1996) who argued that the heterogeneous micro-habitat created by the hedgerows are suitable for high fauna species diversity, and that as technology develops they shoud be regenerated and used as suitable substitutes for the destroyed natural habitats. The use of hedgerows as a strategy for the conservation of bees and other insect pollinators has also been implemented in other countries such as United Kingdom (Matheson, 1994) and Poland (Banaszak, 1992). The most important bee resource plants, among those observed in the hedgerows, ranked in order of importance were: *Justicia flava, Tithonia diversifolia, Asystacia gangetica, Craessocephallum vitellinum, Aspillia mossambicensis* and *Acanthus pubescens*. This ranking was based on the number of bees that visited each plant species. Some plants were more attractive to certain bee species than the others, for example, more *M. bocandei* were recorded visiting *Tithonia diversifolia* flowers than any other plant. On the other hand most carpenter bees *(Xylocopa* spp.) foraged mainly on *Caesalpinia decapetala, Acanthus pubescens and solanum incanum* plants. However, the honey bee (*A. mellifera)* was found to be more generalised and visited most of the plants in the hedgerows, which is in agreement with a study in Canada (Richards and Kevan, 2002) that described honeybee as a generalist feeder that visits and pollinates most of the crops grown. *Lantana camara,* a common plant in the hedgerow, attracted few bees when other plants were in flower, but recorded high visitation during the dry period when most of the other plants were not flowering. Several herbaceous plants such as *Justicia flava, Asystacia gangetica, Craessocephallum vitellinum, Aspllia mossambiscensis* and *Biden pilosa*, growing mainly on the sides of the major hedgerow plants, were found to be important bee resource plants, especially when there were no flowering crops in the farms. Some of these plants were also reported by Gikungu (2006) as important bee resource plants in farmlands. Although, hedgerows are an integral part of the farming landscape in Kakamega farmland (Kasina, 2007), they are maintained for economic and social purposes, other than pollination. In addition to these uses it is necessary for the farmers to be aware of the important role these hedgerows play in the provision of pollination. This would enable them to manage the farms, including the hedgerows, with the requirements of the bees and other pollinators in mind. Maintaining a suitable mixture of annual, biennial and perrenial plant species, that flower at different times, in the hedgerows would be necessary to provide floral bee resources throughout the year.

4.2 Conclusion

The study established that there is a wide diversity and abundance of bee pollinators that visit hedgerow plants in the farmland sorrounding Kakamega forest. The most common social bees in the hedgerows are *A. mellifera* and *M. bocandei* while *X. calens* and *X. nigrita* were the most abundant among the solitary bees. The study revealed that the hedgerows are rich in plant species that have flowers throughout the year and if well managed could ensure availability of bee resources through-out the year. The most important bee resource plants in the hedgerow are *Justicia flava, Tithonia diversifolia, Asystacia gangetica, Craessocephallum vitellinum, Aspillia mossambicensis* and *Acanthus pubescens.*

4.3 Recommendations

From the study the following recommendations can be made:

1 Incorporation of the use of hedgerows as an important strategy that may be applied in the conservation of bee pollinators in the farm landscapes.

2 Proper management of a mixture of herbs, shrubs, climbers and trees (annual,biennials and perrenial) in the hedgerows to ensure availability of flowers throughout the year.

3 Establishment of the most important bee plant species in the hedgerows should be encouraged, growing of important herbaceous plants such as *Justicia flava,* that are not usually planted should also be encouraged. This can be achieved by leaving a strip of about one metre on the sides of hedgerows unweeded.

4 Create awareness on the farming community, government agents and other stakeholders in the agricultural sector on the importance of hedgerow plants in the conservation of bee pollinators in the farmland.

5 Further research work is recommended on the bee - pollinator interaction of the important bee resource plants in the hedgerows. It would also be necessary to establish whether the bee species reported on the hedgerows are effective pollinators of the crops grown in the sorrounding farms.

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