

**EFFECTS OF ANTHROPOGENIC DISTURBANCE ON FRUIT-FEEDING
BUTTERFLY COMMUNITIES IN KILAK CENTRAL FOREST RESERVE, AMURU
DISTRICT, UGANDA**

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DECLARATION

I, **Okiya Geoffrey Onyango**, hereby declare that this dissertation is my original work and that it has never been submitted to any University or higher Institution of learning for the award of any qualification, and where secondary data have been used, the source has been duly acknowledged.

Signed  _____

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APPROVAL

This dissertation has been produced under our guidance as University supervisors.

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DEDICATION

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CWM	Community Weighted Mean
FDis	Functional Dispersion
GLM	Generalized Linear Model
GPS	Global Positioning System
GUREC	Gulu University Research Ethics Committee
HSD	Honestly Significant Difference
IndVal	Indicator Value
KCFR	Kilak Central Forest Reserve
MWE	Ministry of Water and Environment
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NMDS	Non-Metric Multidimensional Scaling
PA	Protected Area
PERMANOVA	Permutational Multivariate Analysis of Variance
SSA	Sub-Saharan Africa
UWA	Uganda Wildlife Authority

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ABSTRACT

The global loss of natural forests due to anthropogenic activities has negatively impacted on fruit-feeding butterflies. In Uganda, for example, illegal logging and the conversion of forested land for agriculture have resulted in the loss of over one million hectares of forest in just two decades. As butterflies serve as important flagship species and bio-indicators in ecological studies, understanding of these impacts is crucial. This study aimed to assess the effects of anthropogenic disturbance on butterfly community composition and functional characteristics in Kilak Central Forest Reserve. A longitudinal research design was used to collect data on fruit-feeding butterflies and vegetation across four habitat types over six months to assess habitat-specific and seasonal variations in fruit-feeding butterfly assemblages. Data were collected using a standardized field protocol approved by the Research Ethics Committee. Fruit-feeding butterflies were sampled using white cylindrical trap nets, and vegetation was assessed using 20x40m nested plots. Four univariate variables including; species richness, abundance, dominance and diversity were evaluated across four habitats and six sampling months. Overall differences in average univariate variables were tested with MANOVA and if significant difference was found, then each univariate was tested independently with ANOVA with Tukey post hoc test. Community compositions were visualised using Non-metric Multidimensional Scaling (NMDS) and tested with Permutational Multivariate Analysis of Variance (PERMANOVA). Functional trait characteristics were analysed at both individual and community levels using individual-level and species-level data respectively. The study recorded a total of 3,358 individuals belonging to 55 species across all habitats. Overall results revealed that primary forest exhibited the highest species richness, abundance, and functional traits measures throughout the sampling months. Metrics values decreased along the disturbance gradient from animal-grazed forest, cropland-encroached forest, and charcoal-degraded forest. Significant seasonal declines were detected across all habitats, with January and February recording the lowest values. Indicator value analysis identified *Bicyclus anynana* and *Charaxes fulvescens* as reliable indicators for monitoring primary forest conditions. Based on these findings, the study recommends NFA and the Government of Uganda to strengthen forest protection and management strategies to reduce illegal human activities in the Kilak Central Forest Reserve. Further studies should be conducted in neighbouring forest reserves to support the generalization of findings and accurately inform conservation policies in Uganda.

CHAPTER ONE: INTRODUCTION

1.1 Background

The rapid loss of forests due to human influence has become a critical concern globally (Federico et al., 2024; Luwa et al., 2020). In particular, the Amazon rainforest, which encompasses more than half of the Earth's tropical forests, has undergone significant degradation due to human interventions. This vast ecosystem supports a range of biodiversity, including the fruit-feeding butterflies (Sobral-souza et al., 2020). Across many regions, agricultural expansion and forest fragmentation are the most common forms of anthropogenic disturbances (Sakala et al., 2023). Natural forests provide essential habitats for butterflies and support broader biodiversity, while delivering critical ecological services that benefit human well-being (Melo et al., 2019, 2023). Habitat loss in tropical forests, such as Brazil's Atlantic forest, has significantly altered the structure of butterfly communities, particularly among fruit-feeding species (Karla et al., 2024). Compounding this issue is the declining quality of remaining forests, which continues to threaten sensitive species like butterflies (Lisboa et al., 2022). Fruit-feeding butterflies have been widely used to study the relationship between environmental changes and ecological health due to their sensitivity and ease of sampling (Andrade et al., 2019). Butterfly taxonomy is well-established, and they are relatively easy to identify (Sobral-souza et al., 2020). Because they are highly responsive to vegetation structure, these butterflies serve as reliable indicators for ecological monitoring (Lazarina et al., 2023). Also, changes in forest structure and tree species composition have significantly impacted on the community composition of fruit-feeding butterflies in restored tropical forests (Granados- et al., 2022; Nakadai et al., 2025). Many studies have highlighted the need to understand the roles of butterfly functional traits in forest recovery (Freire et al., 2021; Molleman et al., 2020). However, few studies have used species-level functional traits to assess community-wide patterns of biodiversity in tropical forests ecosystem in most parts of the world (Azrizal-wahid *et al.*, 2023).

In Sub-Saharan Africa, butterflies are among the most recognized arthropods (Kasisi et al., 2024) and their distribution in East Africa has been extensively documented (Nkwabi et al., 2017). Since a large proportion of yet-to-be-discovered species are believed to be insects, using known taxa like fruit-feeding butterflies is a pragmatic choice for ecological assessments in this region (Jenber et al., 2020; Jenber & Dar, 2021). Studies in Zimbabwe's Miombo woodlands indicate that butterfly species richness declines along disturbed forest

gradients (Jew et al., 2015; Kiruki et al., 2017). Similarly, heavily altered landscapes in East Africa show clear changes in species diversity and community composition (Kasisi et al., 2024; Tanya, 2011). Butterflies have proven useful in conservation science for tracking ecosystem health and guiding biodiversity strategies (Addo-Fordjour et al., 2015). Additionally, Miombo woodland support diverse plants and animals' species and provided essential services to support forest ecosystems (Bullock et al., 2021; Kiruki et al., 2017). The increasing rates of forest destructions due to population pressure and illegal forest activities threatens the future of this tropical forest which provide home for several species including arthropods such as the fruit-feeding butterflies (Kissanga et al., 2024; Nkwabi et al., 2017). Nonetheless, some studies also reported that larger fruit-feeding butterfly species are more vulnerable to habitat loss than smaller species because they require more substantial forest resources (Alegre et al., 2019; Brito & Ribeiro, 2014).

In Uganda, widespread forest degradation caused by illegal logging and conversion of forested landscape for agriculture have resulted in the loss of key plant and insect species (Korkiatupa *et al.*, 2023; Nyafwono *et al.*, 2014). Fruit-feeding butterflies, which depend heavily on forest cover, are among the most vulnerable groups affected by these changes (Oloya et al., 2021b; Province, 2023). Moreover, the establishment of sugarcane plantations and encroachment for subsistence farming in forest reserves has further diminished habitat quality (Luwa et al., 2021; Sobral-souza et al., 2021). Butterflies are not only ecologically important but also contribute to Uganda's eco-tourism industry, reinforcing the need for their protection (Nyafwono et al., 2014; Valtonen et al., 2017). In Uganda, fruit-feeding butterflies have been widely used to assess forest regeneration, notably in Kibale and Budongo Forest Reserves (Oloya et al., 2021b). Preserving forest ecosystems is essential for Uganda's development objectives under the National Development Plan IV (NDPIV) 2025/26 to 2029/30, and this can only be achieved by promoting inclusive and sustainable forest management (Addo-Fordjour et al., 2015; Sagwe et al., 2015). Empowering local communities to participate in biodiversity conservation is key to every successful environmental projects (Barakagira & De Wit, 2019; Kral et al., 2018). Documenting butterfly populations at the community level can provide critical insights for environmental decision-making and policy formulation (Amazonia *et al.*, 2023; Kasisi *et al.*, 2024).

1.2 Statement of research problem

Over the past twenty years, Uganda has lost more than a million hectares of forest primarily due to anthropogenic activities amongst which includes; charcoal burning, agricultural expansion, and illegal logging (Kissanga *et al.*, 2024). Kilak Central Forest Reserve (KCFR) in Northern Uganda has not been spared from this trend. Fruit-feeding butterflies, which are the most vital ecological indicators and prominent flagship species in Uganda, are increasingly threatened by intensified human pressures on forested landscapes (Andama *et al.*, 2024; Ekpo & Mba, 2020). Understanding how these butterflies respond to various types of anthropogenic disturbance in Kilak CFR is crucial for developing effective conservation strategies. Unfortunately, a review of current research reveals a significant gap in knowledge regarding how anthropogenic activities affect butterfly communities in this central forest reserve. Therefore, this study aimed to address the gap by evaluating the effects of anthropogenic disturbances on fruit-feeding butterflies in Kilak CFR to inform conservation planning and policies.

1.3 General objective

To assess how anthropogenic disturbances influence community composition and functional characteristics of fruit-feeding butterflies in Kilak Central Forest Reserve (KCFR).

1.3.1 Specific objectives

- i. To evaluate how habitat and sampling months influence species richness, abundance, diversity, and community composition of fruit-feeding butterflies in KCFR.
- ii. To identify the species of fruit-feeding butterflies that serve as indicators in various forest types within the Kilak Central Forest Reserve.
- iii. To evaluate whether certain functional characteristics (e.g., size distribution) of fruit-feeding butterflies vary among habitat types within Kilak Central Forest Reserve.

1.4 Specific research questions

- i. How do species richness, abundance, diversity, and community composition of fruit-feeding butterflies vary across different forest types in KCFR?
- ii. Which fruit-feeding butterfly species can be considered reliable indicators within each forest type?
- iii. How do certain functional characteristics (e.g., size distribution) of fruit-feeding butterflies vary among habitat types in Kilak Central Forest Reserve?

1.5 Significance of the study

This research provides valuable insights for National Forestry Authority (NFA) to develop conservation interventions that address both ecological integrity and community livelihoods. The findings are helpful to local and national policymakers in crafting evidence-based forest management policies. Additionally, the study provides credible data that can attract support from development partners interested in promoting biodiversity conservation, especially for butterflies and other vulnerable invertebrates impacted by human activities in Kilak Central Forest Reserve. For the academic and research community, the study offers empirical data relevant to monitoring anthropogenic impacts in tropical forest ecosystems. Lastly, this research enhances public awareness at community level about the ecological role of butterflies in crop pollination and encourage the adoption of practices that foster both biodiversity protection and sustainable farming systems.

1.6 Justification of the study

Kilak Central Forest Reserve serves as an ecologically important savannah woodland, offering essential habitat for a wide range of plant and animal species. However, this ecosystem is increasingly under pressure from anthropogenic disturbances; including charcoal burning, illegal logging, farming, and settlement expansion, all of which compromises its ecological stability. Despite the ecological significance of fruit-feeding butterflies in maintaining biodiversity, there remains limited empirical research assessing how these anthropogenic disturbances impact their communities within this specific forest. This study was therefore warranted to fill that gap by generating scientific data on how anthropogenic pressures influence butterfly diversity and distribution. The findings inform the development of sound biodiversity conservation policies by relevant stakeholders, including environmental managers, local governments, and government agencies. Furthermore, the research provides evidence-based recommendations for improved planning, implementation, and enforcement of environmental laws in Uganda, thereby contributing to achieving national conservation goals and global commitments.

1.7 Conceptual Framework

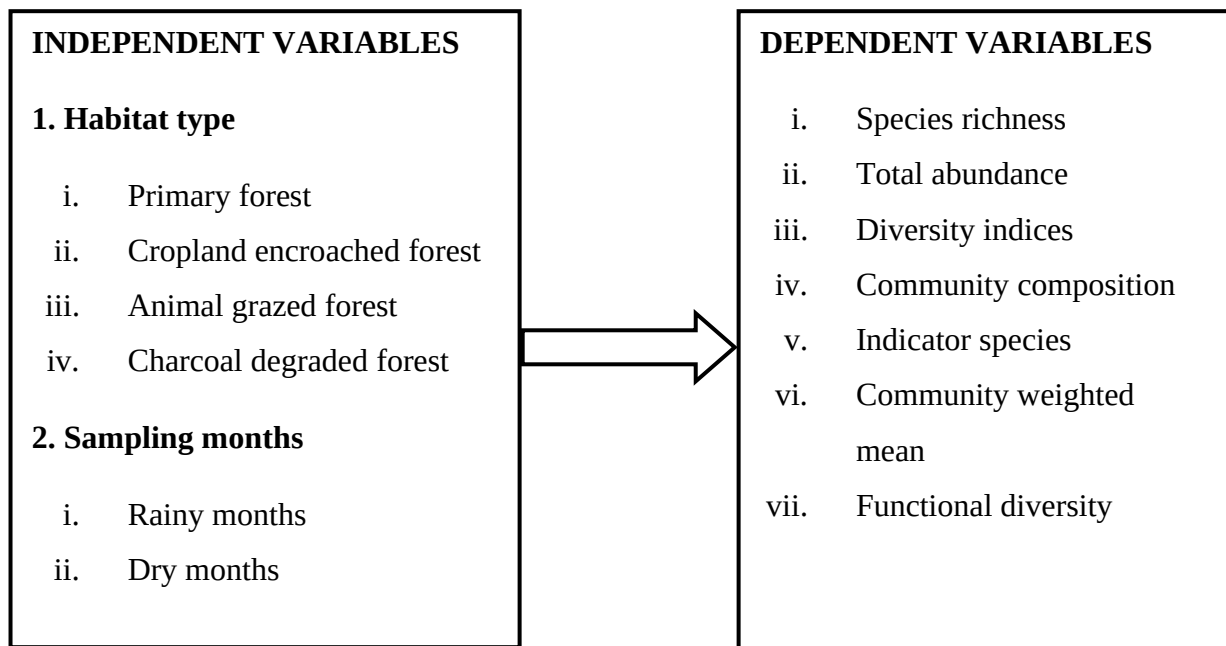


Figure 1: Conceptual framework developed by author based on literature (Oloya *et al.*, 2021; Mwinzi *et al.*, 2026)

Variations in the independent variables (i.e. habitat types and sampling months) are expected to influence the dependent variables; species richness, abundance, diversity, indicator species occurrence, community compositions and functional diversity of fruit-feeding butterflies. Primary forests are known to provide more abundant and stable food resources compared to anthropogenically disturbed habitats, and thereby expected to support higher species richness, abundance, diversity, and more complex community structures (Oloya *et al.*, 2021b). Similarly, rainy months are anticipated to sustain higher butterfly assemblages than dry months, largely due to increased availability of food resources during the rainy months (Korkiatupa *et al.*, 2023). Furthermore, interactions between habitat type and sampling month are expected to differentially shape butterfly community composition across primary forest and disturbed forests reflecting context-specific responses to both spatial and temporal environmental variations (Nyafwono *et al.*, 2015; Valtonen *et al.*, 2017).

1.8 Scope of the study

This study assessed the effects of anthropogenic disturbance on fruit-feeding butterfly communities in the Kilak Central Forest Reserve, Amuru District, northern Uganda. The research focused on four selected sampling sites within the forest reserve: (i) Primary forest, (ii) Cropland encroached forest, (iii) Animal grazed forest, and (iv) Charcoal degraded forest. Therefore, the findings were limited to the ecological conditions within Kilak Central Forest Reserve. The study was restricted to fruit-feeding butterflies and did not include other butterfly guilds or other insect taxa. Standard butterfly trap nets were used to capture fruit-feeding butterflies and standardized data collection protocols were used to record primary data to assess species richness, abundance, diversity, community composition, and functional characteristics (i.e., size distribution) of fruit-feeding butterflies. Sampling of fruit-feeding butterflies were conducted over a period of six months, with three months in the dry season and three months in the rainy season, to capture seasonal variations. However, long-term inter-annual trends in butterfly assemblages were not assessed. The research primarily examined the relationship between habitat type and study months with butterfly attributes, while considering vegetation attributes to explain differences among habitat types.

CHAPTER TWO: LITERATURE REVIEW

2.1 Detection and classification of fruit-feeding butterflies

Butterflies represent one of the most species-rich arthropod groups, with over 28,000 identified globally, of which nearly 80% are found in tropical regions (Amazonia et al., 2023). Among these, fruit-feeding butterflies are widely researched across many parts of the world, yet remain under-studied within tropical African contexts (Nakadai et al., 2025; Oloya et al., 2021b). In this region, classification is hindered by limited taxonomic expertise and a shortage of trained entomologists capable of accurately identifying species (Federico et al., 2024; Richter et al., 2023). Many species exhibit close morphological similarities, which complicates their identification (Sobral-souza et al., 2021). Accurate classification often demands specialized skills and resources that are frequently scarce in fieldwork conditions (Ghats, 2023). Traditional identification methods, which are still widely used in tropical Africa, are less precise and contribute to classification errors (Araujo et al., 2020; Iserhard et al., 2014). Typically, these methods involve capturing butterfly specimens and consulting standard identification manuals (Federico et al., 2024; Molleman., 2022). Encouragingly, interest in fruit-feeding butterfly research is growing across Sub-Saharan Africa, offering promise for improved classification accuracy in future studies (Calvin et al., 2023). This study used the Butterfly Identification Guide for Uganda by Molleman (2012) and trained field assistants conducted the identification of fruit-feeding butterflies. The identified butterflies were verified by taxonomist from Gulu university to improve accuracy of identification.

2.2 Fruit-feeding butterflies as indicator species for forest ecosystem health

Fruit-feeding butterflies have been widely recognized as effective bioindicators due to their rapid and sensitive responses to environmental disturbances (Oloya et al., 2021a, 2021b). Araujo *et al* (2020) emphasized their value in detecting ecological shifts caused by human activities, especially given that many species in this guild are restricted to closed-canopy forests. Their taxonomy is relatively well-established, with numerous species already described in scientific literature (Melo et al., 2023). These butterflies are often abundant, broadly distributed, and easily sampled using standardized bait traps, which simplifies both data collection and species identification (Sobral-souza et al., 2020). However, some scholars have criticized their use in ecological assessments, arguing that fruit-feeding butterflies are

better suited for detecting small-scale changes in land use or habitat degradation (Ghats, 2023; Jemal & Patharajan, 2018). Although the impact of human disturbance on butterfly diversity has been explored across tropical forests (Nkwabi et al., 2017), findings remain inconsistent (Province, 2023). While numerous studies in Africa reveal substantial differences in species richness between disturbed and undisturbed forest sites, a few studies have shown negligible or contrary results (Iserhard et al., 2014; Melo et al., 2023). Generally, higher species richness and abundance among fruit-feeding butterflies are viewed as a sign of healthy forest ecosystems (Korkiatupa et al., 2023; Nakadai et al., 2025). Nonetheless, populations of these butterflies have declined sharply in areas facing habitat degradation driven by human encroachment (Karla et al., 2024). This study used the fruit-feeding butterflies despite criticism by some researchers (Andrade et al., 2017; Jenber, 2021), because they have been used in other parts of the world including amazon forest in southern America (Bonebrake *et al.*, 2010). Inconsistencies of findings in the previous researches were addressed by sampling fruit-feeding butterflies for a period of six months to improve efficiency and provide reliable data for biodiversity assessment (Nowicki & Henry, 2008).

2.3 Spatial and temporal dynamics of fruit-feeding butterflies

Like many tropical insects, fruit-feeding butterflies display notable variation in their diversity, abundance, and species richness depending on spatial and temporal factors (Nyafwono et al., 2014), especially in regions marked by alternating wet and dry seasons (Uwizelimana et al., 2022). In areas where rainfall is more evenly distributed throughout the year, seasonal changes tend to exert less influence on butterfly populations (Melo et al., 2023). However, fluctuations in rainfall, temperature, food availability, and vegetation cover significantly shape butterfly community dynamics (Jenber, 2021; Jenber et al., 2020). The production of leaves, flowers, and fruits by host plants is particularly crucial, as these elements directly supply food and shelter to support population growth (Melo et al., 2019). While most butterflies thrive in the warm and humid conditions of tropical forests, some species are adapted to environments such as wetlands, grasslands, forest edges, or even arid zones (Andrade et al., 2017; Korkiatupa et al., 2023). Warmer temperatures are generally preferred by butterflies, as they accelerate physiological development across all life stages (Federico et al., 2024). Heat boosts metabolic rates in larvae and pupae, allowing for quicker maturation (Araujo et al., 2020). Additionally, butterflies tend to inhabit areas with less wind, since their delicate flight mechanics limit their ability to travel or forage effectively under

strong winds (Jenber & Dar, 2021). Seasonal variations in temperature and precipitation also alter vegetation cover, which in turn impacts the availability of feeding and breeding sites (Alegre et al., 2019; Melo et al., 2019).

2.4 Importance of fruit-feeding butterfly diversity and implications for conservation

Fruit-feeding butterflies play a crucial ecological role in terrestrial food webs (Journal & Science, 2021). As herbivores, their larvae consume a wide range of plant species, contributing to the transfer of energy across different trophic levels (Andrade et al., 2017; Barkmann et al., 2023; Oloya et al., 2021b). Also, butterflies serve as prey for numerous insectivorous animals, forming an essential link in many predator-prey relationships (Balogun & Kehinde, 2021). A sharp decline or disappearance of butterfly populations would likely disrupt multiple ecological functions and processes (Amazonia et al., 2023). Globally, fruit-feeding butterflies are increasingly used in ecological monitoring due to their sensitivity to habitat changes, making their conservation vital (Richter et al., 2023). Beyond their monitoring role, they contribute to forest ecosystems through pollination of flowering plants (Sobral-souza et al., 2021). Remarkably, some species have also been observed feeding on invasive plant species, providing potential for biological control strategies in certain regions (Ecosystem, 2021). Protecting butterfly populations is also essential for maintaining pollination services that support both wild plant diversity and agricultural productivity (Alegre et al., 2019; Melo et al., 2019). However, it is worth noting that some butterfly caterpillars can damage economically important crops, prompting concerns among farmers (Jenber & Dar, 2021). Despite this, butterflies remain an important component of overall biodiversity, valued not just for their ecological functions but also for their aesthetic appeal and role as indicators of environmental health (Kral et al., 2018). Their responsiveness to small-scale environmental changes and well-established taxonomy enhance their usefulness in biodiversity assessments (Katel, 2022; Kyerematen et al., 2018). Key threats to fruit-feeding butterflies include habitat destruction, agricultural expansion, and the widespread use of pesticides (Brazil & Bordin, 2024). Addressing these threats requires urgent research on fruit-feeding butterflies, especially in northern Uganda to provide reliable data to inform policies to preserve natural forests and promote ecological sustainability (Province, 2023; Sagwe et al., 2015).

2.5 Effects of anthropogenic disturbances on butterfly species richness, abundance, diversity, and community composition

The response of fruit-feeding butterflies to forest disturbances has been a subject of ongoing debate (Kyerematen et al., 2018). While some studies have found higher diversity levels in moderately disturbed forests compared to pristine ones, others report a decline in diversity or no significant difference at all (Kiruki et al., 2017; Oloya et al., 2021b). A critical factor influencing butterfly diversity under human disturbance is the intensity of such disturbances (Kasisi et al., 2024). Persistent or severe forest degradation tends to negatively impact butterfly assemblages, leading to reduced species richness, abundance, and altered community structures (Alegre et al., 2019; Araujo et al., 2020; Henry & Anderson, 2016; Karla et al., 2024). Conversion of forest land for agriculture or other uses often results in a simplified habitat structure and disrupts community composition (Ecosystem, 2021; Valtonen et al., 2017). In heavily cultivated zones, declining butterfly populations have been linked to the loss of floral resources and the application of harmful agrochemicals like pesticides and herbicides (Desta et al., 2022). Such agricultural practices frequently lead to the disappearance of native fruit-bearing plants that are crucial for butterfly feeding and reproduction (Araujo et al., 2020). Moreover, the remaining vegetation have been dominated by a limited range of grasses, further reducing habitat quality (Barkmann et al., 2023).

Some research suggests that minimal levels of forest disturbance may not significantly affect butterfly diversity, with noticeable changes typically occurring only under more severe degradation (Korkiatupa et al., 2023). These findings are consistent with the Intermediate Disturbance Hypothesis proposed by Cornell (1978), which proposes that species diversity tends to peak under moderate disturbance levels, whereas too little or too much disturbance leads to biodiversity loss (Jew et al., 2015). Nonetheless, evidence from across Sub-Saharan Africa highlights that fruit-feeding butterflies are particularly sensitive to habitat destruction (Richter et al., 2023; Sagwe et al., 2015). Overall, intact forests with minimal human interference provide better conditions to sustain diverse butterfly communities by offering more consistent food sources and microhabitats (Pereira et al., 2023). Kilak Central Forest Reserve still suffers persistent anthropogenic disturbance and it needs immediate intervention to restore the degraded habitats.

2.6 Effects of anthropogenic disturbance on functional traits (size distribution) of fruit-feeding butterflies

Studies conducted in Afrotropical forest highlighted the need to understand the roles of size distribution of fruit-feeding butterflies in forest restoration gradient of Kibale National Park in Uganda (Nakadai et al., 2025). Limited studies used species-level traits to assess community wide patterns in fruit-feeding butterfly. Both species-level data and individual-level data comparison are important to produce accurate data for environmental monitoring when using butterflies' functional traits (Alegre et al., 2019; Freire et al., 2021). Adult size of fruit-feeding butterfly is considered to be critical functional traits because body size often interact with biotic and abiotic components of environment and intern relates directly to performance of the organism (Alegre et al., 2019; Brito & Ribeiro, 2014). Butterfly forewing length diversity and their mean were observed to increase in primary forest than in secondary forest. This is particularly because mature primary forest contains a wide range of available resources to sustain both large and small butterfly species (Freire et al., 2021). Also, older forest ecosystem tends to support more functionally diverse and stable community than the younger counterparts.

Significant positive correlation was observed between body size and seasonality of butterfly species, where larger butterflies were frequent in narrow periods when forest resources were abundant (Molleman et al., 2020; Nakadai et al., 2025). Dependency on superior forest resources imply that larger butterfly species are more susceptible to anthropogenic disturbance and more prone to local extinction from climate variability, deforestation and habitat fragmentation (Granados- et al., 2022; De Vries, 1988). Habitat fragmentation changes the biotic and abiotic components, including the vegetation structure and this will affect butterfly functional traits and community compositions. Also, forest destruction exposes larger butterflies to natural enemies, shortage of resources and reproduction crisis. Generally, large sized insects are more affected by habitat disturbance than the smaller ones because of their poor dispersal ability and high level of habitat specialization (Molleman et al., 2020). Studies about the effects of anthropogenic disturbance on size distribution of fruit-feeding butterflies are limited in northern Uganda and this research as perceived to close the knowledge gap by providing real time data.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

Kilak Central Forest Reserve is a savannah woodland under the jurisdiction of the National Forestry Authority (NFA) of Uganda. It is located in Pabbo Sub-county, Amuru District, in northern Uganda at approximately 50km east of the Nile. The forest reserve lies at 3.0613°N latitude and 31.9767°E longitude (approximate centre coordinates), with an altitude ranging from 880m to 1390m above sea level and encompasses an estimated area of 102.05 km² (10,205 hectares). The area experiences a warm, semi-humid climate, with average temperatures between 22°C and 29°C, and an annual rainfall of around 1,200 mm. The area has a single, extended wet season from March to November, with August being the wettest month, followed by a distinct dry season from December to February/March. Characterized by rolling hills, the forest is the source of numerous rivers and streams that flow into the River Nile. The soil is predominantly acidic and rich in organic materials. Kilak Central Forest Reserve was established to support ecological functions, including biodiversity preservation and landscape protection. However, over the past decade, persistent human activities have caused extensive degradation, resulting in the loss of approximately 60% of its forest cover.

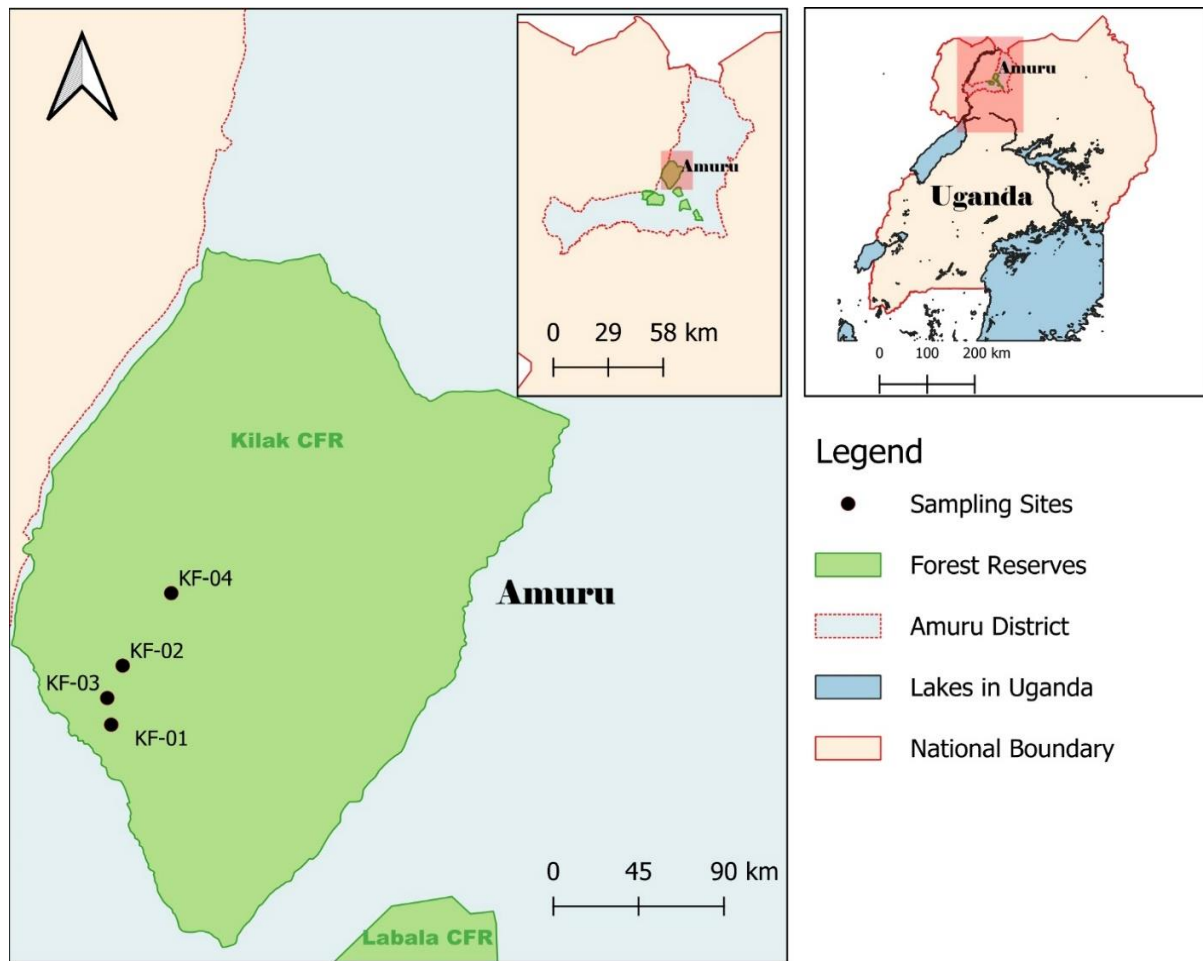


Figure 2. Location of Kilak Central Forest Reserve (CFR) in Amuru District, Uganda. The map was created using QGIS Version 3.44.0

Note: Sampling sites are labelled as: Primary forest (KF-01), Cropland-encroached forest (KF-02), Animal-grazed forest (KF-03), and Charcoal-degraded forest (KF-04).

3.2 Study design

The study employed longitudinal research design, allowing for repeated sampling of fruit-feeding butterflies across four sampling sites (Habitat types) over a period of six months from September 2025 to February 2026. The study also employed quantitative research design where numerical data about fruit feeding butterflies and vegetations were collected across the selected habitat types. The selection of sampling sites was informed by observable vegetation structure and the type of anthropogenic activity taking place within the specific habitat type.

3.3 Data collection methods

To ensure consistency and reproducibility, data on both vegetation and fruit-feeding butterflies were collected using Standardized Field Protocol. Butterflies were sampled using white cylindrical traps, baited with yellow bananas fermented for at least four days. These traps were hung on tree branches for four consecutive days every month over a six-month period, during which each species and its abundance were recorded. Vegetation data were collected within 40m x 20m nested plots established at each sampling site. These plots were demarcated by the principal investigator and research assistants in consultation with the National Forestry Authority to ensure compliance with national forestry policies. To ensure accuracy, all data were collected and recorded by the principal investigator and trained research assistants, and subsequently entered into Microsoft Excel 2016 spreadsheet.

3.3.1 Vegetation sampling

At each butterfly sampling location, five spatially separated plots (at least 250m apart) with size of 40m x 20m were randomly demarcated and sampled for vegetation attributes. Data on vegetation structure and tree species composition were gathered using nested sampling plots (Tabuti, 2007). This standardized protocol involved categorizing woody vegetation based on Diameter at Breast Height (DBH);

- i. Trees with $DBH \geq 20\text{cm}$ were counted within $40\text{m} \times 20\text{m}$ plot.
- ii. Poles with ($DBH \geq 10\text{ cm}$ and $< 20\text{ cm}$) were counted within $20\text{m} \times 20\text{m}$ plot.
- iii. Saplings ($DBH \geq 5\text{ cm}$ and $< 10\text{ cm}$) were counted within $20\text{m} \times 10\text{m}$ plot.
- iv. Seedlings ($DBH < 5\text{ cm}$) were counted within $10\text{m} \times 10\text{m}$ plot.

Vegetation attributes such as canopy cover, shrub cover, and grass cover were visually estimated within the $40\text{m} \times 20\text{m}$ plots using a 0-10 scale. The scoring system included the following intervals: 0 (0%), 0.5 (<10%), 1 (10%), 2 (20%), up to 10 (100%) (Nyafwono et al., 2015). Vegetations in this forest reserve were broadly categorized into four distinct habitats described as follows;

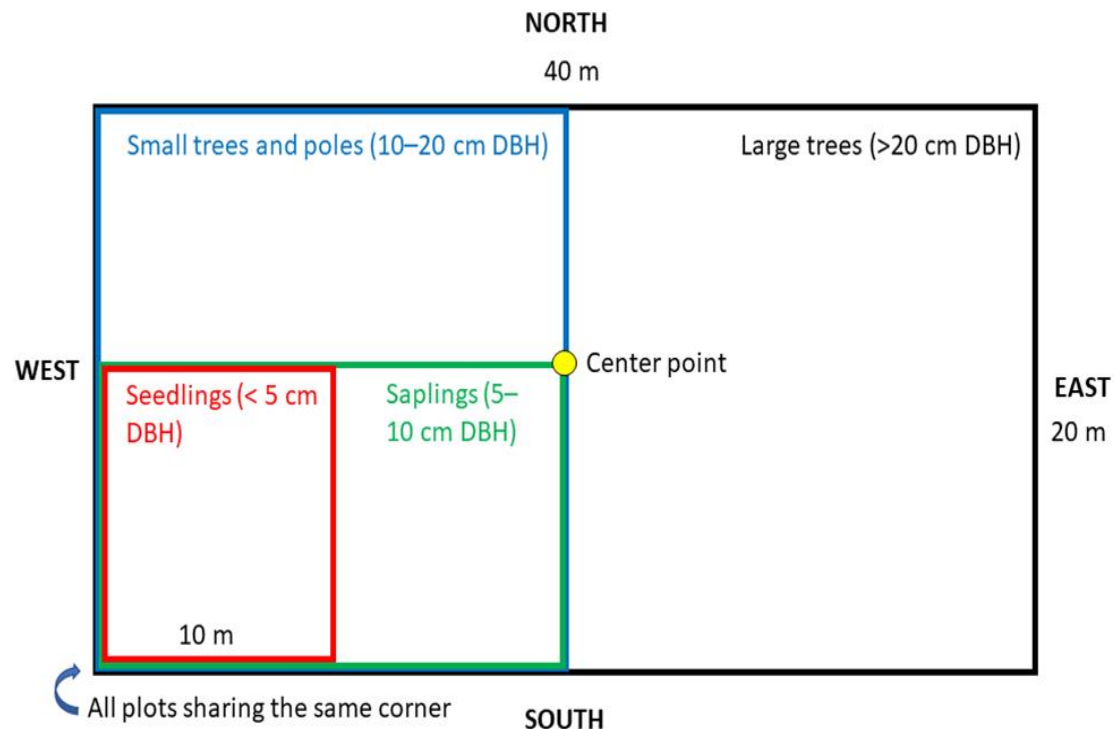


Figure 3: Nested plot for vegetation assessment

- i. Primary forest (KF-01): The compartment is one of the undisturbed fragments of the natural forest characterized by closed canopy throughout with minimal open gaps. The site contains many large trees and dense undergrowth of shrubs, poles, and saplings. Due to its inaccessibility, bordered by streams, this forest compartment experiences minimal human activity, protecting it from logging and charcoal production.
- ii. Cropland encroached forest (KF-02): This compartment consists of forested land that has been encroached upon for crop farming. Consequently, contributing to few large trees, poorly formed canopy and sparse undergrowth of vegetations, mainly along farm boundaries. Crops are grown on subsistence scale and they include; rice, soybeans, maize, bananas, and various vegetables.
- iii. Animal grazed forest (KF-03): This compartment is disturbed by grazing, browsing, and trampling from domestic animals, primarily goats and cattle. The forest features regenerating vegetation, with abundant shrubs, poles, and saplings. While some large trees also exist, wide gaps occur in the upper-storey canopy. Vegetation is significantly damaged along animal trails and near livestock enclosures.

- iv. Charcoal degraded forest (KF-04): This compartment has been heavily degraded by charcoal burning, firewood collection, and logging with very few large trees occurring, mainly those unsuitable for charcoal production. Although characterized with only few large trees, the compartment features numerous regenerating saplings and seedlings.

3.3.2 Fruit-feeding butterflies sampling

Butterfly sampling were conducted across the four habitat types using a design based on DeVries *et al.* (1997), with modifications described in Oloya *et al.* (2021b). Within each habitat, two parallel 400-meter transects were established, spaced 100 meters apart. To maintain consistency, all transects were oriented North to South direction. Along each transect, traps were placed at 100-meter intervals, offset 10 meters from the transect line. A total of 10 baited traps were set up per habitat type, amounting to 40 traps across all the four sites. Standard cylindrical butterfly traps (height 125cm and diameter 35cm) were used for sampling. Traps were hanged on tree branches such that the base is positioned at least 50 cm above ground level. Butterfly traps were baited with fermented banana placed on a plastic dish mounted on a 45cm × 45cm wooden platform (Molleman *et al.*, 2006). Baits were prepared by smashing yellow ripe bananas and fermenting the pulp in sealed containers for at least four days (Valtonen *et al.*, 2017). Baits were replenished regularly during inspection rounds to maintain effectiveness. Butterflies were sampled for six months from September 2025 to February 2026 and traps remained open for four consecutive days from 8:00hrs to 16:00hours. Captured butterflies were identified from the field using a guidebook specific to Uganda's forest butterfly species (Molleman, 2012). Specimens that were not reliably identified on-site were preserved and taken to Faculty of Agriculture and Environment Laboratory at Gulu University for further verification. To reduce recapture bias, captured butterflies were released inside the forest reserve at least one kilometer from any of the four sampling sites.



Figure 4: *Fruit-feeding butterfly trap in Kilak Central Forest Reserve*

3.4 Data analyses

Data collected across all traps were pooled to estimate the total species richness across the four habitats. Pattern of species richness across the four habitat types and six study months were compared using individual-based Species Accumulation Curve with 95% confidence interval in Program Estimate S Version 9.1.1 (Colwell & Elsensohn, 2014). For each habitat and sampling month, four univariate variables were evaluated: 1) species richness (Gotelli & Colwell, 2014), 2) total abundance, 3) Simpson's dominance (D) and 4) Shannon diversity (H'); $H' = -\sum(P_i * \ln(P_i))$, where P_i represents the proportion of individuals belonging to the i^{th} species in the total sample, and $\ln(P_i)$ is the natural logarithm of P_i . Overall difference in the average of the four univariates among the four habitats and six sampling months were tested with MANOVA. If significant difference among habitats and sampling months was found in MANOVA, difference in each univariate was tested separately using ANOVA with Turkey's post hoc tests.

To analyse species composition, species abundance data were first square root transformed to reduce the influence of the highly abundant species followed by computing Bray-Curtis dissimilarities. Non-metric Multidimensional Scaling (NMDS) was used to visualize patterns in species assemblages in two dimensions. Permutational Multivariate Analysis of Variance (PERMANOVA; type III sum of squares; 999 permutations with 50 restarts) was employed to test whether community composition differed significantly among habitats, months, and their interaction. Similarity percentages (SIMPER) were used to show the percentage contribution of different species to average dissimilarity among habitats and sampling months. All multivariate analyses were performed using PRIMER-E software Version 6.1.15 (Clarke et al., 2006).

To identify fruit-feeding butterfly species that were strongly and consistently associated with specific habitat types, Indicator Species Analysis was conducted using the IndVal method (Dufrene & Legendre 1997), implemented via the 'multipatt' function in the 'indicspecies' package in program R software Version 4.5.2 (R Core Team, 2025). Species with significant IndVal (>0.25) scores were considered habitat specialists. To analyze functional characteristics, forewing lengths in (mm) were used as proxy for body size and flight capacity. Individual-level differences in forewing length among habitats were tested using Kruskal-Wallis tests with Dunn's post-hoc comparisons (Bonferroni-corrected). At the community level analysis, Community Weighted Mean (CWM) and Functional Dispersion (FDis) were calculated for each trap per habitat. Habitat differences in both Community Weighted Mean (CWM) and Functional Dispersion (FDis) were tested using Kruskal-Wallis tests, followed by Dunn's post-hoc comparisons.

3.5 Dissemination plan

The findings of this study will be disseminated to the local community in Amuru District through presentations at village meetings, radio talk shows, posters, and policy briefs. Copies of the research findings will also be submitted to Amuru District Local Government, the Executive Director of the National Forestry Authority (NFA), other relevant government institutions, and development partners. In addition, both hard and electronic copies of the study will be deposited in the Gulu University Library to ensure accessibility for students, researchers, and other library users. The findings of this research will further be published in international peer-reviewed journals to enable access by the global scientific community.

3.6 Ethical Considerations

This study received ethical approval from the Gulu University Research Ethics Committee with reference number (GUREC-2025-481). Permission to access Kilak Central Forest Reserve was obtained from the National Forestry Authority (NFA) in compliance with national forest access regulations. Administrative clearance was granted by the Chief Administrative Officer and the Resident District Commissioner of Amuru District. Local community awareness of the research was achieved through sensitization via Local Council leaders. Strict safety measures were implemented to prevent injuries from potential hazards such as venomous snakes and aggressive insects like bees. All research activities complied with the national wildlife conservation policies and ethical guidelines for insect research in Uganda.

3.7 Limitation of the study

The study was subject to certain limitations, particularly with respect to its temporal scope. Data collection was conducted over a six-month period, which may not fully capture long-term or interannual variability in fruit-feeding butterfly communities. Given that fruit-feeding butterflies exhibit strong seasonal fluctuations (Brito & Ribeiro, 2014; Oloya et al., 2021b), this limitation was addressed by sampling across both rainy and dry months, with three months of data collection in each season, while maintaining consistent sampling effort throughout the study period. Also, there were possibilities that butterfly traps might be vandalized by community members and animals. To address this, the research team collaborated with the local council secretary for security to raise community awareness about the research being conducted. Furthermore, ten additional traps were made available to replace any that might be damaged by animals, particularly those in areas where livestock grazing occurred.

CHAPTER FOUR: PRESENTATION OF RESULTS

4.1 Species richness, abundance and diversity

A total of 3,358 individuals representing 55 species were recorded across the four habitat types in Kilak Central Forest Reserve during the six months study period (September 2025-February 2026). Species accumulation curves nearly reached asymptotes for all habitat types. Analysis found an overall significant difference in butterfly community univariate measures (species richness per trap, abundance, diversity, and dominance) among the four habitat types (MANOVA; Pillai's trace = 0.952, $F_{12,645} = 24.98$, $P < 0.001$). When tested separately, butterfly species richness differed significantly among habitat types (ANOVA; $F_{3,15} = 111.16$, $P < 0.001$; Figure 5). Primary forest exhibited significantly higher species richness per trap than all other habitat types. Similarly, butterfly abundance varied significantly among habitat types ($F_{3,15} = 156.68$, $P < 0.001$), with the highest abundances recorded in primary forest and the lowest in charcoal-degraded forest. Shannon diversity also differed significantly among habitat types ($F_{3,15} = 106.09$, $P < 0.001$; Figure 5), as did Simpson's dominance ($F_{3,15} = 91.89$, $P < 0.001$). Both Shannon diversity and dominance were highest in primary forest and lowest in charcoal-degraded forest.

There was an overall significant effect of sampling months on the four butterfly univariate variables (MANOVA, Pillai's trace = 0.637, $F_{20,864} = 8.19$, $P < 0.001$). When analyzed separately, butterfly species richness differed significantly among the sampling months (ANOVA, $F_{5,15} = 25.85$, $P < 0.001$; Figure 6). Species richness was significantly lower during the dry-season months of January and February than during the rainy-season months of September, October, and November. Butterfly abundance also varied significantly among the sampling months ($F_{5,15} = 29.89$, $P < 0.001$), with September, October, and November recording significantly higher abundances than January and February (Figure 6). Similarly Shannon diversity also differed significantly among the months ($F_{5,15} = 25.18$, $P < 0.001$), with the lowest diversity observed during January and February and the highest during September, October, and November (Figure 6). Dominance also varied significantly among the sampling months ($F_{5,15} = 22.88$, $P < 0.001$). The proportion of individuals represented by the most abundant species was significantly higher in January and February, indicating greater species dominance during the dry season. In contrast, September, October, and November exhibited lower dominance, reflecting a more even distribution of individuals among species and consequently higher butterfly community diversity (Figure 6).

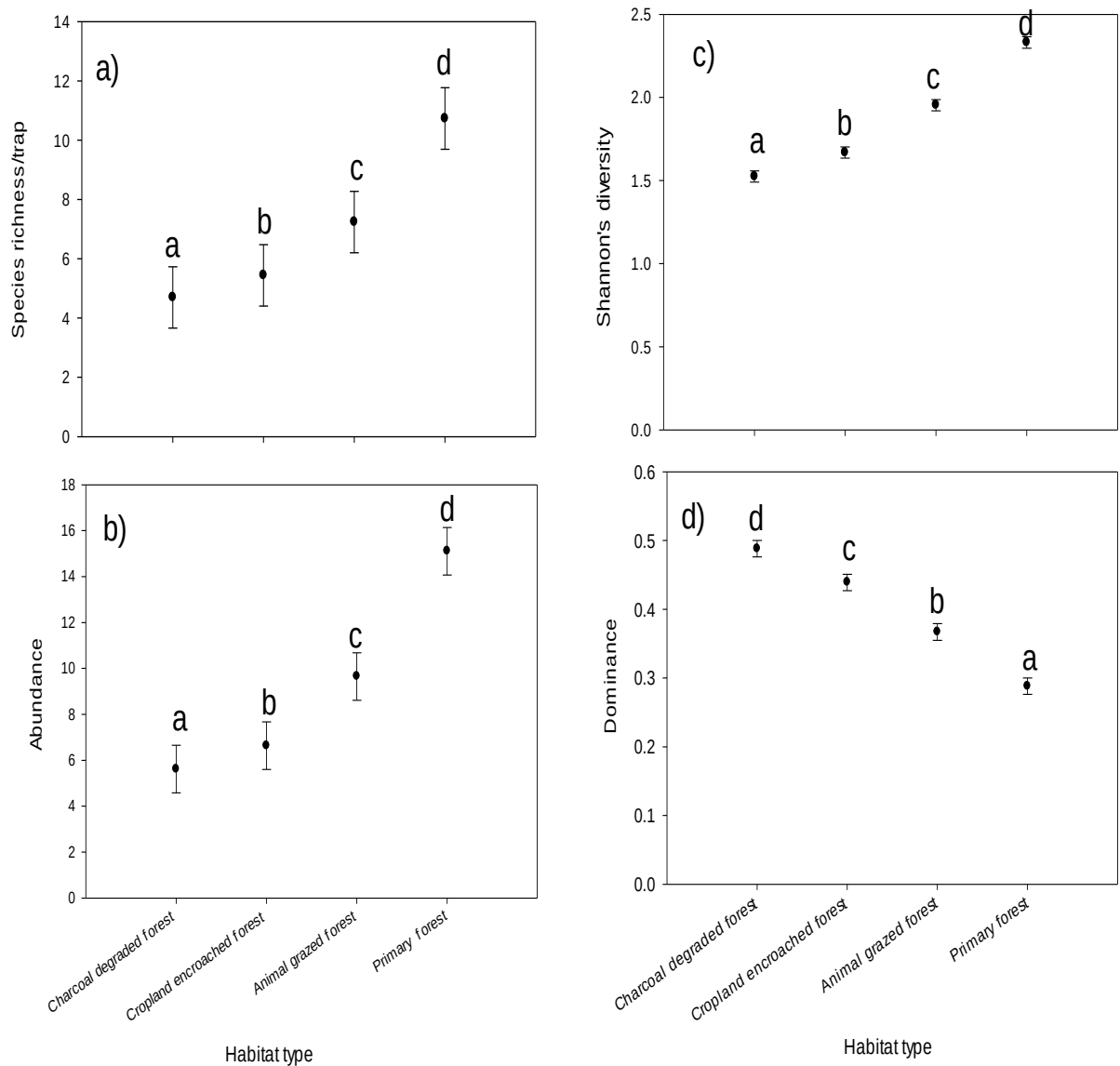


Figure 5: (a) Butterfly species richness/trap, (b) butterfly abundance, (c) butterfly diversity (Shannon) and (d) dominance (Berger-Parker) in the four habitat types in Kilak CFR, Northern Uganda. Values are marginal means ($\pm$ standard errors). Habitat types differing from each other in pairwise comparisons (Tukey, $p < 0.05$) are indicated by different letters

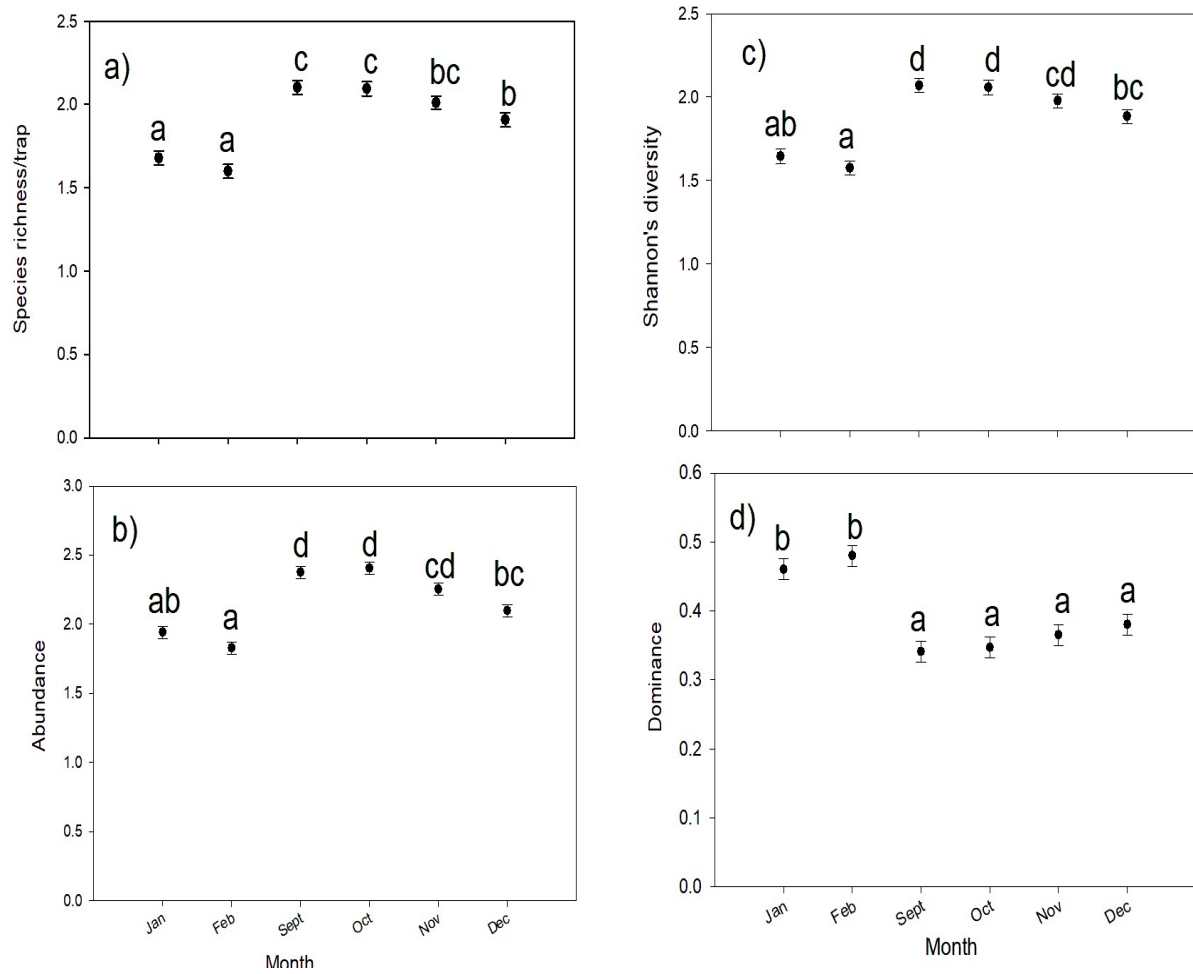


Figure 6: (a) Butterfly species richness/trap, (b) butterfly abundance, (c) butterfly diversity (Shannon) and (d) dominance (Berger-Parker) in the six study months. Values are marginal means ($\pm$ standard errors). Months differing from each other in pairwise comparisons (Tukey, $p < 0.05$) are indicated by different letters

4.2 Butterfly communities

The butterfly community composition differed significantly among the four habitat types (pseudo- $F_{3,15} = 12.77$, $p = 0.001$, stress = 0.01) and across the study months (pseudo- $F_{5,15} = 2.45$, $p = 0.001$, stress = 0.01), as illustrated by the NMDS ordination (Figure 7). Habitat type accounted for 27.35% of the variation in butterfly community composition while sampling month explained 10.90% of the observed variation. In addition, there was no significant interaction between habitat types and sampling month, indicating that the temporal changes in butterfly communities were consistent across the different habitat types. Pair-wise PERMANOVA comparisons showed that butterfly communities differed significantly among all habitat types ($p < 0.001$). Similarly, significant differences were detected among most sampling months, except between January and February, September and October, September and November, and November and December ($p > 0.001$). Similarity percentages (SIMPER) analysis indicated that three butterfly species that made the strongest contributions to the dissimilarities in the butterfly community composition among the habitat types were *Bicyclus buea*, *Melantis leda* and *Charaxes fulvescens*. Meanwhile, the butterfly species contributing most strongly to the observed dissimilarities in community composition among the sampling months were *Bicyclus buea*, *Bicyclus safitza*, *Melanitis leda*, and *Charaxes fulvescens*.

Table 1: Results of PERMANOVA based on Bray-Curtis similarity for the effects of habitat type and months and their interactions on the species composition of butterflies in four habitat types and six study months. *df* = degrees of freedom, *MS* = mean-squares, *P* = permutational *p*-value of the test statistic obtained under 999 permutations

Source of variation	df	MS	Pseudo F	p
Habitat	3	24,604.0	12.772	0.001 ***
Month	5	4,328.6	2.247	0.001 ***
Habitat × Month	15	1,199.3	0.622	0.999 ns
Residual	216			
Total	239			

Note. *** $p < 0.001$ highly significant; **ns** = not significant

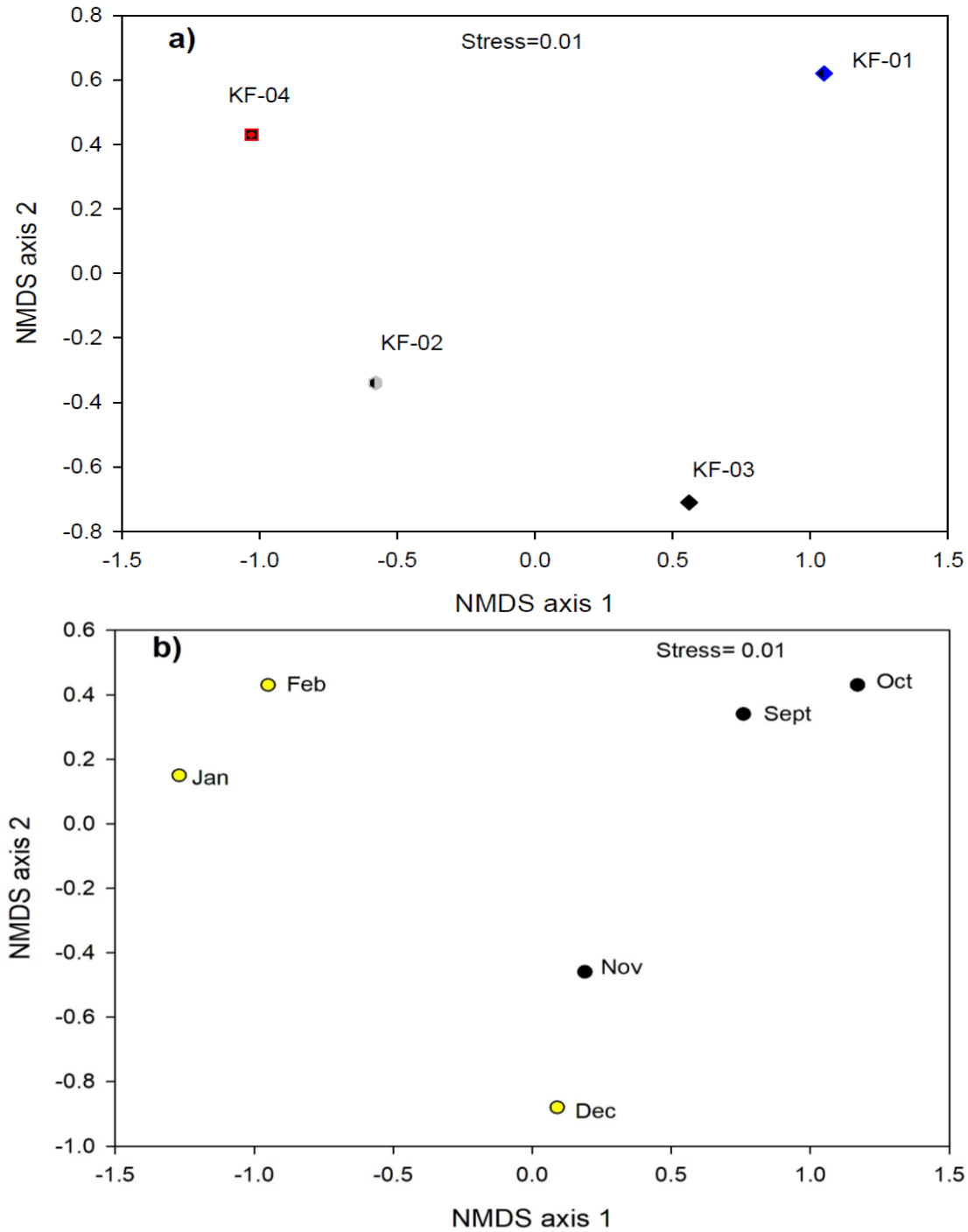


Figure 7: Non-metric multidimensional scaling (NMDS) ordination centroids for community similarities of fruit-feeding butterflies among (a) habitat types: Primary forest (KF-01), Cropland encroached Forest (KF-02), Animal grazed Forest (KF-03) and Charcoal degraded Forest (KF-04), and (b) months: Dry season (yellow) and Wet season (black)

4.3 Butterfly Indicator species

Dufrene-Legendre Indicator Species Analysis (IndVal) identified 16 species of fruit-feeding butterflies as reliable indicators across four habitats (Table 2). Primary forest had the highest number of indicators (13 species), followed by Animal-grazed forest (11 species). The three strongest indicators in primary forest were *Melanitis leda*, *Bicyclus anynana*, and *Bicyclus safitza*, which together accounted for 22% of the total butterfly abundance in that habitat. Cropland-encroached and Charcoal-degraded forest recorded five and two indicator species respectively (Table 2).

Table 2: Butterfly Indicator species in the four habitats in Kilak CFR, Uganda ($p \leq 0.05$; $IndVal \geq 0.25$)

Species	IndVal	p-value	Habitat type
<i>Melantis leda</i>	0.615	0.001	Primary, cropland encroached and animal grazed
<i>Bicyclus anynana</i>	0.611	0.001	Primary
<i>Bicyclus safitza</i>	0.56	0.001	Primary, cropland encroached and animal grazed
<i>Charaxes fulvescens</i>	0.521	0.001	Primary
<i>Junonia westermanni</i>	0.485	0.001	Primary
<i>Charaxes brutus</i>	0.467	0.001	Primary
<i>Bicyclus golo</i>	0.419	0.004	Primary, animal grazed and charcoal degraded
<i>Bicyclus mesogena</i>	0.418	0.001	Primary, cropland encroached and charcoal degraded
<i>Bicyclus simithi</i>	0.397	0.001	Primary and animal grazed
<i>Bicyclus mollitia</i>	0.369	0.001	Primary and animal grazed
<i>Catacroptera cloanthe</i>	0.365	0.001	Primary and animal grazed
<i>Junonia oenone</i>	0.35	0.001	Animal grazed
<i>Precis octavia</i>	0.346	0.001	Animal grazed and cropland encroached
<i>Euphaedra alacris</i>	0.325	0.001	Animal grazed
<i>Melantis ansorgei</i>	0.311	0.001	Primary
<i>Gnophodes betsimena</i>	0.264	0.003	Animal grazed and cropland encroached

4.4 Functional characteristics of butterflies

Forewing length of individual butterflies ranged from 13.0mm to 53.0mm. The largest species were from genera *Charaxes*; *C. candiope* (with mean of 47.00mm), *C. tiridates* (46.33mm), and *C. fulvescens* (45.57mm). Median forewing lengths were 26mm in primary forest, 25mm in cropland-encroached forest, 24mm in animal grazed forest and 23mm in charcoal degraded forest (Figure 8; Figure 9).

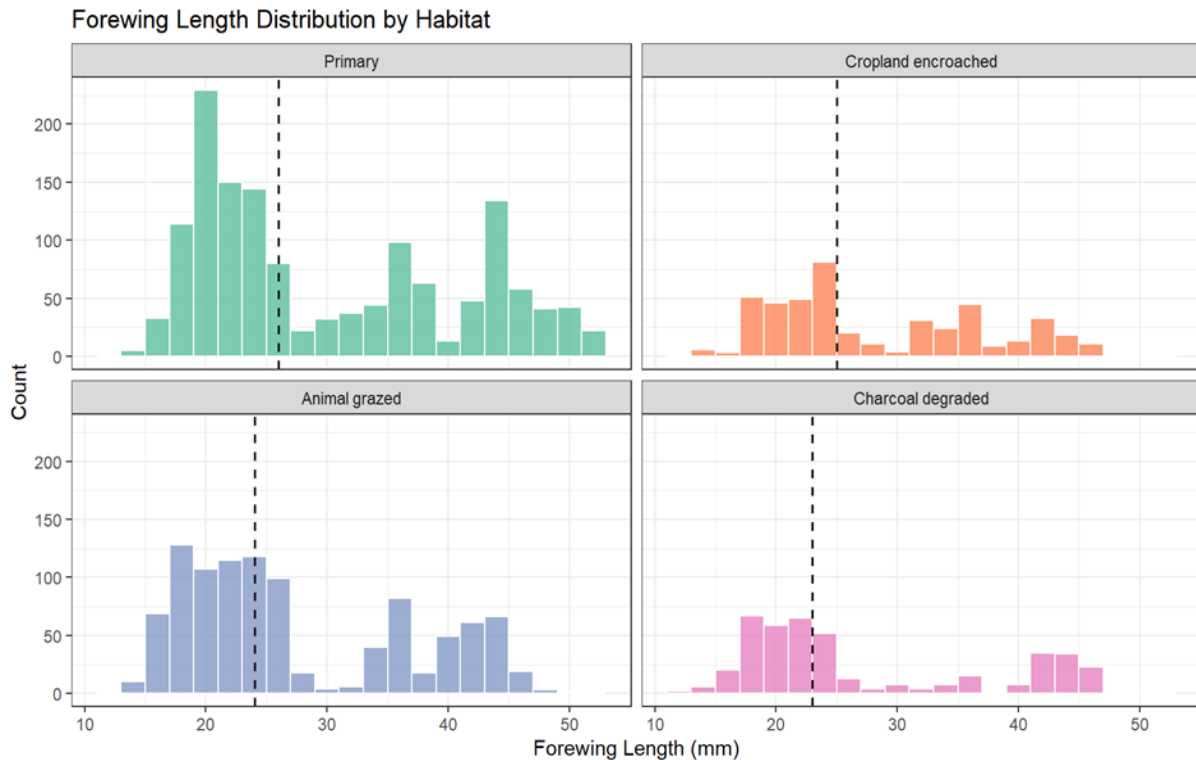


Figure 8: Forewing length frequency distributions by habitat

Based on Kruskal-Wallis test, individual forewing lengths differed significantly across habitats ($X^2(3) = 56.18$, $p < 0.001$). Dunn post-hoc tests with Bonferroni correction revealed significant differences between Primary forest and both Animal grazed ($p < 0.001$) and Charcoal degraded forests ($p < 0.001$), and between cropland-encroached and charcoal-degraded forests ($p = 0.016$). However, there was no significant difference between animal grazed and charcoal-degraded forests ($p = 1.000$).

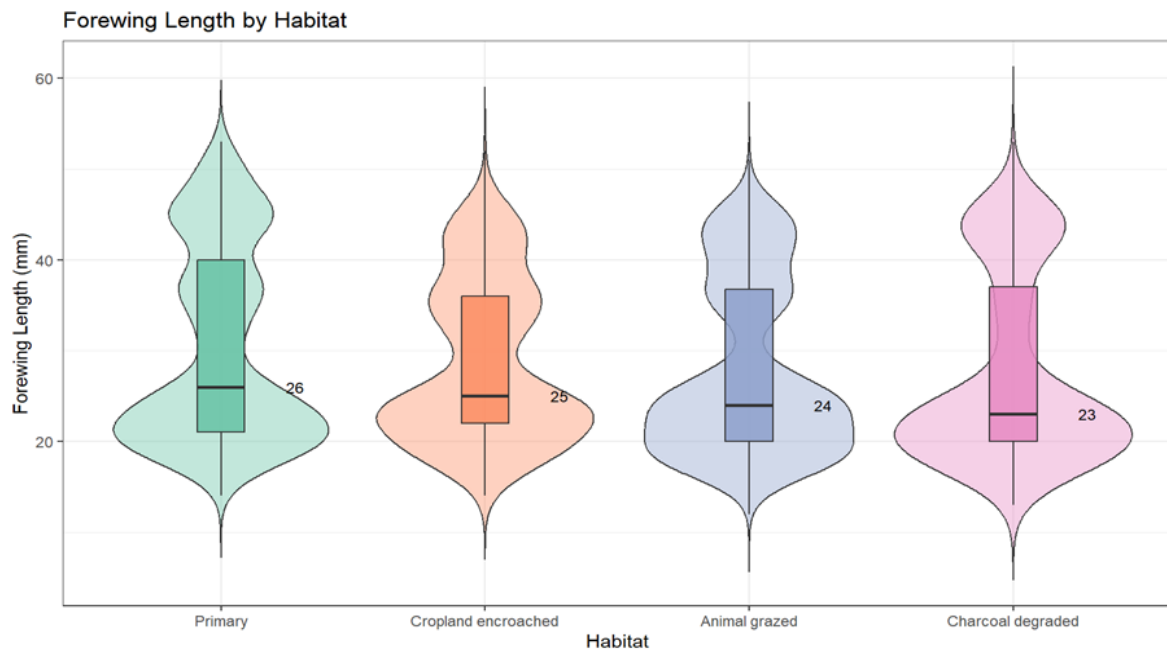


Figure 9: Violin and boxplot showing forewing length variations among habitats. Numeric labels indicate median forewing length (mm)

At species level analysis, Kruskal-Wallis test showed no significant differences in community-weighted mean (CWM) forewing lengths across habitats ($X^2 (3) = 0.783$, $p = 0.854$). The community-weighted average forewing length remained consistent at approximately 28-30 mm across all habitats. However, Functional Dispersion (FDis) varied significantly among habitats ($X^2 (3) = 15.04$, $p = 0.002$). Specifically, mean functional dispersion was significantly highest in primary forest (mean = 0.844mm) compared to all three disturbed habitats (Table 3). The three anthropogenically disturbed habitats did not differ significantly from each other (all $p = 1.000$).

Table 3: Community-weighted mean (CWM) forewing length and Functional dispersion (FDis) by habitat type

Habitat	Mean CWM (mm)	SD CWM	Mean FDis	SD FDis	CWM sig.
Primary forest	28.96	4.01	0.844*	0.263	ns
Animal-grazed forest	29.76	5.59	0.702	0.340	ns
Cropland-encroached forest	29.31	4.89	0.668	0.358	ns
Charcoal-degraded forest	29.40	6.95	0.666	0.504	ns

Note: Significantly highest functional dispersal indicated by asterisk (*), ($p < 0.001$ vs all other habitats)

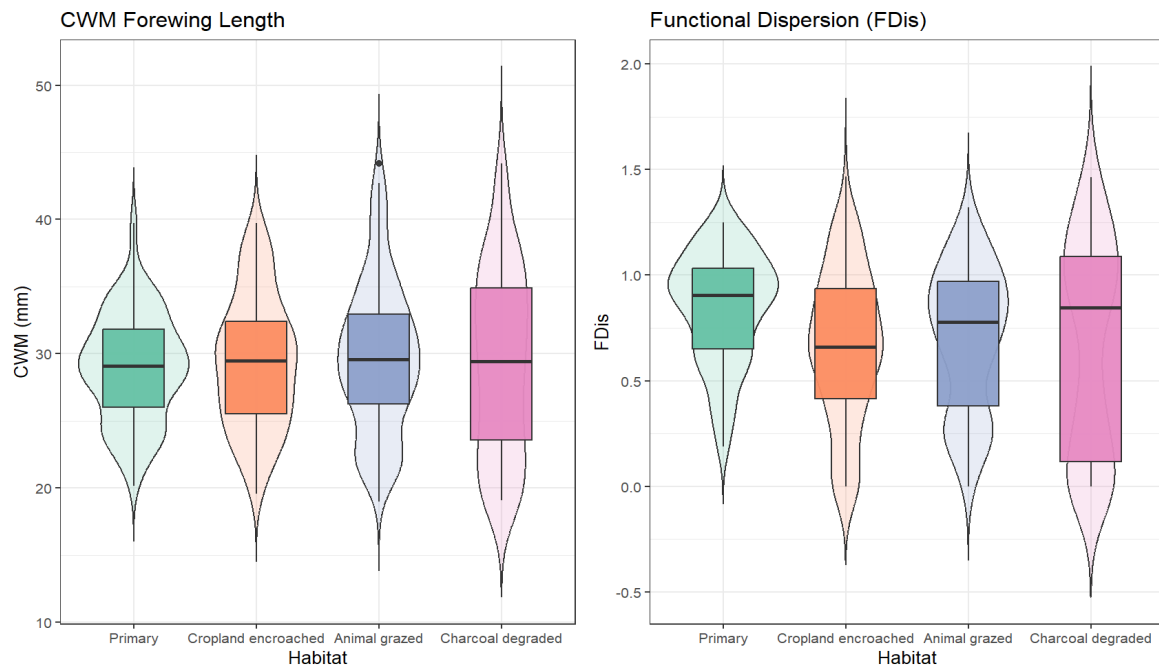


Figure 10: Community-weighted mean (CWM) forewing length (left) and Functional dispersion (FDis; right) by habitat

CHAPTER FIVE: DISCUSSIONS

5.1 Effects of habitat types and months on fruit-feeding butterfly communities

Anthropogenic activities were found to have significant negative effects on butterfly species richness, abundance, diversity, and community composition (Figure 5; Figure 7). Primary forests consistently recorded the highest species richness, abundance, and diversity compared to the three disturbed habitats, maintaining high richness throughout the sampling months. Similar patterns of fruit-feeding butterfly species richness have been reported in Budongo forest reserve in Uganda, where Primary forest exhibited higher species richness than the disturbed forest types (Oloya et al., 2021a, 2021b). This could be attributed to the increased amount of resources, such as plant biomass in primary forests, which provide a wider range of host plants for butterfly larvae, many of which are host-plant specific (Mwinzi et al., 2026). Additionally, the high butterfly diversity in primary forest of Kilak aligns with a study conducted in Tanzanian forest, which recorded a higher butterfly abundance and diversity in undisturbed natural forests compared to disturbed fragments (Kasisi et al., 2024; Nkwabi et al., 2017). Furthermore, ecological studies conducted in Ethiopia also reported that butterfly prevalence depends on a range of factors, with food availability being the most crucial (Jenber & Dar, 2021; Kiruki et al., 2017).

Findings from this study showed significant temporal variations in fruit-feeding butterfly species richness, abundance, diversity, and community composition over the six-month study period, with the highest abundance occurring during the rainy-season months of September, October, and November (Figure 6). Conversely, low butterfly abundances were recorded in the dry-season months of January and February. These seasonal shifts in species abundance and diversity might be attributed to variations in rainfall and food resources (de Araújo Silva et al., 2025; Munisi et al., 2024; Rossato et al., 2025). Similar studies done in Miombo woodland revealed that, the abundance of some butterfly species varied significantly across different habitats and seasons (Jew et al., 2015; Kasisi et al., 2024). This highlights the importance of both habitat structure and temporal resource dynamics in shaping butterfly communities (Lazarina et al., 2023; Montejo-Kovacevich et al., 2018). Generally, butterfly species exhibiting strong seasonal responses are likely influenced by fluctuations in host plant availability, nectar resources, and microclimatic conditions, all of which differ considerably between the wet and dry seasons (Habel et al., 2024; Ombugadu et al., 2024).

Non-metric multidimensional scaling (NMDS) ordination effectively captured fruit-feeding butterfly community structure in Kilak forest, revealing significant differences across habitat and sampling months (Figure 7). PERMANOVA showed that habitat and month accounted for the largest sources of variations, while their interaction was not significant (Table 1). The observed variations in community composition from PERMANOVA results across both habitats and months in Kilak central forest reserve might be attributable to the ongoing forest disturbances (Ombugadu et al., 2024; Wyatt, 2022). These anthropogenic forest activities were reported to slow the process by which the community composition of secondary forests becomes similar to that of primary forests (Addo-Fordjour et al., 2015; Margaret et al., 2014; Province, 2023). Similar studies done in Afro-tropic also reported that fluctuations in the number of the most abundant species, which can mask successional changes, could also contribute to dissimilar community composition (Aduse-Poku et al., 2018; Ghats, 2023). Also, the observed high residual from PERMANOVA results highlights the crucial role of unmeasured environmental variables and dispersal limitation shaping ecological processes in forests (Mwinzi et al., 2026; Rossato et al., 2025).

5.2 Indicator species of fruit-feeding butterflies

Indicator value (IndVal) analysis revealed butterfly specialization to different habitat types within Kilak forest reserve (Table 2). These habitats were defined by the presence of various exclusive single-habitat specialist and multi-habitat specialist species. Primary forests, in particular, stood out with the highest number of indicator species. Within primary forests, *Bicyclus anynana* and *Charaxes fulvescens* exhibited the highest indicator values, followed by *Junonia westermanni*, *Charaxes brutus*, and *Melantis ansorgei* (Table 2). This habitat specialization may stem from habitat-specific differences, such as variations in host plant density or quality, and the availability of courtship sites (Oliveira et al., 2021; Rija, 2022; Wyatt, 2022). This finding aligns with studies conducted in Uganda (Margaret et al., 2014) and Kenya (Mwinzi et al., 2026), who independently observed that the highest number of interior forest specialists belong to the genera: *Charaxes*, *Bicyclus*, *Melantis*, and *Euphaedra*. For instance, the preference for shady areas by some butterfly species may explain the prevalence of the genera *Charaxes* and *Bicyclus* in primary forests (Federico et al., 2024; Karla et al., 2024). Among the multi-habitat indicators, *Melantis leda* and *Bicyclus safitza* had the highest Indicator values in the Analysis (Table 2). Both species were associated with primary forest, cropland-encroached, and animal-grazed habitats, but neither were indicators

of charcoal-degraded forest. The presence of these species across multiple habitats, coupled with their absence from the most degraded habitat, suggests a warning sign of advanced forest degradation in charcoal degraded habitat (Nkwabi et al., 2017; Tørseth et al., 2012).

5.3 Variations of butterfly functional characteristics across habitats

This study revealed that individual forewing length differed significantly across habitats (Figure 9). Primary forest further exhibited a broader distribution with a pronounced right tail and a bimodal appearance, reflecting the co-occurrence of both small and large butterflies (Figure 8). This pattern further suggests that primary forests expand the range of available niches, allowing for the persistence of both smaller and larger butterflies and thus contributing to more evenly distributed trait values (Brito & Ribeiro, 2014; Nakadai et al., 2025). In contrast, the absence of significant difference between Primary and Cropland encroached forests for individual-level forewing size, despite significant differences in species richness, diversity, and community composition contradicts most ecological studies conducted in Afro-tropical forests (Nakadai et al., 2025). The observed results may suggest that cropland encroachment selectively filters species based on traits other than body size (Alegre *et al.*, 2019). Previous studies conducted in Afro-tropical forests demonstrated that butterfly responses to disturbance were mediated by habitat preference and functional morphology (Pinterich & Krenn, 2020), in which forest specialists in particular exhibited negative responses irrespective of body size (Kasisi *et al.*, 2024).

However, Community Weighted Mean (CWM) forewing length did not significantly differ among habitats. There was consistent community-weighted average forewing length of approximately 28-30 mm across all habitats (Table 3). The observed CWM trends among habitats is consistent with the idea that habitat degradation reshapes the variance and composition of the body-size distribution, rather than shifting its central tendency (Alegre *et al.*, 2019). Additionally, recent study conducted in Uganda revealed the importance of capturing both species-level and individual-level morphological trait data, as relying solely on species-level data may risk overlooking transitional processes along anthropogenically modified forest gradients (Nakadai et al., 2025). Species-level analysis may inaccurately suggest that certain morphological characteristics remain unchanged across different levels of forest disturbance (Brito & Ribeiro, 2014; Freire et al., 2021; Granados- *et al.*, 2022).

While CWM did not significantly differ among habitats, Functional dispersion (FDis) differed significantly, with primary forest exhibiting the highest mean (Table 3). The high FDis in primary forest could be explained by its greater structural complexity, which includes multiple canopy layers, a dense understory, and a stable microclimate (Melo et al., 2019). This complexity accommodates species spanning a wide range of body sizes, a pattern consistent with studies from Neotropical (Iserhard et al., 2014), Afrotropical (Kasisi et al., 2024), and East African forests (Munisi et al., 2024). In contrast, the three disturbed habitats showed no significant difference from each other, indicating functional homogenization across these types despite varying degradation drivers (Figure 10). This finding aligns with a similar study conducted in Brazilian forests (Amazonia et al., 2023; Brito & Ribeiro, 2014), which reported functionally similar butterfly assemblages in different human-modified forest gradient. The decline in FDis in disturbed habitats results from the truncation of body size extremes (Anderson, 2006; Isaac et al., 2011). Specifically, large-bodied forest specialists (e.g., *Charaxes* species) and very small-bodied specialists (e.g., certain *Bicyclus* species) are lost, leading to a dominance of intermediate-sized generalists (Iserhard et al., 2014).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Primary forest exhibited the highest species richness, abundance, and functional diversity of butterflies across all metrics. These values decreased along a gradient of disturbance: from animal-grazed to cropland-encroached to charcoal-degraded forest. This pattern, consistent across the six sampling months, aligns with the severity of human disturbance. Additionally, a significant seasonal decline in species richness, abundance, and diversity was detected across all habitats, with January and February recording substantially lower values than the September-November peak. This temporal pattern broadly coincides with the dry season and suggests that butterfly activity in Kilak Central Forest Reserve is strongly mediated by rainfall and associated fruiting phenology.

Indicator species analysis identified a functionally and taxonomically distinctive assemblage of forest specialists in primary forest, with *Bicyclus anynana* and *Charaxes fulvescens* recommended as the key species for monitoring primary forest condition. The two strongest multi-habitat indicators, *Melanitis leda* and *Bicyclus safitza*, are proposed as sensitive bioindicators of advanced forest degradation given their absence from charcoal-degraded forest.

While the null result for community-weighted mean forewing length indicates conservation of mean body size across habitats, the significantly higher functional dispersion in Primary Forest reveals that degradation produces functional homogenization. Anthropogenically disturbed habitats support narrower ranges of body sizes within communities, indicating reduced niche diversity. The convergence of functional dispersion values across all three disturbed habitats, regardless of specific disturbance driver, suggests a common functional response to forest degradation that transcends the particular human pressures imposed. Together, these multi-metric findings provide robust, statistically rigorous, and ecologically interpretable evidence that anthropogenic disturbances in Kilak Central Forest Reserve has significant negative consequences on butterfly diversity, community structure, indicator species occurrence, and functional integrity.

6.2 Recommendations

Based on the result of this present study, the following recommendation can be made to National Forestry Authority (NFA), development partners and researchers.

6.2.1 Recommendation to the National Forestry Authority and Development partners

- i. Given that most disturbances are human-induced, conservation of the KCFR can be achieved through the involvement of the local community. To foster a sense of ownership, the entire forest reserve should undergo active restoration while allowing regulated access to certain forest resources by the local community.
- ii. To ensure robust results for the practical application of fruit-feeding butterflies as indicators for monitoring forest integrity, NFA and other agencies should consider designing monitoring program that capture both taxonomic and functional diversity data. This information is crucial for identifying biodiversity hotspots within the study area, and zoning the Kilak Central Forest Reserve.
- iii. NFA should strengthen enforcement against illegal forest activities by deploying rapid response units, conducting intelligence-led patrols, and collaborating with the Uganda Police Force and the Uganda People Defence Force to dismantle networks involved in illegal forest activities in Kilak Central Forest Reserve.

6.2.2 Recommendations for future research

- i. To better understand the significance of the indicator species, further studies are needed. Additional relational studies should determine whether the sensitivities of the indicator species accurately reflect trends in both related and unrelated taxa within the habitat.
- ii. Further research should encompass other butterfly guilds, such as nectar-feeding species, and additional insect taxa to provide a more comprehensive understanding of Kilak forest ecosystem.
- iii. Comparative studies across neighbouring forest reserves, such as Labala, Got Gweno, and Wii Ceri, are highly recommended to support the generalization of findings and inform conservation planning and policies.

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APPENDICES

Appendix 1. Data collection tool

Part 1: Fruit-feeding butterfly data collection sheet.

Plot Code: _____

Date: _____

[illegible]

Part 2: Fruit-feeding butterfly wing length data collection sheet

Plot code: _____

Date: _____

[illegible]

Part 3: Vegetations data collection sheet.

Plot code: _____

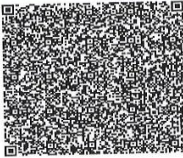
Vegetation category: _____

Date: _____

[illegible]

Appendix 2. GUREC approval

GULU		UNIVERSITY
P.O. Box 166, Gulu (U) Website: www.gu.ac.ug Email: gurec@gu.ac.ug		Tel: +256 471 432 096 Fax: +256 471 432 913 Mob: +256 772 964 491 +256 776 812 147
RESEARCH ETHICS COMMITTEE		



04/02/2026
To: Geoffrey Onyango OKIYA

0789162519

Review Type: Initial Review

Re:GUREC-2025-481: Effects of anthropogenic disturbance on fruit-feeding butterfly communities in Kilak central forest reserve, Amuru district.

I am pleased to inform you that at the **132nd** convened meeting on **27/11/2025**, the Gulu University REC meeting voted to approve the above referenced application.
Approval of the research is for the period of **04/02/2026** to **04/02/2027**.

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **04/02/2027** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by Gulu University REC:

No.	Document Title	Language	Version Number	Version Date
1	Protocol	English	1.0	2026-01-29
2	Community Engagement plan	English	1.0	2026-01-12



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3	Application for waiver of informed consent	English	2.0	2026-01-12
4	COVID-19 & EBOLA risk management plan	English	2.0	2026-01-12
5	Data collection tools	English	2.0	2026-01-12

Yours sincerely,

Julaina A. Obika

Julaina A. Obika (PhD)
For: Gulu University REC



Appendix 3. Plagiarism check

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PLAGIARISM CHECK

Declaration for Originality Form

This form must be completed and signed for all scholarly work produced.

Name: OKIYA GEOFFREY ONYANGO (MR.)

Personal File No.(staff) Reg. (student). REG. NO. 23/U/0550/MSE/PS

Faculty/Institute: AGRICULTURE AND ENVIRONMENT, GULU UNIVERSITY

Department: ENVIRONMENTAL SCIENCE AND NATURAL RESOURCES
MANAGEMENT

Title and bibliographic description of the work

**EFFECTS OF ANTHROPOGENIC DISTURBANCE ON FRUIT-FEEDING
BUTTERFLY COMMUNITIES IN KILAK CENTRAL FOREST RESERVE, AMURU
DISTRICT, UGANDA**

Declaration.

1. I understand what plagiarism is and I am aware of the University policy on this regard,
2. I declare that this ..., **Dissertation** ... (Thesis, Proposal, essay, assignment, paper, report etc.) is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my work has been used, this has been properly acknowledged and referenced in accordance with Gulu University requirements,
3. I have not sought or used the services of any professional agency to produce this work,
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own,
5. I understand that any false claim of this work shall result in disciplinary action in accordance with University Policy on Plagiarism.

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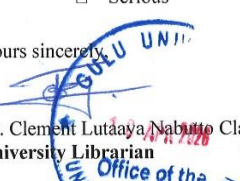
Date 10/04/2026

Originality Report

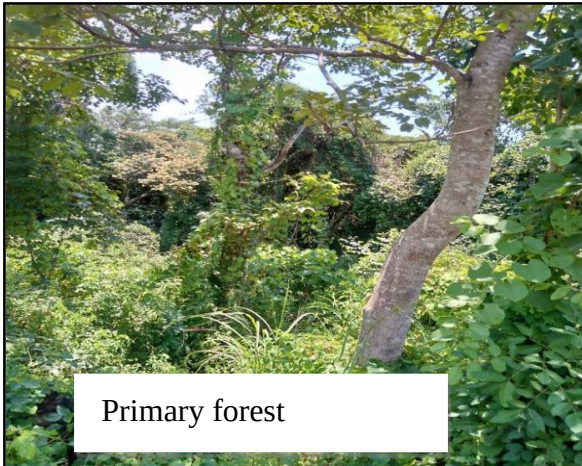
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- ☒ Minor
☐ Moderate
☐ Serious

Yours sincerely,


Dr. Clement Lutaaya Nabuto Claire (PhD)
University Librarian
Office of the

Appendix 4. Field photo.



Primary forest



Animal grazed forest



Cropland encroached forest



Charcoal degraded



Melantis leda



Bicyclus safitza