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**DEPARTMENT OF ZOOLOGICAL SCIENCES (INSECT
SCIENCES STREAM)**

**ASSESSING LEPIDOPTERAN DIVERSITY IN THREE SELECTED LAND-USE
TYPES IN CHEBERA CHURCHURA NATIONAL PARK AND ITS SURROUNDINGS,
SOUTH-WESTERN ETHIOPIA.**

By

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the Master's degree requirement in Zoology (Insect Sciences).**

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Declaration

This is to certify that the thesis prepared by Gebreegziabher Hailay, titled: “Assessing lepidopteran diversity in three selected land-use types in Chebera churchura National Park and its surroundings, south-western Ethiopia” and a thesis submitted to the Department of Zoological Sciences in partial fulfillment of the Master's degree requirement in Zoology (Insect Sciences) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Table of Contents

Declaration	ii
List of Tables	vi
List of figures	vii
Acknowledgments	viii
Abstract	ix
1. Introduction	1
1.1. Background	1
1.2. Objectives	3
1.2.1. General objective	3
1.2.2. Specific objectives	3
2. Review of literature	4
2.1. Diversity and classification of lepidoptera	4
2.2. Biology and external physiology of lepidoptera	4
2.3. Over view of current lepidoptera study in Ethiopia	5
2.4. Overview of some selected families of order Lepidoptera	5
2.4.1. Family Noctuidae	5
2.4.2. Family Sphingidae	6
2.4.3. Family Geometridae	6
2.4.4. Family Pieridae	6
2.4.5. Family Crambidae	7
2.4.6. Family Erbidae	7
2.4.8. Family Lycanidae	7
2.4.9. Family Hesperidae	8
2.4.10. Family Papilionidae	8

2.5.	Importance of Lepidopterans in the Ecosystem	8
2.6.	Diversity of Lepidopterans at different land-use types	9
3.	Materials and methods	10
3.1.	The study area description.....	10
3.2.	Selection of the study sites	10
3.2.1.	Riverine forest (RF)	10
3.2.2.	Wooded grassland habitat (WGL)	11
3.2.3.	Mosaic environment.....	11
3.3.	Specimen collection	13
3.3.1.	Butterfly specimen collection	13
3.3.2.	Moth specimen collection	13
3.4.	Specimen identification.....	13
3.4.1.	Butterfly specimen identification.....	14
3.4.2.	Moth specimen identification	14
3.5.	Vegetation sampling.....	15
3.6.	Climate data analysis.....	15
3.7.	Data analysis	15
4.	Results	17
4.1.	Diversity of butterfly's species	17
4.1.1.	Distribution and abundance of butterfly per month of sampling.....	17
4.1.2.	Metrological data trend analysis	18
4.1.3.	Butterfly diversity across the three habitats.....	20
4.1.4.	Abundance of butterfly species per month of sampling among the land-use types	20
4.1.5.	Butterfly diversity by habitat type	21
4.1.6.	Jaccard index of similarity of butterflies by habitat type.....	22
4.1.6.	Habitat association of butterflies	25
4.1.	Moths' diversity	27

4.2.1. Moth distribution and abundance per month of sampling	28
4.2.2. Moth diversity in the three land-use types	28
4.2.3. Comparison of Moth diversity at different habitats	29
4.2.4. Sorensen similarity index of moths by habitat type	30
4.2.5. Abundance of moth species by month of sampling among land-use.....	30
4.1.7. Habitat association of moths	34
4.1.8. Comparison of moth species with vegetation types across land-use types.....	34
5. Discussion	35
5.1. Analysis of butterfly diversity	35
5.2. Analysis of moth diversity	37
6. Conclusions and recommendations.....	39
6.1. Conclusion.....	39
6.2. Recommendations	40
7. References.....	41
Appendix.....	52
Appendix. A. List of plant species in riverine forest	52
Appendix. List of plant species of Wooded grass land.....	53
Appendix. List of plant species in Mosaic environment.....	54

List of Tables

Table 1 sampling coordinates of all the sampling sites of the selected three land-use types	12
Table 2. Butterfly's abundance in the study area.....	17
Table 3. Trend analysis of climatic variables at Chebera Churchura National Park	18
Table 4. Butterfly diversity and abundance across the three Land-use types.....	20
Table 5. Selected diversity indices of butterfly communities in three different habitat types.....	22
Table 6. Jaccard index of similarity by habitat	22
Table 7. Species list and abundance of butterflies in different habitats.....	23
Table 8. Chi-square result of butterfly diversity by habitat	26
Table 9. Diversity of plants and diversity of butterflies from the three Land-use types	26
Table 10. Regression result of plants and butterflies from the three Land-use types.....	26
Table 11. Moths' diversity and abundance in the study area.....	27
Table 12. Abundance of families in the three selected Land-use types.....	29
Table 13. Diversity indices at different Land-use type.....	30
Table 14. Sorensen similarity index.....	30
Table 15. Full list of moth species from the three selected Land-use types	31
Table 16. Chi-square result for moth diversity among habitats	34
Table 17. Diversity of moth species and plant species at different land-use types	34
Table 18. Regression result of moth and plant diversity	34

List of figures

Figure 1. Study area map	12
Figure 2. Abundance of butterflies across sampling months.....	18
Figure 3. Rain falls trend analysis at Chebera Churchura National Park from 2012-2017 (January- June).....	19
Figure 4. Minimum temperature trend analysis at Chebera Churchura National Park from 2012-2017 (January- June).....	19
Figure 5. Maximum temperature trend analysis at Chebera Churchura National Park from 2012-2017 (January- June).....	20
Figure 6. Abundance of the butterfly species per month of sampling in different Land-use types	21
Figure 7. Abundance and distribution of moths of the study area per month.....	28
Figure 8. Abundance and distribution of moth communities from the three land-use	31

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Abstract

Following the order of Coleoptera, the Lepidoptera is the second largest order of insects. Currently, Lepidoptera (moths and butterflies) comprise about 46 superfamilies, 126 families, and 180,000 species. Lepidopteran biodiversity in three selected land-use types was studied from January 2020 to June 2020, 2020, and around Chebera Churchura National Park, in the southern Nations, Nationalities and People's region, Southwestern Ethiopia. Three selected land-use types: riverine forest, wooded grassland, and Mosaic habitats were studied. The effects of the diversity of plants on the diversity and abundance of lepidopterans were also studied. Metrological data trend analysis was also studied to investigate the effect of rainfall and temperature on population fluctuations. A sweeping net was used to collect adult butterflies and a light sheet trap was used to collect adult moths. The results showed that 184 species (79 butterfly species and 105 moth species) in 16 families (five families of butterflies and 11 families of moths) were recorded. The Nymphalidae were the most numerous of the five butterfly families studied, while the Hespertiidae were the least numerous. Moth families Crambidae, Erebidae and Sphingidae were the dominant and Pyralidae was the least. Species richness, composition, and abundance were variable in the different land-use types. Thus, the riverine forest had the highest number of lepidopteran species with 147 species and 5,203 individuals, followed by wooded grassland with 106 species and 3174 individuals and Mosaic habitat with 52 species and 1610 individuals. The Chi-square test results showed that the diversity of butterflies and moths differed significantly between the three habitats. Linear regression was calculated to study the role of the diversity of plants on the diversity of moths and butterflies and the results showed that the effect was not significant. The diversity of Lepidoptera captured varied with the month of sampling and the highest number was recorded in January and the least was recorded in June and the trend of rainfall showed increments and the temperature decreased from January to June. The Sorensen index of similarity and Jaccard's index of similarity were observed among the three habitats and the highest similarity was found between riverine forest and wooded grass land with 70% for moth habitat and the highest similarity was found between wooded grass land and mosaic habitat with 34% for butterfly habitat. Generally, the habitat was good for moth and butterfly diversity.

Key words: *Butterflies, Climate Change, Chebera Churchura, Ecological services, Moths*

1. Introduction

1.1. Background

In the terrestrial environment, insects account for more than half of the animals identified (Price, 1997). There are currently 33 insect orders, with lepidopterans being the second largest group of insects after Coleoptera (Goldstein, 2017). Insects having little scales are classified as lepidoptera (Collins & Pierre, 1992). They are densely covered by scales, including parts of the head, body, wings, and appendages, and have lengthy mouthparts called a proboscis. They are characterized by a coilable proboscis, enabling the insect to feed on fluid food. They are the most successful insects found in all parts and habitats of the world except Antarctica (Kristensen & Skalski, 1999). There are approximately 46 super-families, 126 families, and 180,000 species of lepidoptera in the world today (Lepidoptera in GBIF Secretariat, 2019, of which less than 10% are butterflies and more than 90% are moths (Kristensen et al., 2007). Of the 180,000 lepidopterans described in the world, only 2,438 species comprising 48 families are listed in Ethiopia, with only 664 endemic species (Tesfu Fekensa et al., 2019).

Color, type and position of antennae, wing positioning at rest, type of pupa, size, and time of movement are all important characteristics to distinguish between moths and butterflies (Shields & Heinbockel, 2006). Day-flying is a character of butterflies, and night-flying is a character of moths (Munroe, 1979). Lepidopterans have a complete metamorphosis (Kristensen et al., 2007). Cocoon is the name of the pupal stage in moths and the chrysalis in butterflies. Butterfly antennae are club-shaped, long-shafted, and bulbous at the termination, whereas moth antennae are feathery or saw-edged (Munroe, 1979). At rest, butterflies stretch their wings vertically across their bodies, while moths flatten their wings to the ground. Butterflies have thinner abdomens and more directed wings than moths (Kristensen et al., 2007). Moths are delicate fliers and butterflies are virtuous fliers. Butterflies are good-looking and bright-colored and are typically large, unattractive and generally smaller in size than moths (Shields & Heinbockel, 2006).

Lepidopterans (butterflies and moths) have been proposed as suitable indicators for monitoring environmental effects on biodiversity in various habitat types (Nilsson *et al.*, 2013) and planning conservation and management practices (Habel *et al.*, 2021). Lepidopterans (moths and

butterflies) are considered as environmental indicators because they have a short generation time, high mobility, and are sensitive to climate change (Schule *et al.*, 2004; Summerville *et al.*, 2004; Fleishman & Murphy, 2009; Rakosy & Schmitt, 2011). Lepidopterans also play an important role in the regular functioning of the ecosystem through cycling, pollination, predation, parasitism, and decomposition (New, 2011). Sphingidae, Noctuidae, and Geometridae are some moth families important in pollination. Lepidopterans are also pests of important crops in the world, but only less than 5% (Jankielsohn, 2018). Some of the pests include diamondback moths, Gypsy moths, tomato leaf miners, spotted sugarcane borers, stalk borers, and Fall Armyworms (Suckling *et al.*, 2017). Despite the above services, insect biodiversity is rapidly declining (Sanchez-Bayo & Wyckhuys, 2019), with moth butterflies in the forefront and habitat loss, degradation, and fragmentation are the most common causes of species decline (Fox, 2013; Sanchez-Bayo & Wyckhuys, 2019). Scientists have found that different land-use types support different insect species including lepidopterans (Rodríguez-Echeverry *et al.*, 2018; Daskalova *et al.*, 2020; Yang *et al.*, 2020).

Despite Ethiopia's vast area, geographic position, and diversity of habitat types, our knowledge and comprehension of lepidopterans is limited or nearly unexplored (Tesfu Fekensa *et al.*, 2019). The diversity of lepidopterans and generally insects is expected to be higher comparing other African countries but the described species are even more than Kenya. Thus, Chebera Chrchura National Park, a newly founded National Park in Ethiopia, was chosen from among the various habitats and agroecology of Ethiopian environments since no published data on the biodiversity of macro-lepidopterans in the current study area. However, due to a lack of time, funds, and the area's accessibility, just a small portion of Chebera Churchura National Park was chosen to be studied. Based on information gained from literatures and based on the accessibility of the habitats three land-use types were selected namely wooded grassland, riverine forest, and mosaic habitat. Four sites from each habitat type were selected to describe the diversity of lepidopterans for future conservation planning and as initial source for further study and investigation of lepidopterans and other insect groups. Thus, the study focused on the identification, abundance and biodiversity of butterflies on three different land-use types in and around Chebera Churchura National Park, Southwestern, Ethiopia and their impacts. Over all the lepidoptera diversity in different habitat types was investigated in and around the national park.

1.2. Objectives

1.2.1. General objective

- To assess lepidopteran diversity among selected types of Land-use in Chebera Churchura National Park as baseline data for conservation

1.2.2. Specific objectives

- To compare the diversity and abundance of Lepidoptera across three different land-use types
- To investigate how land-use types and the month of sampling affects lepidopteran abundance.
- To analyze the effect of plant diversity and climate on the diversity of lepidoptera
- To analyze trend analysis rainfall and temperature trends in the study area

2. Review of literature

2.1. Diversity and classification of lepidoptera

Lepidopterans constitute the second-largest, most diverse, widely distributed, and most distinguished insects' order (Goldstein, 2017). According to current estimates, lepidoptera is composed of butterflies and moths and it is made up of 126 families, 46 superfamilies, and about 180,000 species worldwide (Lepidoptera in GBIF Secretariat, 2019) of which it contains over 90% moths and fewer than 10% butterflies (Kristensen *et al.*, 2007).

2.2. Biology and external physiology of lepidoptera

Lepidopterans are invertebrates and like other insects have three body parts head, thorax, and abdomen (Price, 1999). Lepidopterans are different from other insect by having scales on their wings and most parts of their body including head, wing, legs, proboscis and appendages. The head of lepidopterans as with rest of the body is covered with scales contains two compound eyes and ocelli, moth parts, proboscis and sense organs (Collins and Pierre, 1999). The antennae functions in different ways and have different shape, size, morphology and function and used as identification tool for species and sex. Moths have generally feathery antennae and butterflies have knobbed antennae. Males' antennae have more sensilla than females for identification of pheromones produced by the females (Shields and Heinbockel, 2006).

The thorax of lepidopterans is divided in to three parts and contains three pairs of legs and the four wings. The wings coloration, variation, shape, size and patterns are different in different species, families and even genera. The inner side of thorax is also used for identification of sex by which males have single spine arising from the hind wing and females have more than three spines arising from the hind wing but there are exceptions. The hind legs starts with epiphysis which is unique to lepidoptera and hind legs have four tibia pretarsal and the middle legs have only two (Shields and Heinbockel, 2006). The abdomen contains mainly male and female reproductive organs, the genitalia. The genitalia are used as identification method of species and sexes such that male and female lepidopterans have different genitalia structures (Kristensen *et al.*, 2007). Male genitalia contain valve for holding the female during sex and the female genitalia have only one opening for sperm insertion. Scales function in different ways in

lepidoptera either give coloration or aids in thermoregulation and defense. Scale's pattern, color, pigmentation, size and structure help for identification (Shields and Heinbockel, 2006).

Lepidopterans have complete metamorphosis includes four phases of development: egg, larvae, pupa, and adults (Kristensen, 1999). The life cycle begins with mating, and after mating, eggs are laid near host plants, which provide food for the larvae. Number of eggs laid depends on several species, from a few hundred to thousands of eggs. The pupa is called chrysalis in butterflies and a cocoon in moths (Pohl *et al.*, 2015). Moths are divided into two groups: macro-moth and micro-moth (Kristensen *et al.*, 2007). The main macro moth families are Geometridae, Notodontidae, Euteliidae, Noctidae and Nolidae (Kristensen *et al.*, 2007).

2.3. Over view of current lepidoptera study in Ethiopia

Although some attempts have been made to describe the diversity of lepidopterans in Ethiopia, considering the habitat heterogeneity and habitat preference, the reported families and species are much less than expected. From the described 128 families and more than 180000 species of lepidopterans (Lepidoptera in GBIF Secretariat, 2019), about 48 families and 2,438 species of lepidopterans have been reported as of 2019 (Tesfu Fekensa *et al.*, 2019). Recent literatures on Ethiopian lepidopterans comprises about 87 butterfly species from Belete-Gera forest from different land-use types have been reported (De Beenhouwer *et al.*, 2015), 46 species of butterflies were reported from Menagesha-Suba State Forest from different altitudes (Abaynew Jemal and Emanu Getu, 2018), 43 butterfly species from Gura-Ferda forest, (Foquet *et al.*, 2019), 19 pieridae species from west Shewa (Gorbunov, 2017), and 64 species of butterflies from Jimma Highlands (Norfolk *et al.*, 2017).

2.4. Overview of some selected families of order Lepidoptera

Some selected and important macro-lepidopterans families and butterfly families are described as follows to understand how they are different from each other.

2.4.1. Family Noctuidae

The second-largest family and the majority of species are vital crop pests worldwide (Kirti & Dar, 2013). Vary in size from little to massive. Most take advantage of nectars, solid proboscis, simple antennas, and uninteresting colors are some distinctive options (Rabieh, 2018). They have

characterized by stout-bodied and rest on the bark of the tree, generally in a roof-like fashion and spread over a drop of sugar to tree trunks is the best way to collect Noctuid moths (Rabieh, 2018). The majority of Noctuid species have binary marks in the center of the forewing, oval and kidney shaped. The relative size, shape and color of these can be important aids to identification. Males have pectinate (comb-like) antennae, while females have plain antennae. They are very varied size, shape, colors and size ranges from very small to large wingspan The majority are nocturnal and forewings narrow and somewhat narrow, hind wings broad (Speidel *et al.*, 1996).

2.4.2. Family Sphingidae

Commonly called sphinx moths, they are speedy fliers, and are widely distributed (Fleming, 2017). Some distinguishing characters include no feathered antennae, scaly body, absence of hearing organ, very long proboscis, and most adults feed on nectars (Osborne, 2010). Hummingbird hawk moth, deaths-head hawk moth, and white-lined hawk moth are listed as Sphingidae moths. Color variation includes black with red, pink, orange, or yellow bands on their abdomen (Fleming, 2017).

2.4.3. Family Geometridae

They are the second-largest family of moth families with more than 24 thousand identified and recorded species (GBIF, 2019). Adults have a slender body and wide wings. The feathery antennae in males are used as an identification method for males from females. All geometrids have a uniform shape and stance (Pitkin, 2002). Forewings are broad and triangular in shape. All geometrids hold their wings outstretched and flat against the surface when they are at rest. Most adults are green in color (Hausmann & Hebert, 2009; Murillo-Ramos *et al.*, 2020; Makhov, 2021).

2.4.4. Family Pieridae

They are usually referred to as white and yellow butterflies and are white, orange, and yellow in color (Wahlberg *et al.*, 2014). Most have dark markings and are small in size. They are migrants and adaptive to every environment (Wahlberg *et al.*, 2014). They can be identified by their non-tailed back wing, normal wing outline, and well-developed forelegs. Examples include orange tips, sulfurs, white, and alfalfa, as well as cabbage butterflies (Arya, 2014). Antennae are weakly

clubbed and there are around 1,275 species globally. The wings are triangular, with the fore wings being larger (Descimon, 2019).

2.4.5. Family Crambidae

The Crambidae (grass moths) have a range of colors and shapes. With scales at the base of the proboscis, the larvae feed on the stems of plants of the grass family. The prementorial, the tympanal organs that connects two tympanal organs, is the main distinction of the family (Leger *et al.*, 2021).

2.4.6. Family Erbidae

The family encompasses a wide variety of well-known macro moth groups and is one of the largest moth families in terms of species count. Under wing litter moths, tigers, tussock moths, and snout moths are all members of this family. Adults range in size from among the largest of all moths to the tiniest of macro moths. The adults' coloring ranges from light to dark. Members of this very large family of moths can be found worldwide. They are defined by the vein structure in the wings (Byrne & Moyle, 2019).

2.4.7. Family Nymphalidae

Members of this family have brush-footed forelegs due to their short and hairy forelegs (Willmott, 2008). They are the largest butterfly family. Monarch butterflies are an example of a commonly occurring species (Khyade & Jagtap, 2016). They're medium-sized, and many of them are orange or brown with dark markings, but size and color differ a lot (Khyade *et al.*, 2018). Legs are used as sense organs and are useless for walking or perching. They are an important component of the dead butterfly trade where they are displayed for their beauty. They are also used widely in education and butterfly houses (Willmott, 2008).

2.4.8. Family Lycaenidae

They are a species of metallic gloss butterfly that is small, vividly colorful, and has a metallic finish (Bartlett, 2017). The color of females and male differ, as do their forelegs. The underwings are usually duller and have a different color and pattern than the upper wings (Van Nieuwerkerken *et al.*, 2011). They feature up to three pairs of delicate, hairy forewings, as well as tails on their hind wings (Van Nieuwerkerken *et al.*, 2011).

2.4.9. Family Hesperiiidae

They vary in size and their antennae are curved at the tip. The robust thorax easily recognizes it from other butterflies. They are predominantly gray or brown in color, with 12 unbranched veins extending from the discal cell or wing base to the wing margin on the forewing (Leger *et al.*, 2021).

2.4.10. Family Papilionidae

They are yellow or white with black markings and are good fliers (Heppner, 2008). Hairless eyes, small antennas, three fully developed pairs of legs, and tails on the hind wings are some morphological features (Kunte, 2009). They lack scales and there are 11 or 12 veins in the fore wing; the 1A and 2A veins are distinct in males and females. Most of them are tropical, and the Old World is particularly diverse (Myers *et al.*, 2021).

2.5. Importance of Lepidopterans in the Ecosystem

Lepidopterans also play an important role in regular functioning of the ecosystem through cycling, pollination, predation, parasitism, and decomposition (New, 2011). Some moth and butterfly families, such as Sphingidae, Noctuidae and Geometridae, and Hesperiiidae and Papilionoidea, have been identified as pollinators for various plants (Jankielsohn, 2018). A study conducted in South Africa on *Crinum macowanii* Bake (Amaryllidaceae) has shown that the hawkmoth *Hyles lineata* (Fabricius, 1775) was recorded as a pollinator of the above pantspecies (Manning & Snijman, 2002). Another study conducted in South Africa confirmed that *Cucullia umbratical* (Linnaeus, 1758) and the hawkmoth species *Basiothia medea* (Fabricius, 1781), *Hippotion Celerio* (Linnaeus, 1758), *Basiothia schenki* (Möschler, 1872), and *Oligographa juniperi* (Boisduval, 1847) were found pollinators of plan species *Habenaria willd.* (*H. polyphylla*; Orchidaceae) (Peter *et al.*, 2009).

Lepidopterans also play an important role in food chains and food webs (Lopez-Vaamonde *et al.*, 2010). Lepidopterans provide food for birds, amphibians, retails, bats, fish, some mammals, and some humans (Kristensen *et al.*, 2007). Less than 5% of lepidopterans are also pests of important crops in the world (Jankielsohn, 2018). Diamondback moth, Gypsy moth, the tomato leaf miner, *Tuta absoluta* (Meyrick, 1917), Spotted sugarcane borer, African sugarcane stalk borer, and Fall Armyworm (FAW) *Spodoptera frugiperda* (Smith, 1797) are some pests (Suckling *et al.*, 2017).

2.6. Diversity of Lepidopterans at different land-use types

The biodiversity of insects is rapidly declining (Sanchez-Bayo & Wyckhuys, 2019). The most common causes of species decline are loss of habitat, deterioration, and fragmentation (Fox, 2013; Sanchez-Bayo & Wyckhuys, 2019). Various land-use types support various insect species (Rodríguez-Echeverry *et al.*, 2018; Daskalova *et al.*, 2020; Yang *et al.*, 2020). As a result, understanding and discovering biodiversity, especially Lepidoptera, is critical for policymakers and biodiversity conservation. According to a study titled "The Effect of Land-use on Butterfly Diversity in the Republic of Moldova," species richness varies depending on the type of land-use (Serik *et al.*, 2018). A study on butterfly alpha and beta diversity in human modified landscapes and tropical rainforests by Sambhu *et al.* (2018) found that landscapes have diverse management practices and support various types of biodiversity, and they concluded that in order to achieve landscape-level conservation goals, land managers and conservation practitioners must incorporate all of the many stakeholder groups. According to a study conducted in Wales, biodiversity richness varies depending on land-use intensity, habitat heterogeneity, and biodiversity, with habitat heterogeneity providing the most diversity (Maskell *et al.*, 2019).

Despite Ethiopia's tremendous biological diversity and different ecosystems, habitat conservation has gotten little attention (NBSAP, 2015) and expansion of agriculture and clearance of forests for investment takes place. Thus, it is important to study the biodiversity of Lepidopterans. Some works that contributed to the biodiversity of Ethiopia by different scholars are listed below to show the overall works in Ethiopia. More than 87 butterfly species have been reported from Belete-Gera Forest (De Beenhouwer *et al.*, 2018), 46 species of butterflies have been reported from Menagesha-Suba State Forest (Abaynew Jemal and Emanu Getu, 2015), 19 species of Pieridae butterflies have been reported from west Shewa (Gorbunov, 2017), and 64 species of butterflies have been reported from Jimma Highlands (Norfolk *et al.*, 2017). There is, however, no data on the diversity of lepidoptera communities in the studied area. This information motivates us to look into the Lepidoptera diversity in Ethiopia's Chebera Churchura National Park.

3. Materials and methods

3.1. The study area description

The study area was situated at 6°53'14"N and 36°38'11"E. The park's elevation ranges from 700 to 2450 meters above sea level, with an average yearly temperature of 10 to 29 degrees Celsius. The annual rainfall averages between 1200 and 2300 mm (Alemayehu Acha and Mathewos Temesgen, 2015). The Park has an area of approximately 1119 km² and is located 480 kilometers along the Addis Abababab –Jimma–Chida–Ameya road. The Park was mainly categorized into four vegetation zones, namely wooded grass land, riverine forest, montane woodland, and woodland (Alemayehu Acha and Mathewos Temesgen, 2015).

3.2. Selection of the study sites

Three land-use types namely wooded grassland, riverine forest, and mosaic habitat were selected based on information from literatures and based on the accessibility of the habitats. Four sites from each of the three land use types and a totally 12 sites were selected from the three land-use types. The geographical coordinates of all the sampling sites were measured with a global positioning system (GPS) device (Table 1). Each of the land use types are described below as follows.

3.2.1. Riverine forest (RF)

The first land use type was the riverine forest (RF) habitat set at 36° 41' 00.60" E and 07° 00' 36" N and at 1176m.a.s. and it was five kilometers away from the mosaic habitat and approximately two km away from the wooded grass land. It was characterized by different plant species and flowing water. The main plant species of this land use types were *Cordia africana* Lam, *Terminalia laxiflora* Engl. & Diels, *Combretum collinum* Swynn. & Bak, *Vitex doniana* L, *Clerodendrum alatum* Gürke, *Satureja montana* L, *Ficus sycomorus* L, *Syzygium guineense* Wall, *Sida rhombifolia* L, and *Grewia mollis* Juss.

3.2.2. Wooded grassland habitat (WGL)

The second land use type was the wooded grassland habitat (WGL) positioned at 36° 37' 47.88''E 06° 54' 00'' N and 1587m.a.s.l. and covers 62% of the park is an area covered by herbaceous plants with less tree and herb coverage. It covers the largest part of the national park and is mainly covered by elephant grass (*Pennisetum purpureum*). It was found next to natural and riverine forests. The approximate distance of this habitat was 15 km from the mosaic habitat. This habitat type was mainly selected due to the fact that it covers the most part of the national. Some plant species found in this habitat was *Acanthus mollis* L, *Eseveria abyssinica* L., *Crinum ornatum* (L.f.), *Ocimum gratissimum* L., and *Clerodendrum alatum* Gürke.

3.2.3. Mosaic environment

The Mosaic environment is found at 36° 40' 17.04''E 07° 01' 12''N and elevation 1444 mal found in Seri kebele outside but at the edge of the national park. This habitat was characterized by the presence of natural forest, crop cultivation, grassland, and human settlement. Seri kebele is primarily selected for the reason that it was inhabited by humans and animals and principally found close to the National Park. The people who live there have a high level of interaction with wildlife, and lepidopterans do not appear to be immune to the effects of human interaction. Some representative plant species of this habitat was *Mangifera indica* L., *Colocasia esculenta* L., *Terminalia loxifelera*, *Combretum mole*, *Combretum collinum*, *Entada Africana*, *Prunus africana* (Hook.f.) and *Harrisonia abyssinica* Oliv.

Table 1 sampling coordinates of all the sampling sites of the selected three land-use types

No	Land-use type	Sampling site	Altitude(m)	Longitude	Latitude
1	Mosaic	M01.km	1444	36° 40' 17.04''	07° 01' 12''
2	Mosaic	M02.km	1376	36° 40' 4.44''	07° 00' 44''
3	Mosaic	M03.km	1293	36° 00' 37.44''	07° 00' 37''
4	Mosaic	M04.km	1308	36° 40' 24.24''	07° 00' 49''
5	Riverine	R01.km	1176	36° 41' 00.60''	07° 00' 36''
6	Riverine	R02.km	1197	36° 40' 41.88''	07° 01' 31''
7	Riverine	R03.km	1184	36° 01' 05.16''	07° 01' 05''
8	Riverine	R04.km	1170	36° 41' 26.88''	07° 01' 30''
9	Wooded Grass Land	W01.km	1587	36° 37' 47.88''	06° 54' 00''
10	Wooded Grass Land	W02.km	1491	36° 37' 30.6''	06° 54' 43''
11	Wooded Grass Land	W03.km	1517	36° 37' 38.52''	06° 54' 37''
12	Wooded Grass Land	W04.kmz	1552	36° 37' 52.56''	06° 54' 34''

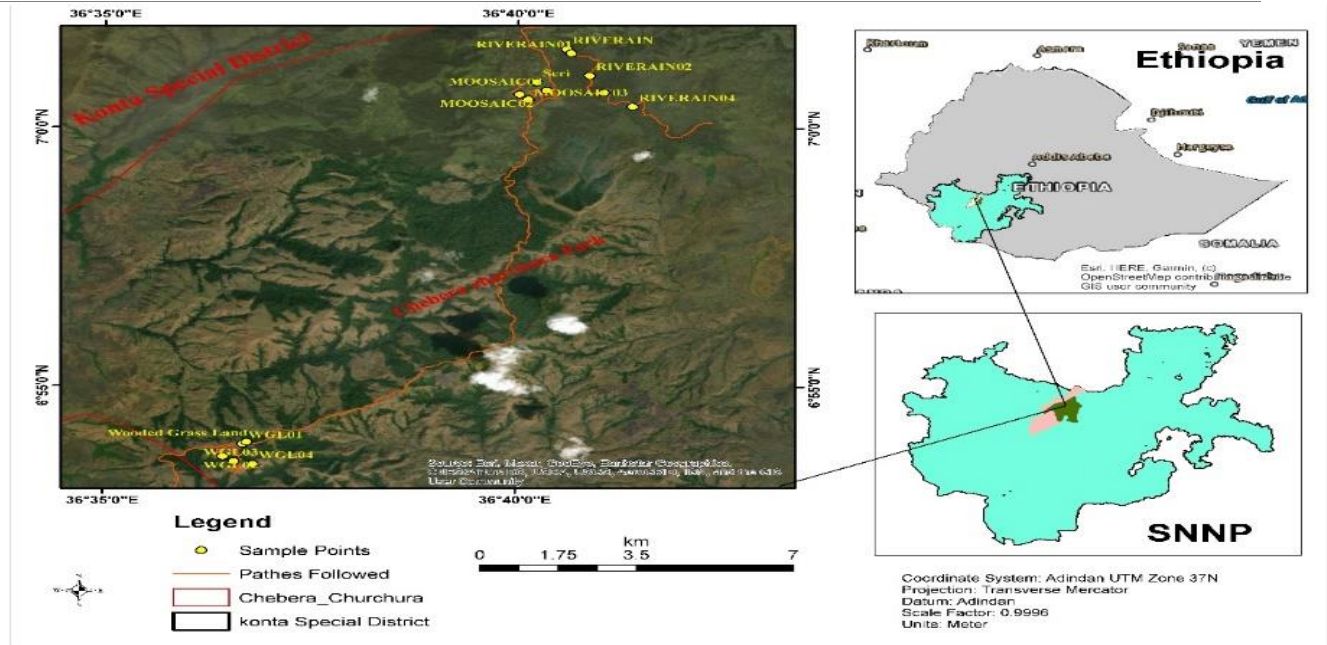


Figure 1. Study area map

3.3. Specimen collection

3.3.1. Butterfly specimen collection

Adult species were collected in each habitat using a sweeping net a 1000 meter long through "walking line transect," following the walking line transect method (Pollard, 1982; Liley et al., 2004; Pellet, 2008). Surveys were conducted once a month for each site for six months, from January 25 to June 25, and sampling was done from 9:00 a.m. to 12:00 a.m. and 2:00 p.m. to 4:00 p.m because butterflies are subject to weather conditions. Each site was sampled once every month and six times throughout the sampling period. The study area was sampled a total of 18 times (6 times sampling * 3 sites =18 total sampling period per total site). Adult butterflies were collected for an average of five hours per month at each site, for a total sampling period of 90 hours (5 hours * 18 sampling sites) (Collinge et al., 2003; Stefanescu et al., 2004; Holland, 2020).

3.3.2. Moth specimen collection

Collection of moths using a light sheet trap was conducted once every month from January to June, 2021. A total of six light sheet trapes were deployed in each sampling habitat and a total of 18 light sheet traps were employed for the total study area. Trap was installed for four hours long, from 19:00 to 23:00, each night for each habitat and total sampling was done for 72 hours. A 20W UV fluorescent light bulb with a length of 50cm was held in front or above the vertical white sheet (1.8m x 1.8m square) in this study and a power source, a portable 12 Volt lead battery was used (Jonson et al., 2014). Moths were drawn to the sheet trap and manually collected using white jars of various sizes charged with cotton and Trichloroethylene or diethyl ether chemicals to kill them. The chemicals are volatile and kill the moths without physical damage to the wings and bodies of the moths with less discoloration effect (Brehm & Axmacher, 2006).

3.4. Specimen identification

External morphological features were used to identify from family to genus and species of lepidopterans. Some features include the type, shape, size of moth parts mouth parts, Wing

coloration, pigmentation, size (wing span), shape, venation, type, size, shape, structures of antennae, scales color, shape, size and pattern, presence or absence of labial palp, morphology of labial palp and structure and shape of sensory organs are among the characters that used for species identifications (Munrose, 1979; Kristensen, 1999; Kristensen and Skalski, 1999; Shields and Heinbockel, 2006; Kristensen *et al.*, 2007; Holland *et al.*, 2020). All voucher specimens were kept at Ethiopian Biodiversity Institute (EBI).

3.4.1. Butterfly specimen identification

The specimens collected were killed by pinching their thorax (todhumme.wordpress.com), which squirts a butterfly's thorax with just enough force to smash the exoskeleton and press some crucial components of the thorax. Every day, all the specimens collected were killed, counted and sorted into morphospecies in the field. All the collected butterfly specimens were placed in storage boxes made locally from paper and cotton and transported to the Ethiopian Biodiversity Institute laboratory for further analysis. Samples were pinned with entomological pins, relaxed in humid chambers and prepared with open wings on spreading boards, and made ready for taxonomy study. The identification of the specimens was done using all available publications/keys such as Williams (2002), Kang *et al.* (2014), Tesfu Fekensa *et al.* (2019), Lepidoptera in GBIF Secretariat (2019) and Holland (2020).

3.4.2. Moth specimen identification

Moth specimens were killed, counted, mounted, and sorted each night from each land-use type to family level in the field. The collected specimens were transported contained in insect boxes made from cotton and hard paper to the Ethiopian Biodiversity Institute. Collected specimens have been pinned with standard entomological pins, relaxed, and mounted in EBI laboratories. Representative voucher specimens were labeled and deposited at the Ethiopian Biodiversity Institute (EBI). Specimens were identified at species level by consulting taxonomists and comparing them with online plates available using available sources Goff (2008), Kirti & Dar (2013), De Prins and Heughebaert (2019, Tesfu Fekensa *et al.* (2019) and Lepidoptera in GBIF Secretariat (2019).

3.5. Vegetation sampling

Vegetation sampling was done for each of the three land use types by totaling all the plants identified within a 100m radius of the light sheet trap set. In addition, flora inspections conducted visually assessed to ensure that they were representative of the study area. All habitats' vegetation types were identified at the species level and categorized as trees, shrubs, and grasses.

3.6. Climate data analysis

Climate data was analyzed by taking five-year average monthly minimum temperature, average monthly maximum temperature and average monthly rainfall. The data included from 2012 G.C to 2017 G.C to investigate how the patterns were associated with the lepidopteran population fluctuation. The data was retrieved from online world climate data (<https://power.larc.nasa.gov/data-access-viewer/>). The climate data trend analysis was done using Microsoft Excel version 2016.

3.7. Data analysis

The data on lepidoptera (moths and butterflies) collected in each month was added to each of the three habitats for the basic biodiversity data analysis. Climate trend analysis was done by taking the climate data for the five years from 2013 to 2017 from the world climate database.

- ❖ The past software Version 4 was used to calculate biodiversity indices and Microsoft Excel version 2016 was also used to draw graphs of the results.
- ❖ The Chi-square test was used to compare the diversity of lepidopterans among habitats because the data failed to satisfy the criteria for both one-way ANOVA and the Kurkul wall test, and it was analyzed using SPSS version 26.
- ❖ The effect of the diversity of plants on the diversity and abundance of lepidopterans in each habitat was analyzed using SPSS version 26.
- ❖ Climate trend analysis was also done using Microsoft Excel version 2016 by taking the climate data for the five years from 2013 to 2017 from the world climate database to analyze the effect on the population's distribution.

- ❖ The identified and collected lepidopterans (moths and butterflies) biodiversity data was analyzed using species richness, species evenness, Simpson's index diversity, and the Shannon waver index of diversity were employed to investigate the overall moth and butterfly diversity of the research area.
- ❖ Shannon-weaver index (H') and is defined as $H' = -\sum (p_i) (\ln p_i)$, where p_i is the percentage of the i^{th} species in the total sample ($p_i = n_i/N$). A species with a higher H' -value is more diverse than with a lower H' -value.
- ❖ The Simpsons Diversity Index (D) is a diversity metric for insects that is used to evaluate habitat diversity. ($D = 1 / \sum (P_i)^2$), where D is the diversity index of Simpsons, $\sum P_i$ is the proportions of individuals in the study. This index shows the probability of sampling two different species at random at once.
- ❖ Species diversity (S) is obtained by simply counting the species found in the study area (Colwell, 2009).
- ❖ Species evenness (J) is calculated according to Pielou (1966) and unlike species richness; it considers how the diversity of the community is equally distributed.
- ❖ Jaccard's index (C_j) = $j / (A+B-j)$ was used to determine the similarity of lepidopterans in different habitats. Where j is the number of species that are similar to both sites, and A is the number of species that are unique to each site1 B = the total number of species at site 2.
- ❖ Sorenson's index of similarity given by Sorenson's index of similarity given by $S = 2C/A + B$ where c = the number of common species to both sites, A = the number of species found on site 1 B = the number of species in site 2.

4. Results

4.1. Diversity of butterfly's species

A total of 79 butterfly species with five families, 3801 individuals and 33 genera were recorded in the study area (Table 2). The abundance of butterflies indicates that the family Nymphalidae with 42 species, 2191 individuals and 17 genera consisting of 58%, was recorded as the most abundant, followed by Pieridae with 17 species, 1173 individuals and 7 genera consisting of 30% of the collected specimens. Hesperidae, with 2 species, 14 individuals and 1 genus consisting of 1%, was the least abundant (Table 2). The abundance of butterfly species in three different land-use types were investigated and result have shown that *Acraea acara* (Nymphalidae) was the most abundant species with 217 individuals followed by *Anthene opalina* (Lycaenidae) with 145 individuals and *Eurema brigitta* (Pieridae) with 117 individuals whereas *Papilio nireus* (Papilionidae) with 30 species and *Papilio demodocus* (Papilionidae) with 40 species were documented the least abundant species across the three land-use types (Table 6).

Table 2. Butterfly's abundance in the study area

No	Family name	Species number (%)	Number of individuals (%)	Genera number
1	Nymphalidae	42 (53%)	2191 (58%)	17
2	Pieridae	17 (22%)	1173 (30%)	7
3	Lycanidae	8 (10%)	278 (7%)	6
4	Papilionidae	10 (13%)	145 (4%)	2
5	Hesperidae	2 (2%)	14 (1%)	1
Total			3801	33

4.1.1. Distribution and abundance of butterfly per month of sampling

Results revealed that the month of January had the highest number of butterflies, with 940 individuals accounting for 25%, followed by February, with 749 individuals accounting for 20%. The lowest number of butterflies was recorded in the month of June with 460 individuals accounting for 12% (Figure 2).

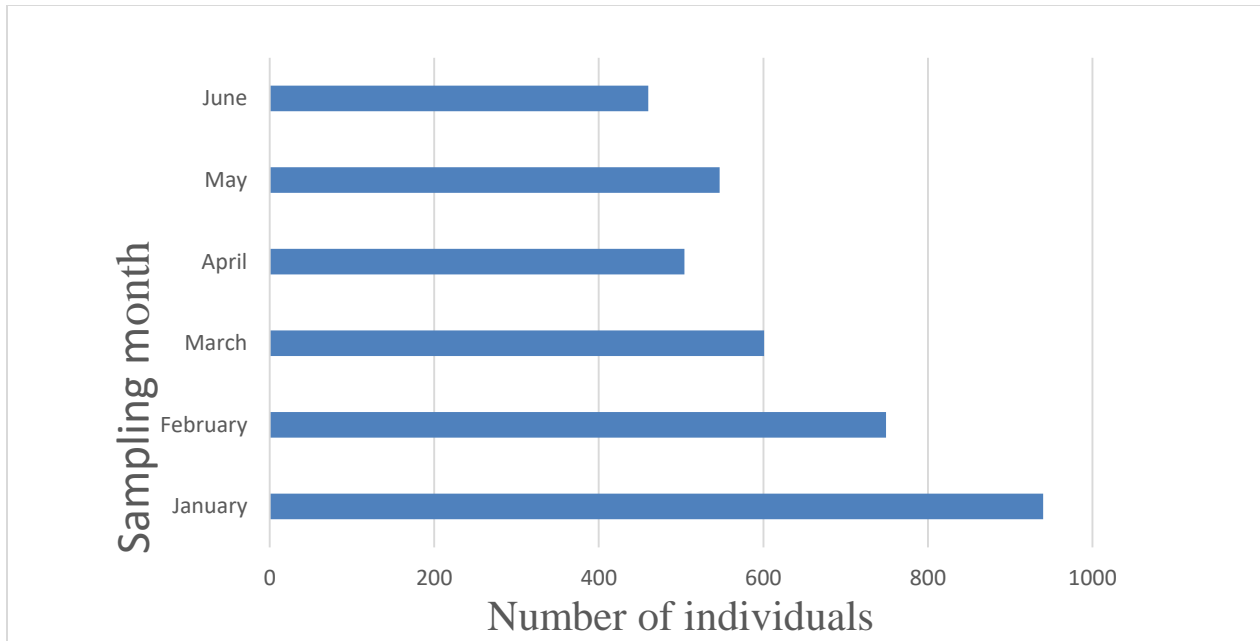


Figure 2. Abundance of butterflies across sampling months

4.1.2. Metrological data trend analysis

A trend analysis of meteorological data average monthly minimum and maximum temperature and monthly average rainfall data recorded of six years (2012-2017) to compare the trend with the lepidopteran population. Results revealed that generally the average monthly rainfall from January to June was increasing and the lower decreasing of the mean of monthly average temperature and mean of average monthly rain fall.

Table 3. Trend analysis of climatic variables at Chebera Churchura National Park

year	Average monthly temperature (from January -June)		Average monthly rainfall (from January - June)
	Minimum	Maximum	
2012	15 ^{0c}	26 ^{0c}	59 mm
2013	16 ^{0c}	28 ^{0c}	41 mm
2014	15 ^{0c}	28 ^{0c}	110 mm
2015	14 ^{0c}	22 ^{0c}	241 mm
2016	14 ^{0c}	21 ^{0c}	353 mm
2017	14 ^{0c}	21 ^{0c}	221 mm

^{0c}= degree centigrade, mm- millimeters

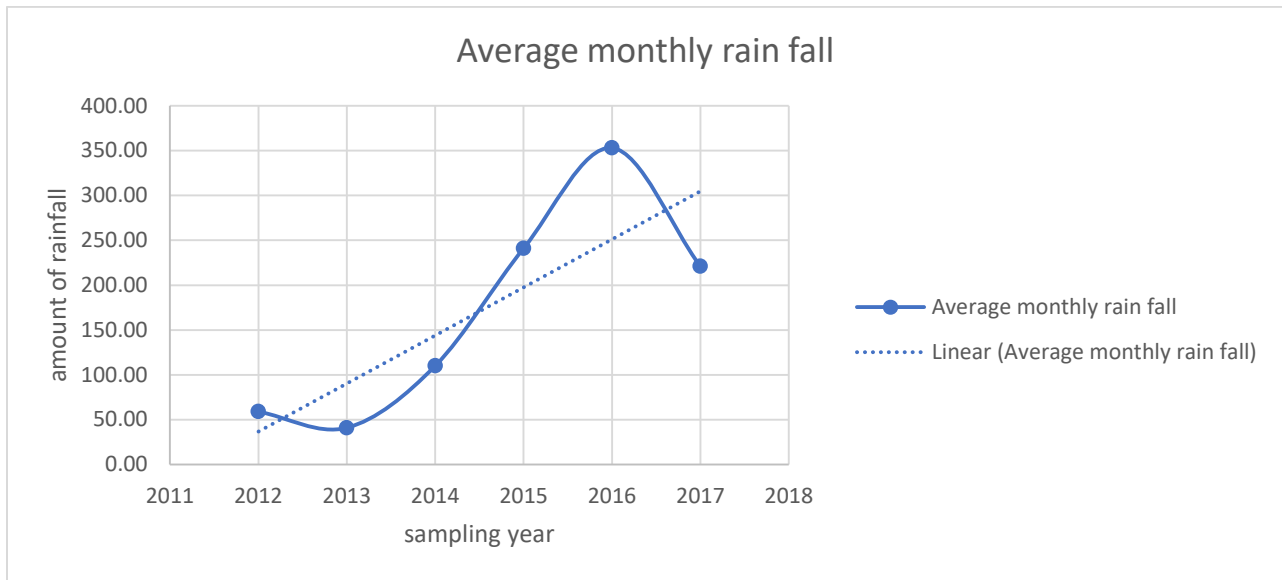


Figure 3. Rain falls trend analysis at Chebera Churchura National Park from 2012-2017 (January- June)

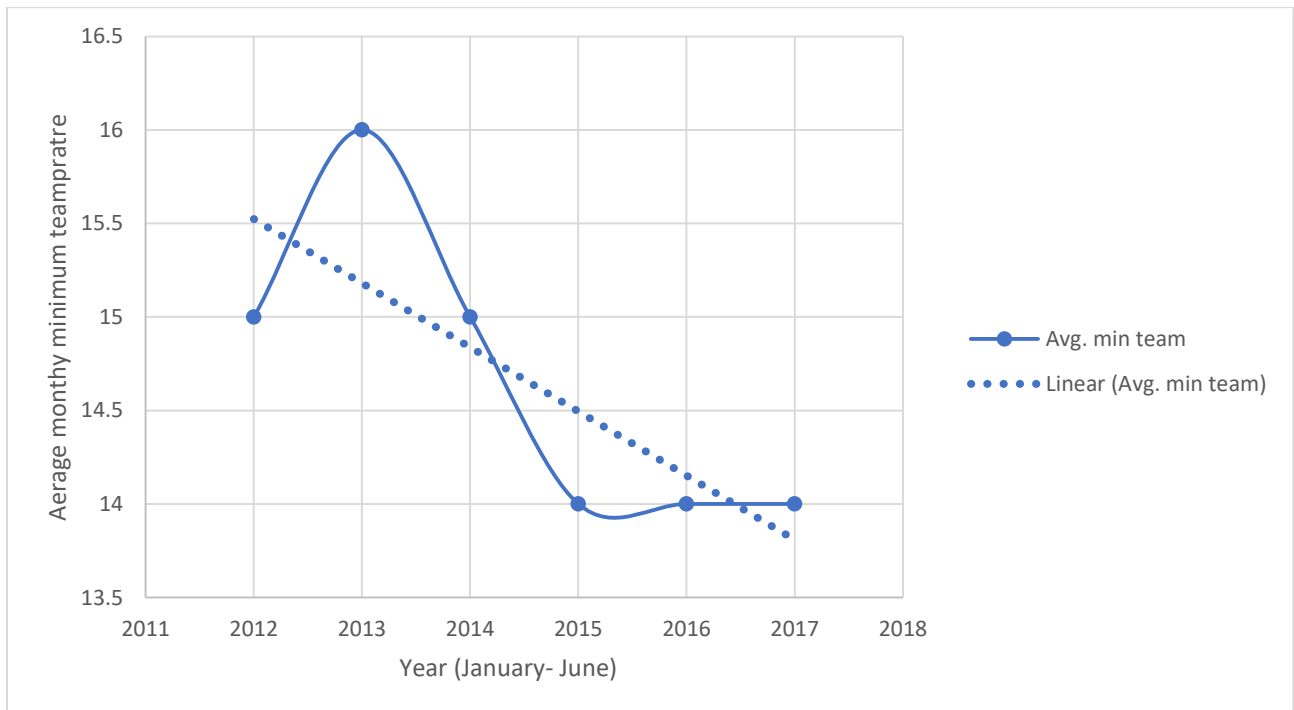


Figure 4. Minimum temperature trend analysis at Chebera Churchura National Park from 2012-2017 (January- June)

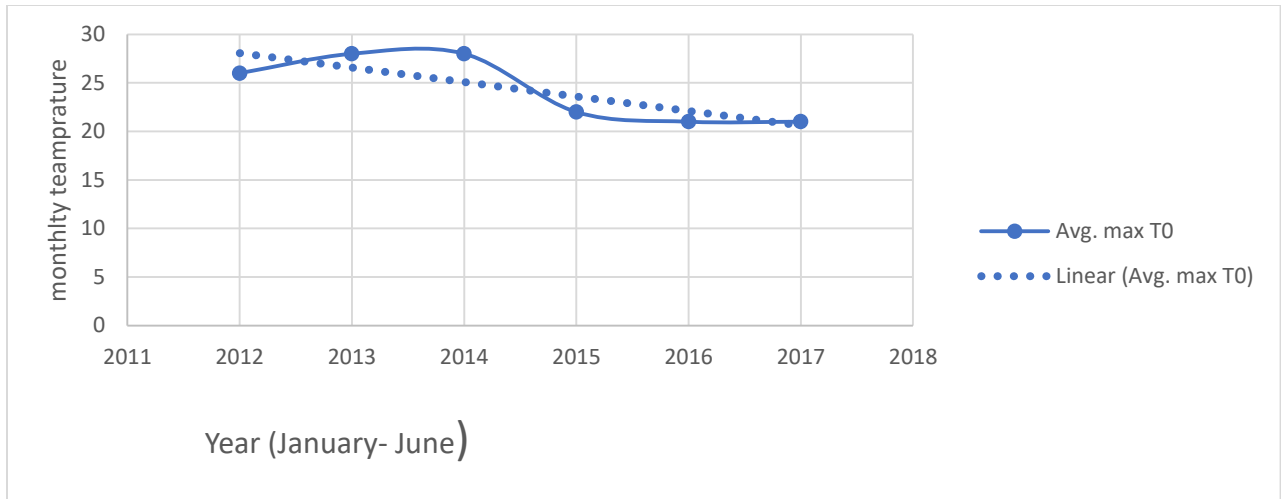


Figure 5. Maximum temperature trend analysis at Chebera Churchura National Park from 2012-2017 (January- June)

4.1.3. Butterfly diversity across the three habitats

The diversity and abundance of butterflies were studied in all three land-use types, and the results revealed that riverine forest had the greatest diversity and abundance, with 54 species and 1611 individuals, while mosaic habitat had the least, with 23 species and 659 individuals (Table 4).

Table 4. Butterfly diversity and abundance across the three Land-use types

Habitat	family	Species	Individuals	Maximum	Minimum	mean	Standard error
Riverine	5	54	1611	100	0	20	2.63
wooded	5	43	1531	80	0	19	2.62
mosaic	4	23	659	99	0	8	2.09

4.1.4. Abundance of butterfly species per month of sampling among the land-use types

Out of 1,611 butterflies recorded from the riverine forest, 420 butterflies were recorded in January and 169 were recorded in June. Wooded grassland had a about 1,531 butterflies with 300 (highest) butterflies in January and the least was 170 in March. From the total of 659 butterflies recorded in mosaic habitat, the highest abundance was recorded in January with 220 butterflies and the less abundant month was in May with 65 individuals (Figure 6). The population

fluctuation of butterflies in each month was recorded in each of the three land-use types, and the results revealed that both riverine forest and mosaic habitat showed decreasing pattern from January to June but the individuals recorded from wooded grass land showed decreasing pattern from January to march and increasing pattern from April to June (figure 6).

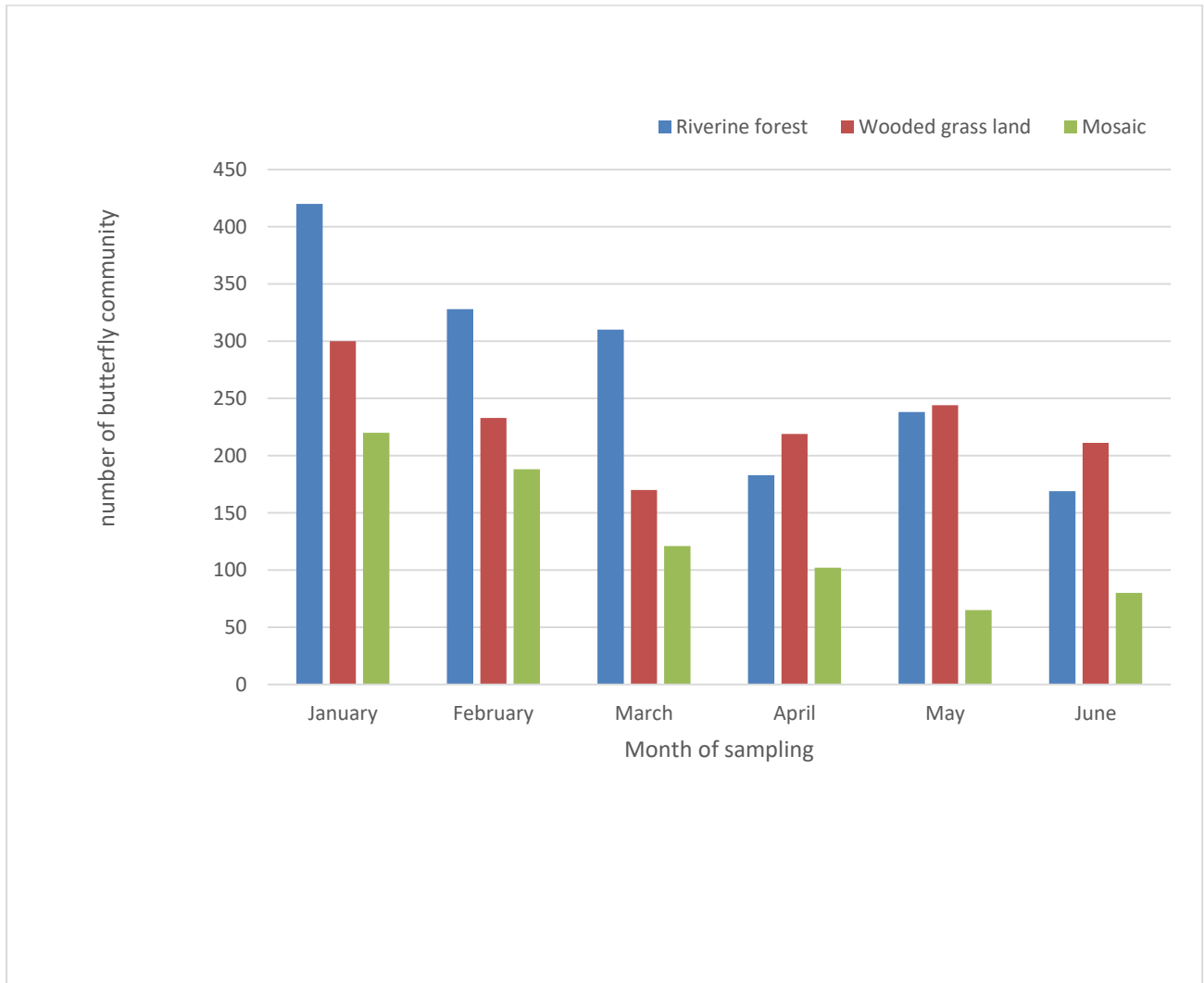


Figure 6. Abundance of the butterfly species per month of sampling in different Land-use types

4.1.5. Butterfly diversity by habitat type

Results demonstrated that the riverine forest with Simpson index of 0.97 and Shannon index of 3.7 was recorded as the most diversified, followed by wooded grass with Simpson index of 0.96 and Shannon index of 3.5 (Table 5).

Table 5. Selected diversity indices of butterfly communities in three different habitat types

No	Biodiversity indices	Land-use types		
		Riverine forest	Wooded grassland	Mosaic
1.	Taxa/ richness'	54	43	23
2.	Individuals	1611	1531	659
3.	Simpson_1-D	0.9707	0.969	0.92
4.	Shannon_H	3.712	3.584	2.81
5.	Evenness	0.75	0.8	0.70

4.1.6. Jaccard index of similarity of butterflies by habitat type

Results showed that the highest similarity was found between wooded grass land and mosaic habitats, followed by riverine forest and wooded grass land, and the least was between riverine forest and mosaic habitat (Table 6).

Table 6. Jaccard index of similarity by habitat

Comparison	Jacarda index of similarity (j)			
	J	A	b	$j/a+b-j$
Riverine vs wooded	22	54	43	0.29
Riverine vs mosaic	16	54	23	0.26
Wooded vs mosaic	17	43	23	0.34

(j = the number of species found in both sites a = the number of species in site A b = the number of species in site B)

Table 7. Species list and abundance of butterflies in different habitats

Family name	Species name	Habitat type		
		Rf	WGL	Mo
Nymphalidae	<i>Acraaea acara</i> (Hewitson, 1865)	100	60	57
	<i>Acreeaea braesia</i> (Godman, 1885)	0	56	0
	<i>Acraea caecilia</i> (Fabricius, 1781)	0	45	0
	<i>Acreeaea cerasa</i> (Hewitson, 1861)	40	0	0
	<i>Acraea chilo</i> (Godman, 1880)	50	70	0
	<i>Acraea egina</i> (Cramer, 1775)	0	61	0
	<i>Acraea pseudEGINA</i> (Westwood, 1852)	21	56	46
	<i>Bematistes aganice</i> (Hewitson, 1852)	34	34	30
	<i>Amauris albimaculata</i> (Butler, 1875)	32	0	0
	<i>Amauris echeria abessinica</i> (Schmidt, 1921)	23	0	0
	<i>Amauris niavius</i> (Rothschild & Jordan, 1903)	55	0	0
	<i>Hamanumida daedalus</i> (Fabricius, 1775)	21	0	0
	<i>Pseudacraea boisduvali</i> (Doubleday, 1845)	23	0	0
	<i>Pseudacraea lucretia walensensis</i> (Sharpe, 1896)	43	0	0
	<i>Bicyclus angulate</i> (Butler, 1896)	64	0	0
	<i>Bicyclus anynanaa</i> (Butler, 1879)	0	75	0
	<i>Bicyclus campus</i> (Karsch, 1893)	0	47	0
	<i>Bicyclus vulgaris</i> (Butler, 1868)	20	40	0
	<i>Byblia anvataracheloia</i> (Wallengren, 1857)	39	20	80
	<i>Charaxes candiope</i> (Godart, 1824)	10	0	0
	<i>Charaxes eurinome birbirica</i> (Ungemach, 1932)	10	0	0
	<i>Charaxes jahlusa ganalensis</i> (Carpenter, 1937)	12	0	0
	<i>Charaxes numenes neumanni</i> (Rothschild, 1902)	8	0	0
	<i>Charaxes tiridates</i> (Cramer, 1777)	9	0	0
	<i>Cyrestis camillus</i> (Fabricius, 1781)	8	0	0
	<i>Hypolimnas misippus</i> (Linnaeus, 1764)	0	30	26
	<i>Hypolimnas anthedon i</i> (Wallengren, 1857)	10	0	0

	<i>Protogoniomorpha parhassus</i> (Palisot De Beauvais, 1805)	10	0	0
	<i>Euphaedra medon</i> (Ungemach, 1932)	9	0	0
	<i>Eurytela dryope</i> (Aurivillius, 1898)	0	30	0
	<i>Junnonia chroimene</i> (Guerin, 1844)	40	30	0
	<i>Junnonia hierta</i> (Trimen, 1870)	25	45	40
	<i>Junonia oenone</i> (Linnaeus, 1764)	30	34	45
	<i>Junonia terea</i> (Drury, 1773)	30	40	61
	<i>Junonia Sophia</i> (Fabricius, 1793)	0	30	0
	<i>Neptis laeta</i> (Overlaet, 1955)	0	30	0
	<i>Neptis serena</i> (Overlaet, 1955)	20	0	0
	<i>Neptis agouale</i> (Collins & Larsen, 1996)	0	25	0
	<i>Phalaanta eurytis</i> (Doubleday, 1847)	42	0	0
	<i>Phlantat phlanta</i> (Rothschild & Jordan, 1903)	50	0	0
	<i>Precis antilope</i> (Feisthamel, 1850)	0	0	10
	<i>Ypthima asterope</i> (Klug, 1832)	50	0	0
Pieridae	<i>Eurema brigitta</i> (Stoll, 1780)	60	45	12
	<i>Eurema desjardinsii</i> (Butler, 1898)	50	34	17
	<i>Eurema regularis</i> (Butler, 1876)	70	34	7
	<i>Eurema hecabe</i> (Butler, 1875)	43	0	11
	<i>Catopsilia florella</i> (Fabricius, 1775)	0	60	17
	<i>Catopsilia scylla</i> (Linnaeus, 1763)	60	0	25
	<i>Leptosia alcesta</i> (Bernardi, 1959)	0	80	0
	<i>Mylothris agathina</i> (Cramer, 1779)	0	54	0
	<i>Mylothris rueppellii</i> (Koch, 1865)	0	70	20
	<i>Nepheronia buquetii</i> (Boisduval, 1836)	0	34	0
	<i>Belenois aurota</i> (Fabricius, 1793)	100	50	0
	<i>Belenois creona</i> (Cramer, 1776)	50	0	10
	<i>Belenois gidica</i> (Lucas, 1852)	0	0	15
	<i>Belenois raffrayi</i> (Oberthür, 1878)	0	56	11
	<i>Belenois thysa</i> (Talbot, 1943)	0	30	0

	<i>Belenois zochalia</i> (Ungemach, 1932)	22	22	0
	<i>Dixeia orbona</i> (Geyer, 1837)	0	0	4
Papilionidae	<i>Graphium almansor</i> (Honrath, 1884)	9	0	0
	<i>Graphium angolanus</i> (Goeze, 1779)	4	0	0
	<i>Graphium leonidas</i> (Fabricius, 1793)	6	0	0
	<i>Papilio dardanus</i> (Oberthür, 1883)	18	8	0
	<i>Papilio demodocus</i> (Esper, 1798)	15	16	9
	<i>Papilio echerioides</i> (Rothschild, 1902)	5	0	0
	<i>Papilio microps</i> (Storace, 1952)	5	8	0
	<i>Papilio nireus</i> (Felder & Felder, 1865)	13	10	7
	<i>Papilio rex</i> (Vane-Wright, 1995)	7	0	0
	<i>Papilio wilsoni</i> (Rothschild, 1926)	5	0	0
Lycaenidae	<i>Anthene definita</i> (Pagenstecher, 1902)	45	9	0
	<i>Anthene opalina</i> (Stempffer, 1946)	35	6	99
	<i>Anthene amarah</i> (Guérin-Méneville, 1847)	35	10	0
	<i>Deudorix antalus</i> (Hopffer, 1855)	0	4	0
	<i>Eicochrysops hippocrates</i> (Fabricius, 1793)	0	12	0
	<i>Cacyreus lingeus</i> (Stoll, 1782)	0	4	0
	<i>Zizula hylax</i> (Fabricius, 1775)	0	9	0
	<i>Lachnocnema emperamus</i> (Snellen, 1872)	10	0	0
Hesperiidae	<i>Coeliades forestan</i> (Stoll, 1782)	6	0	0
	<i>Coeliades pisistratus</i> (Fabricius, 1793)	0	8	0

(RF= riverine forest, WGL- wooded grass land, Mo- mosaic habitat)

4.1.6. Habitat association of butterflies

Chi-square result showed that the butterfly diversity from the three habitats were significantly different (Table 7).

Table 8. Chi-square result of butterfly diversity by habitat

	Riverine forest	Wooded grass land	Mosaic habitat
Chi-Square	226.013 ^a	330.823 ^b	722.772 ^c
df	31	23	19
Asymp. Sig.	0.000	0.000	0.000

Regression analysis was performed to study the role of plant diversity to butterfly diversity and results showed that diversity of plants had no significant effect on the diversity of butterflies in the three land-use types (Table 10). See Appendixes A, B and C for full lists of plants in each habitat.

Table 9. Diversity of plants and diversity of butterflies from the three Land-use types

Habitat type	Butterfly		Classification of vegetation							Species
	S	N	F	Family	Tree	Herb	Shrub	Grass	Climbers	
Rf	54	1611	5	25	19	10	7	2	2	39
WGL	43	1531	5	23	10	10	3	6	3	29
Mo	23	659	4	18	10	7	3	1	0	25
Total	121	3801	5		39	27	13	9	5	93

(RF- riverine forest, WGL- wooded grass land, Mo- mosaic habitat, S- number of species, N- number of individuals, F- number of family)

Table 10. Regression result of plants and butterflies from the three Land-use types

Habitat type	Sum of Squares	df	Mean Square	F	Sig.
Riverine	11.024	1	11.024	.019	.891
Wooded	76.621	1	76.621	.307	.587
Mosaic	1356.402	1	1356.402	3.543	.078

(Df- degree of freedom, F- f value, sig- level of significance)

4.1. Moths' diversity

A total of 105 moth species and 6206 individuals with 11 families were recorded in the study area (Table 8). The abundance of moths shows that the family *Erbidae* is the most abundant, with 41 species, 24 genera, and 2,454 individuals accounting for 40% of the collected individual specimens, followed by *Crambidae* with 22 species and 2,474 individuals accounting for 39% of the collected individual specimens. The least abundant family was *Pyralidae* with 1 species and 10 individuals accounting 1% of the total specimen (Table 11). The most abundant species was *Cyligramma latona* (*Erbidae*) with 399 individuals followed by *Glyphodes shafferiorum* (*Crambidae*) with 388 individuals and *Pseudothyretes perpusilla* (*Erbidae*) with 318 individuals. *Cyligramma magus* (*Erbidae*), *Chiromachla restrictum* (*Erbidae*) and *Cyana abyssinica* (*Erbidae*) were the least abundant species of moth (Table 12).

Table 11. Moths' diversity and abundance in the study area

No	Family name	Number of species (%)	Number of individuals (%)	Genera
1	Arctiidae	2(2%)	115 (2%)	2
2	Cossidae	2(2%)	70 (1%)	2
3	Crambidae	22(21%)	2474 (40%)	17
4	Erbidae	41(40%)	2454 (39%)	24
5	Geometridae	6(5%)	188 (3%)	5
6	Noctuidae	8(7%)	282 (5%)	8
7	Nolidae	2(2%)	27 (0.4%)	2
8	Saturnidae	4(3%)	66 (1%)	2
9	Siphingidae	14(13%)	483 (8%)	10
10	Tortricidae	3(3%)	37(0.5%)	3
11	Pyralidae	1(1%)	10 (0.01%)	1
	Total	105	6206	76

4.2.1. Moth distribution and abundance per month of sampling

Results demonstrated that the highest number of moths was documented in the month of January with 1572 individuals accounting for 25%. The lowest number of moths was recorded in the month of June with 599 individuals constituting 1% of the total collected moth specimens (Figure 4).

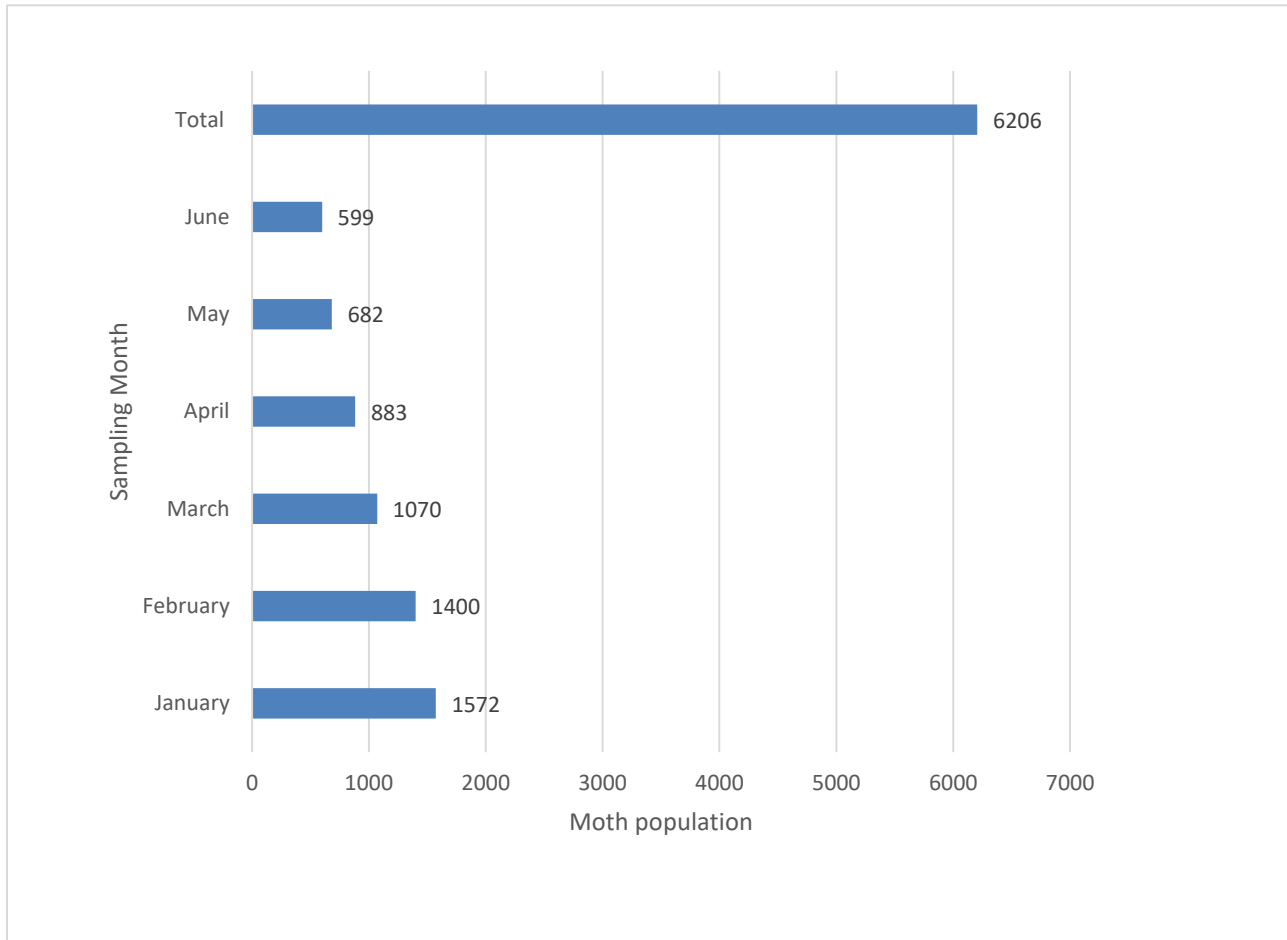


Figure 7. Abundance and distribution of moths of the study area per month

4.2.2. Moth diversity in the three land-use types

Results showed that riverine forest was documented with highest diversity with 94 species and 3592 individuals accounting for 58% and the least was mosaic habitat with 30 species and 971 individuals accounting for 16% of the total collected moth specimens (Table 9 and Table 12).

family Eribidae, Crambidae, and Sphingidae were documented with a high number of moths and Families Nolidae, Saturnidae, and Arctiidae were reported with a smaller number of moths in the three land-use types. The Family Pyralidae was unique to riverine forest and Cossidae and Tortricidae were documented only in riverine forest and wooded grass land (Table 10).

Table 12. Abundance of families in the three selected Land-use types

Family	Abundance of moths by habitat type		
	Number of moths in Rf	Number of moths in WGL	Number of moths in Mo
Arctiidae	60	40	15
Cossidae	50	20	0
Crambidae	1419	531	474
Eribidae	1405	712	337
Geometridae	138	50	0
Noctidae	184	68	30
Nolidae	11	12	4
Saturnidae	30	22	14
Siphingidae	258	178	47
Tortricidae	27	10	0
Pyralidae	10	0	0
Total	3592	1643	971

(Rf- riverine forest, WGL-Wooded grass land, Mo-mosaic)

4.2.3. Comparison of Moth diversity at different habitats

Results have showed that the riverine forest with Simpson index of 0.98 and Shannon index of 4 was recorded as the most diversified, followed by wooded grass with Simpson index of 0.97 and Shannon index of 3.7 (Table 4). Results have shown that riverine forest was highest with all the diversity indices values followed by wooded grass land and mosaic habitat (Table 10).

Table 13. Diversity indices at different Land-use type

Habitat	Richness	Individual	Simpson	Shannon	Evenness	maximum	minimum	mean	Stan.error
Riverine	94	3592	0.98	4	0.898	200	0	34	4
Wooded	62	1643	0.97	3.7	0.896	109	0	19	2.4
Mosaic	30	921	0.94	3	0.872	105	0	9	2.1

4.2.4. Sorensen similarity index of moths by habitat type

Results illustrated that the highest similarity was found between riverine forest and wooded grass land showing 70% of similarity and the lowest was between riverine and mosaic (Table 11).

Table 14. Sorensen similarity index

Comparison	Species found in both sites	Site 1	Site2	$2c/s1+s2$
Riverine vs wooded	55	94	62	0.7 (70%)
Riverine vs mosaic	23	94	30	0.37 (37%)
Wooded vs mosaic	20	62	30	0.43 (43%)

4.2.5. Abundance of moth species by month of sampling among land-use

Results indicated that the highest abundance was documented in January and the lowest abundance was in June. Comparing the three habitats riverine forest was recorded with the highest abundance and mosaic was the least (Figure 5).

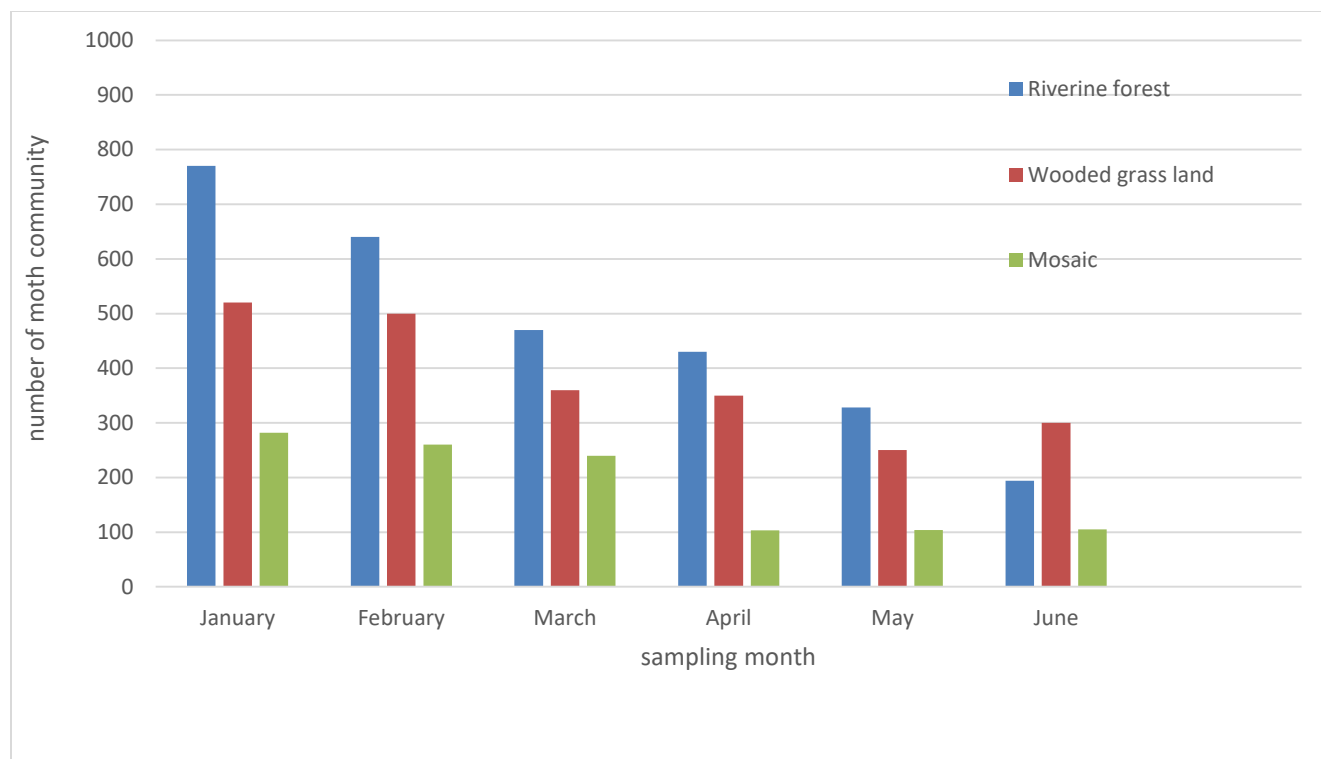


Figure 8. Abundance and distribution of moth communities from the three land-use

Table 15. Full list of moth species from the three selected Land-use types

Family	Species name	Rf	WGL	Mo	Tot
Arctiidae	<i>Apantesis proxima</i> (Guérin- Méneville, 1844)	30	20	0	50
	<i>Nyctemera baulus</i> (Boisduval, 1832)	30	20	15	65
Cossidae	<i>Azygophleps brehmi</i> (Yakovlev & Witt, 2016)	20	20	0	40
	<i>Camellocossus abyssinica</i> (Hampson, 1910)	30	0	0	30
Crambidae	<i>Achyra coelatalis</i> (Walker, 1859)	100	0	0	100
	<i>Aethaloessa floridalis</i> (Zeller, 1852)	103	0	0	103
	<i>Cadarena pudoraria</i> (Hübner, 1825)	80	0	0	80
	<i>Dysallacta negatalis</i> (Walker, 1859)	109	0	0	109
	<i>Diaphania indica</i> (Saunders, 1851)	100	60	54	214
	<i>Diaphania costata</i> (Fabricius, 1794)	0	45	0	45
	<i>Palpita quadristigmalis</i> (Guenée, 1854)	80	60	0	140
	<i>Ghesquierellana hirtusalis</i> (Walker, 1859)	35	28	0	63
	<i>Glyphodes stolalis</i> (Guenée 1854)	0	80	0	80
	<i>Glyphodes bicolor</i> (Swainson, 1821)	102	0	0	102
	<i>Glyphodes shafferoorum</i> Viette, 1987	200	98	90	388
	<i>Glyphodes bitriangulalis</i> Gaede, 1917	102	0	0	102
	<i>Hodebertia testalis</i> (Fabricius, 1794)	90	100	60	250

Erbidae	<i>Hyalobathra dictatrix</i> (Meyrick, 1934)	100	0	0	100
	<i>Syngamia latimarginalis</i> (Walker, 1859)	0	60	80	140
	<i>Spoladea recurvalis</i> (Fabricius, 1775)	0	0	60	60
	<i>Trigonoorda gavisalis</i> (Walker, 1869)	20	0	0	20
	<i>Palpita annulifer</i> Inoue, 1996	130	0	90	220
	<i>Palpita vitrealis</i> (Rossi, 1794)	0	0	20	20
	<i>Obtusipalpis citrina</i> (Druce, 1902)	20		20	40
	<i>Ulopeza conigeralis</i> (Zeller, 1852)	40	0	0	40
	<i>Udea rubigalis</i> (Guenee, 1854)	8	0	0	8
	<i>Achaea catella</i> (Guenée, 1852)	90	0	0	90
	<i>Achaea janata</i> (Linnaeus, 1758)	20	0	0	20
	<i>Achaea lienardi</i> (Boisduval, 1833)	30	0	0	30
	<i>Afromurzinia lutescens</i> (Walker, 1855)	0	20	12	32
	<i>Argina Amanda</i> (Boisduval, 1847)	25	0	0	25
	<i>Amerila leucoptera</i> (Hampson, 1901)	15	0	12	27
	<i>Amerila niveivitrearia</i> (Bartel, 1903)	30	0	0	30
	<i>Amerila puella</i> (Fabricius, 1793)	0	15	0	15
	<i>Amerila affinis</i> (Rothschild, 1910)	10	10	0	20
	<i>Amerila astreus</i> (Drury, 1773)	20	8	0	28
	<i>Aroa discalis</i> (Walker, 1855)	20	0	10	30
	<i>Carcinarctia rufa</i> Joicey & Talbot, 1921	30	0	0	30
	<i>Chiromachla leuconoe</i> (Hopffer, 1857)	23	0	0	23
	<i>Chiromachla restrictum</i> (Butler, 1894)	5	0	0	5
	<i>Cyana abyssinica</i> (Karisch, 2003)	3	0	0	3
	<i>Cyana rubristriga</i> (Holland, 1893)	5	0	0	5
	<i>Cyana rejecta</i> (Walker, 1854)	10	0	0	10
	<i>Cyligramma latona</i> Cramer, 1775	190	109	100	399
	<i>Cyligramma magus</i> (Guérin-Méneville, 1844)	0	2	0	2
	<i>Cyligramma complex</i> Grunberg, 1910	10	20	12	42
	<i>Grammodes euclidioides</i> Guenée, 1852	109	60	70	239
	<i>Hypena scabra</i> (Fabricius, 1798)	76	60	0	136
	<i>Idia aemula</i> (Hübner, 1813)	26	30	0	56
	<i>Metarctia flavivena</i> Hampson, 1901	10	10	14	34
	<i>Metarctia lateritia</i> (Herrich-Schäffer, 1855)	19	10	0	29
	<i>Metarctia tenebrosa</i> (Le Cerf, 1922)	150	90	10	250
	<i>Metarctia unicolor</i> (Oberthür, 1880)	5	5	0	10
	<i>Podomachla antinorii</i> (Oberthür, 1880)	10	5	4	19
	<i>Podomachla apicalis</i> (Walker, 1854)	20	20	0	40
	<i>Popoudina linea</i> (Walker, 1855)	10	15	0	25
	<i>Pseudothyretes kamitugensis</i> (deFrane, 1945)	20	10	0	30
	<i>Pseudothyretes perpusilla</i> (Walker, 1856)	160	80	78	318
	<i>Radiarctia jacksoni</i> (Rothschild, 1910)	30	20	10	60
	<i>Rhabdophora hansali</i> (Felder & Rogenhofer, 1875)	29	20	0	49
	<i>Rhanidophora cinctigutta</i> (Walker, 1862)	40	30	0	70
	<i>Sphingomorpha chlorea</i> (Cramer, 1777)	25	15	0	40

	<i>Teracotona subterminata</i> Hampson, 1901	30	18	0	48
	<i>Thyretes negus</i> (Oberthür, 1878)	15	0	0	15
	<i>Trigonodes exportata</i> Guenée, 1852	30	10	5	45
	<i>Trigonodes hyppasia</i> (Cramer, 1779)	25	10	0	35
	<i>Utetheisa pulchella</i> (Linnaeus, 1758)	30	10	0	40
Geometridae	<i>Antictenia punctunculus</i> T.P.Lucas, 1892	20	10	0	30
	<i>Cleora cancer</i> (Fletcher, 1967)	50	40	0	90
	<i>Cleora oculata</i> (Herbulot, 1977)	15	0	0	15
	<i>Conolophia conscitaria</i> (Warren, 1861)	18	0	0	18
	<i>Eudocima materna</i> (Linnaeus, 1767)	20	0	0	20
	<i>Prasinocyma discipuncta</i> (Hausmann, Sciarretta & Parisi, 2016)	15	0	0	15
Noctuidae	<i>Agrotis ipsilon</i> (Hufnagel, 1766)	30	20	0	50
	<i>Athetis percnopis</i> (Bethune-Baker, 1911)	25	0	0	25
	<i>Antiophlebia bracteata</i> Felder, 1874	20	0	0	20
	<i>Ariathisa abyssinia</i> (Guenée, 1852)	19	18	0	37
	<i>Asota caricae</i> Fabricius, 1775	30	20	10	60
	<i>Eustrotia decissima</i> Walker, 1865	40	0	0	40
	<i>Feliniopsis annosa</i> Hacker & Fibiger, 2007	0	5	0	5
	<i>Tytroca dispar</i> (Püngeler, 1904)	20	5	20	45
Nolidae	<i>Eligma hypsoides</i> (Walker, 1869)	5	4	4	13
	<i>Lophocrama phoenicochlora</i> (Hampson, 1912)	6	8	0	14
Saturnidae	<i>Holocerina angulata</i> (Aurivillius, 1893)	4	6	6	16
	<i>Holocerina smilax</i> (Westwood, 1849)	8	6	0	14
	<i>Ludia hansali</i> Felder C & R, 1874	12	10	8	30
Siphingidae	<i>Andriasa contraria</i> (Walker, 1856)	10	8	0	18
	<i>Basiothea medea</i> (Fabricius, 1781)	0	0	10	10
	<i>Ceratonia catalpa</i> (Boisduval, 1875))	15	12	0	27
	<i>Coelonia fulvinotata</i> (Butler, 1875)	15	10	0	25
	<i>Chaerocina ellisoni</i> Hayes, 1963	40	30	0	70
	<i>Euchloron meagera</i> (Linnaeus, 1758)	0	0	30	30
	<i>Hippotion eson</i> (Cramer, 1779)	12	0	0	12
	<i>Hippotion balsaminae</i> (Walker, 1856)	20	8	7	35
	<i>Hippotion roseipennis</i> (Butler, 1882)	40	38	0	78
	<i>Nephele funebris</i> (Fabricius, 1793)	34	30	0	64
	<i>Nephele comma</i> (Hopffer, 1857)	30	0	0	30
	<i>Nephele aequivalens</i> (Walker, 1856)	20	25	0	45
	<i>Rufoclanis numosae</i> (Wallengren, 1860)	10	8	0	18
	<i>Temnora sardanus</i> (Walker, 1856)	12	9	0	21
Tortricidae	<i>Acleris harenna</i> Razowski & Trematerra, 2010	5	6	0	11
	<i>Phtheochroa lonnvei</i> Aarvik, 2010	12	0	0	12
	<i>Tortrix diametrica</i> Meyrick, 1932	10	4	0	14
Pyralidae	<i>Lamoria anella</i> (Denis & Schiffermüller, 1775)	10	0	0	10

(RF- riverine forest, WGL-wooded grass land, MO- mosaic, Tot- total)

4.1.7. Habitat association of moths

The findings revealed that moth diversity varied significantly between the three habitats (Table 12).

Table 16. Chi-square result for moth diversity among habitats

statistics	Riverine	Wooded	Mosaic
Chi-Square	128.286 ^a	116.423 ^b	583.200 ^c
df	22	21	20
Asymp. Sig.	.000	.000	.000

4.1.8. Comparison of moth species with vegetation types across land-use types

Regression analysis was performed to study the relationship of plant diversity with moth diversity. The results demonstrated that the diversity of plants had no significant effect on the diversity of moths (Table 18). See Appendixes A, B and C for full lists of plants in each habitat.

Table 17. Diversity of moth species and plant species at different land-use types

Habitat type	Moth				Classification of vegetation					Species
	S	N	F	family	Tree	Herb	Shrub	Grass	Climber	
Rf	94	3592	11	25	19	10	7	2	2	39
WGL	62	1643	10	23	10	10	3	6	3	29
Mo	29	971	11	18	10	7	3	1	0	25
Total	185	6206	11		39	27	13	9	5	93

(S- Number of species, N- number of individuals, F- number of family)

Table 18. Regression result of moth and plant diversity

Habitat type	Sum of Squares	df	Mean Square	F	Sig.
Riverine	165.155	1	165.155	.071	.793
Wooded	266.840	1	266.840	.211	.652
Mosaic	2104.602	1	2104.602	1.921	.185

(df- degree of freedom, f- f-value, sig- significance value)

5. Discussion

5.1. Analysis of butterfly diversity

The diversity of butterflies was studied in and around Chebera Churchura National Park on three different land-use types. Based on calculated diversity indices, the diversity of butterflies in and around Chebera Churchura National Park is very high. Because the area was distant, devoid of human settlement and agricultural activities, and no considerable deforestation has occurred. As mentioned in different literatures the diversity of butterflies grows in tandem with the diversity of plants (Bonelli *et al.*, 2015; Norfolk *et al.*, 2017). Five families of butterflies have been reported from Ethiopia (Tesfu Fekensa *et al.*, 2019) and all the five families were reported in the current study.

In this study, 79 species of butterflies were identified, which is more than the 64 species of butterflies identified in a previous study done in the Jimma Highlands of Ethiopia (Norfolk *et al.*, 2017), 43 from Menagesha-Suba State Forest (Abaynew Jemal and Emanu Getu, 2018), 43 from Gura-Ferda forest, (Foquet *et al.*, 2019). Some authors confirmed higher numbers of identified butterfly species, such as 87 species from Ethiopia's Belete-Gera Forest (De Beenhouwer *et al.*, 2015). In the current study family Nymphalidae was the most abundant due to the reason that they inhabit a variety of habitats, they need open habitat, and feed on a variety of plant species. This result agrees with the results of Abaynew Jemal and Emanu Getu (2020), Foquet *et al.*, 2019) and Sagwe *et al.* (2015). Butterfly species from the family Hesperariidae have been recorded with lower abundance and diversity due to most Hesperariidae species have limited host plants (Koneri & Maabuat, 2016).

Comparing the three habitats based on butterfly diversity riverine forest was highly diversified habitat followed by wooded grass land and mosaic habitat was documented with lower diversity of butterflies. The possible reasons could be riverine forest was found inside the National Park that is relatively free of human and animal interaction, has a relatively highest diverse plant and provided with river. Due to heavy human and animal disturbance, the mosaic ecosystem has reduced butterfly and plant variety. This shows that protected habitats support more diversity of butterfly species and unprotected and degraded habitats supports less diversity of butterflies.

Koneri & Maabuat (2016) investigated the diversity of Butterflies in and around Manembo-Nembo Wildlife Reserve in North Sulawesi, Indonesia, and found that diversity out of the wild life reserve were less than inside of the wildlife reserve.

The three habitats' types were compared by butterfly diversity and the highest similarity index of butterfly communities was found between the wooded grass land and mosaic habitat. This could be the reason that the ecological environment of the two habitats could be similar type and the distance between the habitats were not far from each other. Regression analysis was performed to assess the role of plant diversity on the butterfly diversity and results showed that the effect/role was not significant. This contradicts the general truth that diversity of plants affects the diversity of butterflies. This could be due to other different factors other than plants diversity like activity of humans and amount of light or may be another not specified factor.

The number of butterflies varies depending on weather conditions (Roy et al. 2001) because butterflies are ectothermic and weather affects adult flight needed for oviposition (Warren 1992), affects the survival of the immature stages (Dooley et al. 2013) and it affects the fecundity rate of butterflies (Boggs & Freeman 2005). In the current study area, the sampling month affected the abundance of the butterfly individuals. The number of butterflies decreased from January to June, such that the highest number was recorded in January and the lowest number was in June. The weather data trend analysis revealed that the average monthly rainfall increased from January to June, while the average monthly maximum and minimum temperatures decreased. In this case, the results of the current study agree with the above conclusions. But the lowest abundance of individuals in June does not necessarily represent the whole population abundance of butterflies in the study area. Butterflies may be present in the study area but undetected because of diapause as adults (Wolda, 1988). The number of pray and predators may also contribute the population difference in the study area. In general, the diversity of butterflies in and around Chebera churchura National Park was found suitable for butterflies' diversity but at present the main treat to biodiversity in general and butterflies in particular are that tourism development.

5.2. Analysis of moth diversity

This was the first study to assess and better understand the remote but diverse area of Chebera Churchura National Park. Surveys of macro moths in the current study area revealed that the three different land-use types vary in moth diversity and distribution. Thus, the current study documented moth species which were for the first time recorded in the area. The effect of land-use change on species richness is well studied in different parts of the world and the decline of biodiversity and the rate of increasing change of land-use types (Garcia-Vega & Newbold, 2020). Areas with less human interaction, less fragmented, and more protected areas are rich in biodiversity (Reidsma *et al.*, 2006). Protected areas and National Parks play an important role in conserving biodiversity (Wilkie *et al.*, 2006).

A total of 6206 individuals within 105 species of moths were collected from Chebera Churchura National Park and its surroundings. Overall, the richness and diversity of the moth community in and around Chebera Churchura National Park can be considered highest. No other study on diversity of moths in different land use types was found in Ethiopia. Comparison with other African countries was. The current study's result was smaller than the result of a Mount Cameron study named a biodiversity pattern of moths and butterflies on Mount Cameron, because they collected moth populations on Mount Cameron utilizing the light-sheet trapping method (Maicher *et al.*, 2020). Thus, in the current study area, further study should have to include such methods. When compared to other parts of Ethiopia, Chebera Churchura National Park can be regarded as a rich and diversified place. Further research is needed to make more comparisons with other studies.

Extrapolation of moth species richness and abundance revealed that the three land-use types differ significantly in terms of species richness and abundance from each other. Several studies have shown that the diversity and abundance of moth species in non-disturbed habitats may be higher than in disturbed habitats (Marciniak *et al.*, 2007; Sanyal *et al.*, 2013; Aggemyr *et al.*, 2018; Garca-Vega & Newbold, 2020). According to the current study finding riverine forest had the highest number of species and lowest in mosaic environment The Riverine Forest outperformed the mosaic habitat by more than three times, and wooded grassland outperformed

it by at least two times. This was due to the greater diversity of plants in the riverine forest, which is a source of food for both moths and butterflies. Secondly, riverine forest has been discovered with less human and animal disturbance and harbors of more distinctive species. This is the reason that the area is free from human settlement, free from agricultural activity, no significant deforestation, and the park was established recently. Both riverine forest and wooded grassland are found inside of the National Park, while mosaic habitat is located outside of the National Park and is easily exposed to human and animal interaction and, for this reason, the number of species is different in each of the three study sites.

Because of their life cycles, insects in general display seasonal fluctuations in species diversity and abundance (Beck & Linsenmair, 2006; Beck *et al.*, 2007; Danks, 2007) and moths are no exception. The trend analysis of climate data showed that amount of average monthly rainfall in Chebera Churchura National Park increased from January to June whereas moths showed decreasing pattern. This could be due to the reason that high rainfall limits macro moth movement and flying activity, reducing moth survival by increasing larval and pupal mortality, and so lowers moth activity and diversity (Beck *et al.*, 2011; Brehm *et al.*, 2007). Generally, abundance of moth species is highest in months with less cloudy, sunnier, and less wind because this affects the movement of moth (Intachat *et al.*, 2001) such that months January, February, and March were recorded with the highest and April, May, and June recorded with lowest. But the lowest abundance of individuals in June does not necessarily represent the whole population abundance of butterflies in the study area. Lepidopterans (moths and butterflies) may be present in the study area but undetected because they may be at diapause as adults (Wolda, 1988; Wickramasinghe *et al.*, 2004; Brehm & Axmacher, 2006).

According to literatures moth diversity is highly dependent on the type and diversity of vegetation (Beck & Vun Khen, 2007; Kadlec *et al.*, 2009; Biswas *et al.*, 2016; Root *et al.*, 2017; Hassan *et al.*, 2019; Tyler, 2020). The more plant species diversity, the more moth diversity because they depend on plants for food and shelter. But the current study result contradicts the above conditions. The current study result showed that the mothy diversity was not significantly dependent on the plant species diversity. This could be due to other factors like type of soil type, due to sampling difficulties or may be the plant species were not favorite hosts by moth species.

6. Conclusions and recommendations

6.1. Conclusion

The following conclusions can be made on the basis of the biodiversity analysis of moths and butterflies in selected land-use forms of Chebera Churchura National Park.

- A total of 16 families (11 moths and 5 butterflies) and a total of 194 (79 butterfly and 105 moth) species and 10,007 individuals (3801 butterflies and 6206 moths) were collected from the current research, showing that the habitat was good for moths and butterflies.
- Of the five families of butterflies collected, Nymphalidae and Pieridae were the most abundant, while Hesperiidae was the least abundant.
- The families Erebidae, Crambidae, Sphingidae, and Geometridae have been reported as the most abundant and Tortricidae, Arctiidae, Nolidae, Cossidae, and Pyralidae families have been identified with less diversity.
- Of the three land use type's riverine forest was recorded with highest diversity of lepidopterans and mosaic habitat was recorded less.
- The mosaic habitat supports few species and shows that the increasing land-use change affects the species diversity and abundance
- The current study showed that species diversity was significantly different among habitats.
- Plants' diversity in the three habitats was different, but the contribution to the diversity of moths and butterflies across the three habitats was not significant.
- Sampling month greatly affects the diversity and abundance of populations of moths and butterflies. The abundance of moth and butterfly populations was declined from January to June in all the sampling land-use forms in the study field.
- Comparison of the abundance and diversity of moths and butterflies in the three forms of land-use per month of sampling riverine forest was found to be more abundant in all months of sampling. The mosaic habitat showed less abundance and diversity of moths and butterflies.

6.2. Recommendations

The following recommendations were made on the basis of the findings of the current six-month study and from the three selected forms of land-use in and around Chebera Churchura National Park.

- The current study and results may not be conclusive that these are the only ones in the study region. Only adult stages of butterflies and moths were included in the current study. Therefore, more collaborative work needs to be carried out to get more diversity of species of moths and butterflies from the current study area.
- Due to the fact that it is protected from animal and human intrusion, more diversity and abundance of moths and butterflies have been found in riverine forests, while less abundance and diversity of moths and butterflies have been reported in mosaic habitats due to high human and animal interferences and low plant diversity. The conservation of the environment should therefore be given top priority.
- During the sampling process, areal sweeping for butterflies and a light sheet trap for moths were used. It is strongly recommended to combine various collection methods in order to achieve a high diversity of moths and butterflies in the field of research.
- Given the rapid growth of land-use change in the research area, more work is needed to prove the consequences on biodiversity, which may help to inspire local farmers and landscape managers to implement evidence-based conservation interventions to reduce biodiversity loss in human-dominated landscapes.
- Given the poor knowledge of Ethiopian lepidoptera, we believe that it is important to replicate this study or a similar one that focuses on the lepidopteran communities present in different land-use zones in different environments on a larger scale.
- The study region was generally found to be rich in the diversity and abundance of butterflies and moths in all three forms of land-use and in all the months of sampling. The study area is currently becoming an investment hub and many road development projects are being planned and particular attention should be paid to conservation in general.

7. References

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Appendix

Appendix. A. List of plant species in riverine forest

FAMILY	BOTANICAL NAME	KONTA/ AMHARIC NAME	CLASSIFICATION
Arecaceae	<i>Borassus sambiranensis</i> (Jum. & H.Perrier)	Zembab	Tree
Asteraceae	<i>Vernonia gera</i> (Cass.) Less		Shrub
	<i>Vernonia schimperi</i> El-Ghazaly & B.Nord	Girawa	Shrub
	<i>Guizotia abyssinica</i> (L.f.) Cass.	Adile	Herb
Bignoniaceae	<i>Stereospermum kunthianum</i> Cham	Geleshi	Tree
Boraginaceae	<i>Cordia africana</i> Lam.	wanza	Tree
Capparidiaceae	<i>Maerua aethiopica</i> (Fenzl) Oliv.	kontir	Shrub
Combretaceae	<i>Terminalia laxiflora</i> Engl. & Diels	Ambe	Tree
	<i>Combretum collinum</i> Swynn. & Bak.	Digiso	Tree
Cypraceae	<i>Cypraceae tsetse</i> Juses		Tree
Cyatheaceae	<i>Cyathea manniana</i> W.Hooker		Tree
Euphorabriecea	<i>Acalpha ornatum</i> Hochst. ex A.Rich,		Herb
	<i>Croton macrostachyus</i> Del.	Bisana	Tree
	<i>Ricinus communis</i> L.	golo	Shrub
Fabaceae	<i>Abrus precatorius</i> L	Bedelo	Climbe
	<i>Millettia ferruginea</i> (Hochst.) Baker	brbra	Tree
	<i>Tylosema fasoglensis</i> (Kotschy ex Schweinf.) Torre & Hillc	Usunta	Climber
Polypodiophyta	Fern L.		herb
Lamiaceae	<i>Vitex doniana</i> L.	Ozo	Tree
	<i>Clerodendrum alatum</i> Gürke.	Alga	Shrub
	<i>Satureja montana</i> L.		Herb
Moraceae	<i>Ficus sycomorus</i> L.	Boae	Tree
	<i>Syzygium guineense</i> Wall.	Matso	Tree
Piperaceae	<i>Piper capense</i> L.f.	timiz	Herb
Poaceae	<i>Olyra latifolia</i> L.		Grass
Primulaceae	<i>Maesa lanceolata</i> Forssk		Tree
Proteaceae	<i>Protea gagedi</i> J.F.Gmel	Lalo	Shrub
Rosaceae	<i>Prunus Africana</i> (Hook.f.) Kalkman	Tikur enchet	Tree
Rubiaceae	<i>Gardenia ternifolia</i> Schum. & Thonn.	Gambella	Shrub
	<i>Rothmannia urcelliformis</i> (Hiern) Robyns		Tree
	<i>Solanum incanum</i> L.	embuway	Herb
	<i>Capsicum frutescens</i> L	kisho	Herb
Sterculiaceae	<i>Sterculia Africana</i> (Lour.) Fiori	Kopo	Tree

Tiliaceae	<i>Sida rhombifolia</i> L.	Dandrusa	Herb
	<i>Grewia mollis</i> Juss	Gumere	Tree
Ulmaceae	<i>Wersebo</i>	Wersebo	Tree
Urticaceae	<i>Urtica simensis</i> Steudel	Sama	Herb

Appendix. List of plant species of Wooded grass land

NO FAMILY	BOTANICAL NAME	KONTA/AMH ARIC NAME	CLASSIFI CATION
Acanthaceae	<i>Acanthus mollis</i> L	aha	Herb
Agavaceae	<i>Eseveria abyssinica</i> L.	Alkasha	Herb
Amaryllidaceae	<i>Crinum ornatum</i> (L.f.)	Uluzo Utisa	Herb
Anthericaceae	<i>Chlorophytum comosum</i> (Thunb.) Jacques)	Kalkasha	Herb
Asteraceae	<i>Guizotia abyssinica</i> (L.f.) Cass	Adile.	Herb
	<i>Vernonia hymenolepis</i> Delile	Gera	Shrub
Boraginaceae	<i>cordia spp.</i>	Arba.	Tree
Combretaceae	<i>Terminalia laxiflora</i> Engl & Diels	Ambe	Tree
Euphorbiaceae	<i>Bridelia scleroneura</i> Müll.Arg	Zuze	Tree
Fabaceae	<i>Abrus precatorius</i> L	Bedelo.	Climber
	<i>Piliostigma thonningii</i> (Schum.) Milne-Redh.)	Kankalo	Tree
	<i>Tamarindus indica</i> L.	Kore	Tree
	<i>Ocimum gratissimum</i> L.		Herb
	<i>Clerodendrum alatum</i> Gürke	Alga	Shrub
Leguminosae	<i>Robinia pseudoacacia</i> L.		Tree
Moraceae	<i>Ficus citrifolia</i> Mill.	Solo	Herb
Poaceae	<i>Andropogon sp</i> L		Grass
	<i>Hyparrhenia rufa</i> (Nees) Stapf	senbelet	Grass
	<i>Sorghum halepense</i> (L.) Pers.		Grass
	<i>Pennisetum polystachion</i> (L.) Schult.		Grass
	<i>Dactylis glomerata</i> L.		Grass
	<i>Pseudechinolaena polystachya</i> (Humb., Bonpl. & Kunth) Stapf		Grass
Rubiaceae	<i>Catunaregam nilotica</i> (Stapf)	Hagla	Climber
Sapotaceae	<i>Mimusops</i> L	Hatso	Tree
Tiliaceae	<i>Grewia mollis</i> Juss	Zuze	Tree
Ulmaceae	<i>Wersebo</i>	Wersebo	Tree
Vitaceae	<i>Cissus populnea</i> Guill & Perr		Climber
Solonaceae	<i>solonum incanum</i> L)		
	<i>Tiliaceae (Sida rhombifolia</i> L.).		

Appendix. List of plant species in Mosaic environment

FAMILY	BOTANICAL NAME	KONTA/AMHARIC NAME	CLASSIFICATION
Anacardiaceae	<i>Mangifera indica</i> L.	mango	Tree
Araceae	<i>Colocasia esculenta</i> L.	Godere	Herb
Asteraceae	<i>Xanticum spinosum</i> L.		Herb
	<i>Vernonia theophrastifolia</i> L.	Durnake	Shrub
Boraginaceae	<i>Cynoglossum cynglo</i> L.	kerechinch	Herb
	<i>Cordia Africana</i> Lam.	Wanza	Tree
Brassicaceae	<i>Brassica carinata</i> A.Braun	gomen	Herb
Combrataceae	<i>Terminalia loxifera</i>		Tree
Combretaceae	<i>Combretum molle</i>	Kerchito	Tree
	<i>Combretum collinum</i>	Digiso	Tree
Fabaceae	<i>Entada africana</i>	Sisa	Tree
	<i>Vicia faba</i> L.	Fava Beans	Herb
	<i>Dichrostachys cinerea</i>		Shrub
Lamiaceae	<i>Vitex doniana</i> L.	Ozo	Tree
	<i>Salvia Rosmarinus</i> L.	Rosemary	Herb
Lauraceae	<i>Persea americana</i>	Avocado	Tree
Musaceae	<i>Ensete ventricosum</i> (Welw)	Enset	Herb
Myrtaceae	<i>Eucalyptus</i> L'Hér		Tree
Poacea	<i>Sorghum arundinaceum</i> (Desv.) Stapf, 1917	Telehi Genbo	Grass
	<i>Zea mays</i> L. corn P		Grass
Polysonaeae	<i>Rumex abyssinicus</i> Jacq		Herb
Rosaceae	<i>Prunus Africana</i> (Hook.f.)	Tikur enchet	Tree
Simaroubaceae	<i>Harrisonia abyssinica</i> Oliv	Kontire	Shrub
Zingiberaceae	<i>Zingiber officinale</i> L.	Ginger	Herb
Rutaceae	<i>Citrus limon</i> (L		