ECOLOGICAL DIVERSITY AND CONTRIBUTION OF EDIBLE INSECTS TO HOUSEHOLD FOOD SECURITY

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Abstract: -

Food insecurity is compounded by the impact of climate change as well as increased human population. Even though, several African countries have put tremendous efforts in improving food security but the output is still limited. Diversification could be the key to unravel the problem of food insecurity; moreover, the use of insects for food has a long history. Insects are rich source of protein and at the same time provide essential nutrients With Greater contribution in reducing the complications of malnutrition. In this study, the researchers sought to investigate the contribution and ecological diversity of edible insects by mapping their ecological niches within and around Kakamega tropical Rainforest. The communities around the rainforest have a long tradition of using various insects as food. The study adopted a structured questionnaire which was administered to 209 households in the months of April and September, during the long and short rainy seasons, respectively. The forest ecosystem was stratified into five zones, namely dense forest, riverine, forest edge, open grassland and hills. Plant sampling was done within the forest strata using transect for species identification. Plants where insects were spotted were counted and recorded. A total of 88 insect species from 30 families and 13 orders were obtained whereas 97 food plants from 42 families were also observed. The families Nymphalidae were the most abundant which was closely followed by the Apidae family. The study showed that there was high species diversity of both insects and plants within the dense forest than the rest of study sites. This is attributed undisturbed nature of the habitat.

Keywords: *Ecological Diversity, Edible insect, edible insect diversity, edible insect Habitat, food insecurity*

INTRODUCTION

African countries are increasingly focusing on investing in agricultural production to strengthen food security. These efforts are to ensure that the citizens have the capacity to access adequate nutritious and affordable food for consumption. However, food insecurity has remained a challenge for human welfare and economic growth due to the unavailability of sufficient food to meet the nutritional needs, this could be attributed to increase in population growth as well as climate change (Kelemu et al., 2015).

World food committee in their statement pointed out that food security will only exist when all people have the ability to meet their dietary demand through physical, social and economic access to sufficient, safe and nutritious food at all times. The committee went further by looking at the pillars of food security which include access, availability, utilization and stability. However, the sustainability of food is still challenged by the growing population as well as the shocks of climate change that affect the food production. These effects of climate variabilities have interfered with the livestock production resulting into dwindling protein. The demand for animal protein is still expected to increase as the price is skyrocketing affecting the poor people mostly as they lack the ability to purchase the protein food products. Food systems therefore need to take into consideration these prevailing challenges by supplementing the diets by use of other protein sources like edible insects. Insects have adequate quality of protein and they emit less greenhouse gas to the atmosphere as compared to the agricultural livestock which require larger space and more feed to be reared(van Huis, 2015).

Since 1980 the consumption for fish, meat, eggs and milk is on a continuous increase. The global demand for meat is projected to increase by 76% in the year 2050 as the world population is also expected to hit 9.15 billion. Therefore, there is urgent need for other alternative sources of protein to sustain feeding demand by the surging population. Thus, the sustainable use of insects as food and feed plays a vital role in supplementing the diet to reduce the cases of malnutrition (Kokwaro, 1988).

Achieving global food security remains a key challenge for the future and will likely require an increase in the productivity, resilience and sustainability of farming systems. Increasing food security is particularly important for developing counties, such as Kenya. Due to its importance, the Government of Kenya has identified food security as one of the Big Four Agenda. Furthermore, the country has developed Agricultural Sector Transformation and Growth Strategy 2019-2029 all geared towards food security and nutrition. The key message in these policy documents is that diversification of food sources plays essential role in ensuring nutritional security and tackling the problems of hidden hunger through micronutrient deficiencies. In addition, the Government have a Health Policy whose directives ensures that the overall health status stipulated in the country's development agenda, vision 2030, the constitution 2010 are well implemented. This can only be realised by including edible insects to supplement the protein that is required in the diet because the edible insects are still neglected in most of the consumer diets in the country. These country development agenda mostly focus on the access, availability affordable grains and other sources of protein neglecting the vital role that can be played by edible insects.

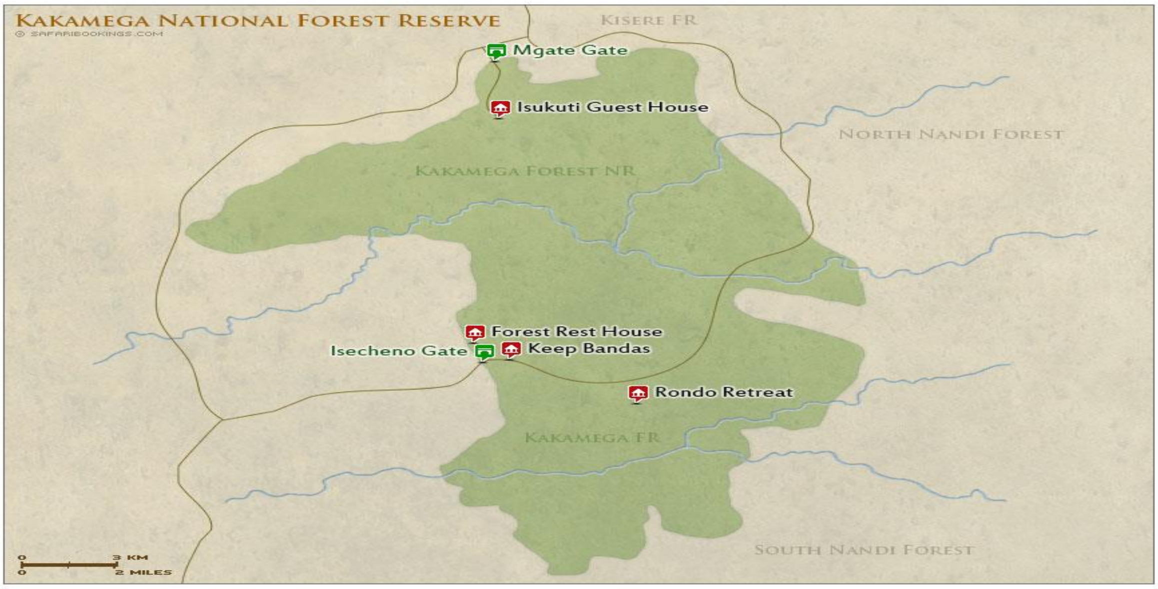
While diversification is often considered in crops, the potential of insect as food and feed often goes unnoticed. This is evident by the fact that the above key policy documents are silent on the role of insects in food security. Use of insect for food and feed is not new. Insect gathering is an old practice that was done by the local communities both for food and feed. Insect has been included in the diet due to their nutritional significance.

To fully utilize insects to address food security, there is need to understand their ecology including factors determining their distribution. Insect ecology can be defined as the interaction of individual insects and insect communities with the surrounding environment. This involves processes such as nutrient cycling, pollination and migration, as well as population dynamics and climate change(Garofalo et al., 2017). More than half of all known living organisms are insects(Van Huis, 2016). Some species that have long been considered valuable for their products – such as honeybees, silkworms and cochineal insects – are well known, while knowledge of many others remains scarce (FAO, 2013). Western Kenya is one of the regions where use of edible insect is culturally well grounded with Kakamega Forest being one of the main habitats for insects. Habitat characteristics play noble role in regulating the diversity of species found within the wild. This is because the animals and plants depend on the quality of the habitat which influences the distribution patterns of the animals such as edible insects (Nkoba et al., 2012).

Kakamega forest is Kenya's only rainforest and is distinguishably rich in biodiversity but threatened by agricultural encroachment and other forms of human activity. Furthermore, the forest is heavily disturbed and fragmented due to high population that exerts pressure on the resource coupled with the devastative effects of climate variabilities that leads to decline of forest cover. As a result, alien and invasive species sets in hence leading to loss of biodiversity within the tropical forest ecosystem. Kakamega forest is also one of Kenya's Important Bird Areas and a significant source of natural products to neighbouring rural communities, such as medicinal plants, food, wood and other fibres. It is therefore expected to have higher diversity of insects thus the community around it can use this forest to gather insects for consumption (Mang & O, 2019). Kakamega forest like any other forest in Kenya is affected by the human activities such as logging, medicinal harvesting, forest fire which influences the variety of plant species found within the forest. The species themselves act as host plant that provide conducive habitat for the insects as they camouflage against the predators as well as direct sunlight that cause desiccation of insects thus interfering with their breeding patterns. However, little information is available on which types of plants used by the edible insect and their interaction with the plants (Farwig et al., 2009). Plants normally produce flowers and the flower attracts the insects through their colour and scents. Diversity of plants species results to variety of flowers that attract different species of edible insects within the same ecosystems. The government of Kenya through Kenya Forest Service and Kenya Wildlife Service are working through joint effort to preserve, conserve and protect the forest against degradation by human activities such as forest

encroachment. The role played by the local community in conservation is equally important by empowering them to know the benefits derived from the non-wood forest products such as edible insects.
According to the study done by Mamo et al. (2007) most of the communities surrounding the forests tend to be the rural poor whose life depend entirely on the forest resources for their livelihood. As they derive the resources from the forest through logging, charcoal burning, clearing for cattle pasture grazing and hunting they cause massive destruction of forest canopy which forms the habitat for edible insects. Kakamega forest is not an exemption as it is surrounded by the locals who are poor whose income are low and earn their living from the forest (Nambiro, 2000). The communities around this resource derive their household income from the proceeds that come from the small plots where they grow staple food such as cassava, bananas, beans and maize. The objectives of the study were, first and foremost, to determine the species diversity of edible insects in different vegetation type within and around Kakamega Forest. Secondly, to determine the species diversity of plants used as habitat by edible insects within and around Kakamega Forest. And thirdly, to investigate the contributions of edible insects towards food security among the households around Kakamega Forest.

Material and Methods
Study Area
The study was conducted in Kakamega Forest and the households around the Forest, located in Eastern region of Kakamega County (00º07'-00º023'N, 34º46'-34º58'E, altitude 1500 – 1700m) approximately 50Km North-East of Lake Victoria. It is the only Kenya's remnant mid-altitude tropical rainforest of easternmost relict of Guineo – Congolian rainforest (kokwaro, 1988). The area experiences high rainy season from April to November and a dry season between December and March (Kokwaro, 1988). The forest is located in one of the globally most populated rural area with a population density of 600 people/Km2 (Blackett, 1994). This high density exerts a lot of pressure on the forest resource such as logging, agricultural activities, and charcoal burning leading to fragmentation decline in forest vegetation cover. Kakamega forest being a biodiversity hotspot and a home of edible insect that are used to supplement the household dietary diversity as a source of protein within the household need to be protected to avoid habitat loss(Müller & Mburu, 2009; Vuyiya et al., 2014). Insect gathering from the wild is an old practice and Kakamega forest that forms a habitat for edible insect should be used sustainably to avoid insect loss. Apart from habitat loss, the population of the community surrounding the forest is also tremendously increasing leading to increased demand for the protein required in human diets. Kakamega forest harbors variety of edible insect that can contribute directly to the household food security (Vuyiya et al., 2014). The study was conducted between the month of April to September 2020.



https://www.safaribookings.com/kakamega/map#map. A map of Kakamega forest

Sampling Design
The study site
The forest was stratified into four regions, and designated as dense forest, riverine, forest edge and open grassland to a maximum distance of 2 kilometers from the forest edge. A belt transect was established across all the strata. These areas were then further subdivided into zones. Within the zones collection sites/sampling points were identified using random sampling technique. The collection sites were then fed into the computer. Random numbers were generated from a computer to identify collection sites. The collection sites were marked by quadrants of approximately 10m by 10m where both edible insects and plant species used by edible insects were collected.
All the plant species in the quadrant were identified and all plants where insects were spotted were counted and put into record. Samples of leaves and/or twigs, flowers and fruits from unknown plant species were collected, pressed and bagged (Bomolo et al., 2017). The collected plant samples were identified using the field guide according to the trees

and shrubs of Kenya. Photographs were also taken of each plant, leaves, flowers and/or fruits sampled to aid in plant identification, and voucher specimens of all plant species collections were maintained at National Museum of Kenya.
The images of all the insects collected were taken from the forest using a Digital Camera then printed. The images were used as a pictorial guide during the surveys (Bomolo et al., 2017).

Sampling design of the Household survey

The target population for the preference and consumption survey involved residents residing within 2 kilometers around the forest. The survey was conducted using face-to-face interviews by use of structured questionnaires which were digitized into ODKcollect, and the method allowed respondents to raise their concerns and questions with the interviewers and ensured that key household persons responsible for dietary decisions were intensively interviewed. The method also ensured that further clarifications were provided instantly by the use of visual aids, which were field manual book accompanied by images and a specimen box containing the insects pinned by conventional methods of insects' assembly. The sampling units were the households, from which respondents were drawn using a systematic random sampling criteria. To select the households, a line sampling method was used; that is, a 'line' was drawn on the village map, and every third household along the 'line' with a random start (either left or right by tossing a coin) was interviewed (Bomolo et al., 2017; Nichols, 2000). Where the targeted respondent was unavailable or uninterested in participation, the next randomly selected household on the list was chosen to ensure that the desired sample size was realized.

Statistical Analysis

All ecological data on insect diversity was analyzed using R 3.5.3 statistical software. Insect species diversity index in different strata was established using e.g. Shannon wiener diversity index while the Simpson's diversity index was used to measure the species relative abundance and the number of species present. The similarity of the samples was tested using Jaccard's Similarity index. The Jaccard's similarity Index was used in the analysis to compare members for two locations to find out which members of either insect or plant species were shared and were distinct. This is a measure of similarity for the two data sets with a range from 0% to 100%. The higher the percentage the more similar the two populations
Jaccard Index = (The number of both sets/ the number in either sets) x100

$$J\,(X,Y) = \frac{|X \cap Y|}{|X \cup Y|}$$

The insect and plant species diversity were established using Shannon wiener diversity index. The Shannon index (*H'*) assumed that all the species of either Insect or plant were represented in the sample and that they were randomly sampled.

$$H' = -\sum_{i=1}^{s} PiLnPi$$

Where
P is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)
Ln is the Natural Logarithm
∑ is the sum of the calculations and *S* being the number of species.
The analysis also used Simpson Index (*D*), a dominance index which gives more weight to common dominant species.

$$D = \frac{1}{\sum_{i=1}^{s} Pi^2}$$

Where
P is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)
∑ is the sum of the calculations and *S* being the number of species.
The species diversity was also determined using species evenness to ascertain how close in numbers each species in the environment is. It is a measure of biodiversity that quantifies how equal the community is numerically.

$$J' = \frac{H'}{H'max}$$

Where
H is the number from which the Shannon diversity index and
H'max is the maximum possible value of H' (if every species was equally likely) equal to

$$J' = \frac{H'}{Ln(S)}$$

3. Results

3.1 Species abundance and richness as determined by Shannon, Simpson, Jevenness and Berger indices

The values of Shannon index increased with increase in species richness. Nyayo Tea Zone and Pond had the least diversity whereas highest diversity was evidenced in the Dense Forest. Furthermore, the species richness also increased from the Nyayo Tea Zone and the Pond area to the Dense Forest region as displayed in **Table 1**
Table 1. Diversity indices for insect

	Shannon	Simpson	Jevenness	abundance	Berger	richness
Nyayo Tea Zone	0.0000	1.0000	0.0000	238	0.1335	1
Ponds	0.0000	1.0000	0.0000	131	0.1529	1
Lirhanda Hill	0.6506	1.8454	0.9387	456	0.0496	2
Lugusida River	2.1652	8.4454	0.9854	1771	0.1108	9
Buyangu Hill	2.1653	8.4776	0.9855	1720	0.1129	9
Sianda River	2.1693	8.5526	0.9873	2010	0.6447	9
Open grassland	2.2497	9.0258	0.9770	1871	0.1671	10
Isiukhu Falls	2.3866	10.7602	0.9953	2320	1	11
Forest Edge	2.5810	12.5320	0.9780	2663	0.1507	14
Yala River	2.5871	12.6869	0.9803	2493	1	14
Agricultural land	2.7760	13.7677	0.9428	2696	0.1403	19
Dense Forest	3.7069	38.5273	0.9856	8358	0.1199	43

3.2 Correlation analysis of the insect species distribution in various habitats/ecosystems

According to the results in **Table 2,** it was evident that when a location of study was compared against self the results from the Jaccard's indices outcome displayed 1.00. This means that the species against self are 100% similar. The values of Jaccard ranged from zero (0.00) to 1.00. Those values with one are 100% similar whereas a value of zero means no similarity of species between the two locations under study. From the results in **Table 2.** Nyayo Tea Zone and Pond did not share the insect species with any other locations under study. Lugusida River and Sianda River tended to have species in common.

Table 2. Correlation analysis by Jaccard indices method

	Agricultural land	Buyangu Hill	Dense Forest	Forest Edge	Isiukhu Falls	Lirhanda Hill	Lugusida River	Nyayo Tea Zone	Open grassland	Ponds	Sianda River	Yala River
Agricultural land	1.00	0.08	0.17	0.14	0.07	0.05	0.08	0.00	0.04	0.00	0.08	0.10
Buyangu Hill	0.08	1.00	0.06	0.05	0.18	0.10	0.13	0.00	0.06	0.00	0.13	0.15
Dense Forest	0.17	0.06	1.00	0.12	0.06	0.02	0.06	0.00	0.04	0.00	0.06	0.10
Forest Edge	0.14	0.05	0.12	1.00	0.09	0.07	0.10	0.00	0.04	0.00	0.10	0.12
Isiukhu Falls	0.07	0.18	0.06	0.09	1.00	0.08	0.67	0.00	0.05	0.00	0.67	0.56
Lirhanda Hill	0.05	0.10	0.02	0.07	0.08	1.00	0.10	0.00	0.09	0.00	0.10	0.07
Lugusida River	0.08	0.13	0.06	0.10	0.67	0.10	1.00	0.00	0.06	0.00	1.00	0.53
Nyayo Tea Zone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Open grassland	0.04	0.06	0.04	0.04	0.05	0.09	0.06	0.00	1.00	0.00	0.06	0.04
Ponds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Sianda River	0.08	0.13	0.06	0.10	0.67	0.10	1.00	0.00	0.06	0.00	1.00	0.53
Yala River	0.10	0.15	0.10	0.12	0.56	0.07	0.53	0.00	0.04	0.00	0.53	1.00

3.3 Vegetation diversity in Kakamega forest

Table 3. Vegetation Diversity indices

	Shannon	Simpson	Jevenness	abundance	Berger	richness
Nyayo Tea Zone	0	1	0	261	0.464	1
Ponds	0	1	0	88	0.2196	1
Lirhanda Hill	0.673012	1.923077	0.970951	285	0.0893	2
Open grassland	0.880345	1.560336	0.423357	2465	0.162	8
Buyangu Hill	1.720102	5.263547	0.883958	634	0.1495	7
Sianda River	2.152191	8.334252	0.979505	678	0.6	9
Lugusida River	2.153215	8.289665	0.97997	702	0.1652	9
Agricultural land	2.20055	4.279351	0.747358	1836	1	19
Isiukhu Falls	2.30723	9.440284	0.96219	856	0.7959	11
Yala River	2.517166	11.90626	0.98137	858	1	13
Forest Edge	2.53569	11.63593	0.960832	969	0.1652	14
Dense Forest	3.524044	29.9323	0.968786	3001	0.1201	38

Based on the results in **Table 4**, the use of Jaccard's index to determine the similarity of plant species in different location was evident that when a location is compared between self the Jaccard's indices results obtained were 1.00 which means that the plat species were 100% similar. The outcome also showed that only Nyayo Tea zone did not share the plants with other locations.

Table 4. Jaccard indices for plants

	Agricultural land	Buyangu Hill	Dense Forest	Forest Edge	Isiukhu Falls	Lirhanda Hill	Lugusida River	Nyayo Tea Zone	Open grassland	Ponds	Sianda River	Yala River
Agricultural land	1.00	0.00	0.16	0.06	0.10	0.05	0.00	0.00	0.04	0.00	0.04	0.00
Buyangu Hill	0.00	1.00	0.00	0.05	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.05
Dense Forest	0.16	0.00	1.00	0.02	0.02	0.03	0.00	0.00	0.02	0.00	0.07	0.06
Forest Edge	0.06	0.05	0.02	1.00	0.04	0.07	0.00	0.00	0.16	0.00	0.00	0.00
Isiukhu Falls	0.10	0.00	0.02	0.04	1.00	0.00	0.11	0.00	0.00	0.00	0.05	0.04
Lirhanda Hill	0.05	0.00	0.03	0.07	0.00	1.00	0.00	0.00	0.25	0.00	0.00	0.00
Lugusida River	0.00	0.00	0.00	0.00	0.11	0.00	1.00	0.00	0.06	0.11	0.20	0.10
Nyayo Tea Zone	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Open grassland	0.04	0.07	0.02	0.16	0.00	0.25	0.06	0.00	1.00	0.00	0.00	0.00
Ponds	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	1.00	0.00	0.00
Sianda River	0.04	0.00	0.07	0.00	0.05	0.00	0.20	0.00	0.00	0.00	1.00	0.16
Yala River	0.00	0.05	0.06	0.00	0.04	0.00	0.10	0.00	0.00	0.00	0.16	1.00

3.4 Role of environment in influencing the ecology of edible insects

The paradigm shift in environmental conditions has impacted negatively on the diversity and distribution of edible of insects globally (Pereira et al., 2012). This has further been accelerated due to human activities. In determination the insect population within the study area, questionnaires were structured to capture various aspects such as the probability of getting insects in the forest, agricultural lands, homes, and insect farms, while those with no information could indicate, I don't know. The results showed that a higher percentage of 66% indicated that the insects were more likely to be found within the forest compared to homes with 43%, Agricultural farms with 22% and insect farms with 14%. These findings is corroborated by the work done by Leidinger et al. (2019) which found out that less dense canopies together with longer rotation age are beneficial for herbivorous insects (**Table 5**).

Table 5. Displaying insect sources

	Counts	Percent (%)
Forest	138	66%
Agricultural farms	46	22%
Insect farmers	29	14%
Don't Know	16	8%

3.5 Culture and insects for food and feeds in the study area

Culture denotes peoples ways of life. This study looked at how local people around Kakamega were able to respond towards the sources of in sects based on gender and this involved the assessment based on the distribution of the sources of insects where a total of 137 respondents had a response that insects were obtained from the forest and out of this 74% females and 26% malesThe second source was agricultural farms with 46 whereby 76% were females while 24% were males. The third cadre was the responses based on insect farmers as source of insects used as food and feed with 29 responses where 69% were females whereas 31% were males. The least under this cadre was those who responded that they dont know about the sources of insects at 16 where 75% were females and 25% were males as presented in **Table 6**.

Table 6. Display of Insect sources by gender

	Forest	Agricultural farms	Insect farmers	Don't know
Female	101	35	20	12
Male	36	11	9	4

The age category used in the study involved under 18years, 18 to 45 years and those people who are above 45 years. The study assed whether age determines the knowledge about the sources of insects and it came out that most of the responses were from the age category of between 18- 45 years across all the sources of insects while only 1 respondent was below 18 years in terms of age at 1% displayed in **Table 7**

Table 7. Display of Insect sources by age categories

Age	Forest	Agricultural farms	Insect farmers	Don't know
18 - 45 years	79	24	20	12
Above 45 years	58	22	9	4
Below 18 years	1	0	0	0

Discussion

The results demonstrate that Nyayo Tea Zone had few numbers of insect species than dense forest. This could be probably due to the residual effects of herbicides, insecticides and other chemicals that are normally applied. This study affirms the study done by Sonoda et al. (2011) which found out that pesticide application negatively affects the insect biodiversity within the peach orchards. This low number could also be probably due to the existence of monoculture of *Camellia sinensis* within the Tea zone whereas within the dense forest there is variety of plants that could form various habitats for various insect species. This study supports the study done by Ghazali et al. (2016) which found out that polyculture farming may improve the conservation of biodiversity as opposed to monoculture practices in palm small holdings. The Nyayo Tea Zones equally showed that the lower diversity of edible insect was likely be due to lack of variety of flowers that insect use as food. This is in accordance to the work done by Carreck & Williams (2001) who also found out that mixture of flowers for pollinators could benefit farmers by attracting pollinating insects. The lower diversity within the Nyayo Tea zones could also be likely due to lack of overhead cover thus the insects could have been exposed to the various insect predators. However, this is in contrast with the findings obtained by Johnson et al. (2009) who found out that the vegetation complexity is likely to attract the beneficial insect eating birds that scavenge on the arthropods thus reducing their population and reduced damage to foliage of the coffee.
From the results the highest insect diversity was evident within the dense forest. This high diversity could have been probably due to the presence of variety of plants that have different flowers that attract edible insects and plants used as habitat as well as camouflaging hence protecting them from the predators. This is supported by the work done by Scohier et al.(2012) who found out that exclusion of sheep temporarily from the pasture through rotational grazing during peak flowering period offered an opportunity for the preservation of flower visiting insects diversity. This study also supports the results done by Haddad et al. (2012) which shows that the diversity of insects relates to the diversity of resources used by the insects. The highest diversity was also likely due to undisturbed habitat due to minimized human activity within the dense forest. This is in line with the work done by Sánchez-Bayo & Wyckhuys (2019) whose findings states that change in habitat and use of agrochemicals in farms form the major cause of insect diversity decline.

The plant species diversity was higher within the dense forest as compared to the other study locations. This high diversity within the dense forest could be probably due to low level of human activities within the dense forest. This is substantiated based on the study done by Parthasarathy (1999) which emphasized on forest conservation as human interferences relates strongly with species richness and abundance. The high plant species diversity could also be probably due to availability of humus/litter that decomposes to improve soil fertility. This is in accordance to the study done by Laurance et al. (2010) which states that soil and topographic features have pronounced effects on diversity of trees and influences community structure as well as tree abundance. Furthermore, the rich diversity could also be due to the ability of seed dispersal by the animals within the dense forest. This is underpinned in accordance to the study done by Böhning-gaese & Schleuning (2017) who found out that the efficacy of grazing network boosts spatial dispersal and upholds diversity of the community management tool that conserve local and regional species diversity. Moreover, the high species richness could be probably due to the availability of dung manures produced by animals which improves the soil fertility enhancing the growth of plants. Additionally, the higher plant species diversity could also be that the thicket is not so much affected by issues of fire, logging, and charcoal burning among others. This is supported by the study done by Kittur et al. (2014) which found out that fires impacts negatively on native plant diversity with varying effects on ecosystems and species as well as species extinction. However, in accordance to the study by Pausas & Ribeiro (2017) it was found out that fires cause delay in competitive exclusion, increase the heterogeneity of landscape and generate new niches, hence fire encourages existence of variety of species. The dense forest could also be due to decreased wind speed leading to low cases of tree fall within the forest. Based on the study done by Karstens et al. (2013) which found out that tree might have been associated with the internal surge of rear-flank downdraft during the intensification stage of tornado which is a strong wind.

In conclusion it is evident that higher insect species diversity was found within the dense forest than any other regions. This could be probably due to low number of pesticides within the dense forest and low disturbed habitat for the edible insects. The findings also reveal that diversity of food plants is more abundance within the dense forest due to low human activities within the dense forest as compared to other regions.

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