



**UNIVERSITI PUTRA MALAYSIA**

***COMPARISON OF MAMMAL COMMUNITY BETWEEN LOWLAND/HILL  
DIPTEROCARP FORESTS AND RUBBER TREE PLANTATIONS***

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**2024**

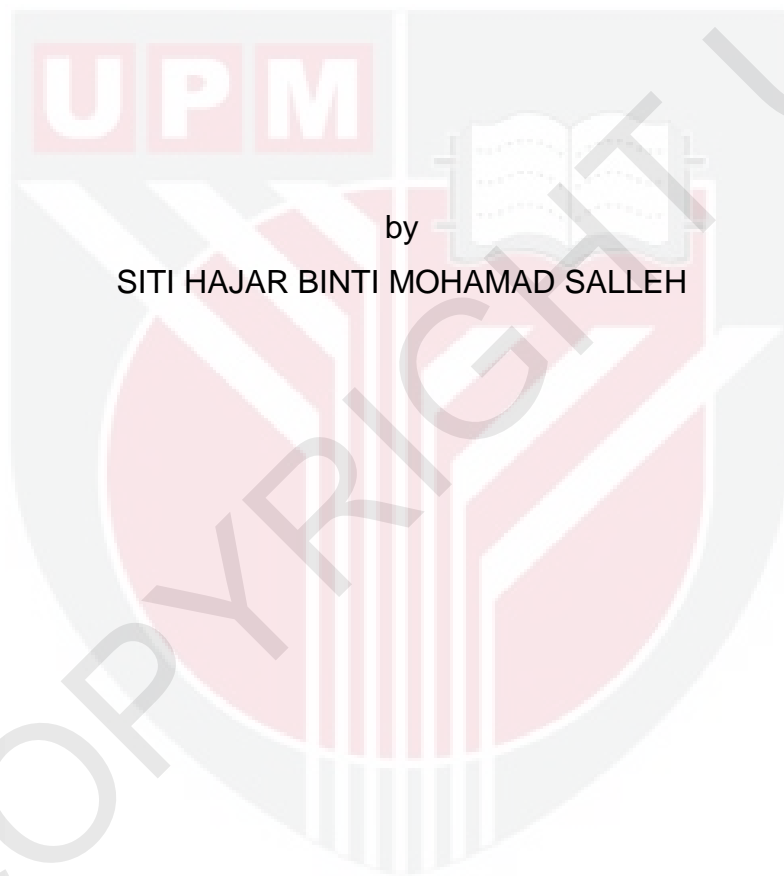
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**SITI HAJAR BINTI MOHAMAD SALLEH**

**A Project Report Submitted in Partial Fulfilment of the  
Requirements for the Degree of Bachelor of Forestry Science  
with Honours in the Faculty of Forestry and Environment**

**2024**

## DEDICATION

I dedicate this final year project to me and my family for their steadfast support and encouragement, which has been the cornerstone of my academic journey. Their belief in my capabilities has fueled my determination, and their sacrifices have paved the way for my success.

Gratitude extends to my fellow final year project partners and supervisor for their guidance and inspiration. This achievement is a testament to the collective efforts and love surrounding me.

Ultimately, I dedicate this work to the pursuit of knowledge and the countless individuals who strive to make a positive impact through academic inquiry, with the hope that this thesis contributes, even in a modest way, to the advancement of our understanding and the betterment of the world.



## ABSTRACT

The conversion of forest into human-modified landscape has contributed to biodiversity loss and threatening its diversity in Southeast Asia. Wildlife such as mammals are one of the categories that face serious threats due to these changes. The utilization of advanced device such as camera trap. This study investigated several potential environmental factors (tree height, number of trees) that affect the frequency of mammals sighting in two different habitats (lowland/highland forest, rubber tree plantations) situated in Rembau, Negeri Sembilan, Malaysia. Generalized Linear Models (GLM) were used to compare the species richness, species composition and site occupancy between different habitats. Based on analysis, mean tree height and number of trees influenced the variability in mammals' presence for one response variable which is number of wildlife images documented by camera trap. Ultimately, the presence of mammal community is varied between each habitat and are influenced by several environmental factors.

## ABSTRAK

Pernukaran hutan kepada landskap yang diubah suai oleh manusia telah menyumbang kepada kehilangan biodiversiti dan mengancam kepelbagaian di Asia Tenggara. Haiwan liar seperti mamalia merupakan salah satu kategori yang menghadapi ancaman serius akibat perubahan ini. Penggunaan peranti canggih seperti perangkap kamera telah digunakan dalam kajian ini. Kajian ini mengkaji beberapa faktor alam sekitar berpotensi (tinggi pokok, bilangan pokok) yang mempengaruhi kekerapan penampakan mamalia dalam dua habitat berbeza (hutan rendah/tanjung, ladang getah) di Rembau, Negeri Sembilan, Malaysia. Model Linear Am Umum (GLM) digunakan untuk membandingkan kekayaan spesies, komposisi spesies, dan okupansi tapak antara habitat yang berbeza. Berdasarkan analisis, purata ketinggian pokok dan bilangan pokok mempengaruhi keragaman kehadiran mamalia untuk satu pembolehubah respons iaitu jumlah imej hidupan liar yang direkodkan oleh perangkap kamera. Akhir sekali, kajian ini dapat menyimpulkan bahawa kehadiran komuniti mamalia berbeza antara setiap habitat dan dipengaruhi oleh beberapa faktor alam sekitar.

## ACKNOWLEDGEMENT

I extend profound gratitude to those who played a pivotal role in my academic journey, offering unwavering guidance, motivation, and support throughout my thesis.

Dr. Badrul Azhar bin Md Sharif, my supervisor, deserves special thanks for his expertise and profound insights, shaping the entire process and broadening my intellectual horizons. Heartfelt appreciation to Ku Noor Khalida, Ilya Yasmin, Wan Muhammad Zaki, Amirah Azrul, Syazlina Omar, Azamuddin Ahmad Zuki, Syabil Razin, Juliyana Mirus and Ali Hanafiah for their invaluable assistance during data collection and engaging discussions.

Special mention goes to my friends, Akidah Yusri, Hazimah Mumtazah and Athirah Amni who provided constant moral support and motivation, being a pillar during challenging times. Their encouragement and uplifting spirits played a vital role in reaching the completion of this thesis.

Lastly, immense gratitude to my parents, Mak and Bapak, and my siblings for their boundless love, unwavering support, and constant prayers. Their influence formed the bedrock of my determination to successfully complete this final year project.

## APPROVAL SHEET

I certify that this research project report entitled “Comparison of Mammal Community Between Lowland/Hill Dipterocarp Forests and Rubber Tree Plantations” by Siti Hajar Binti Mohamad Salleh has been examined and approved as a partial fulfilment of the requirements for the degree of Bachelor of Forestry Science with Honours in the Faculty of Forestry and Environment, University Putra Malaysia

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Date: February 2024

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## LIST OF ABBREVIATIONS

CE	Critically endangered
Df	Degree of freedom
E	Endangered
GPS	Global positioning system
HDF	Highland dipterocarp forest
IUCN	International Union for Conservation of Nature
LC	Least concern
LDF	Lowland dipterocarp forest
SIMPER	Simple percentage
V	Vulnerable

# CHAPTER 1

## INTRODUCTION

### 1.1 General Background

Over the past three decades, the global expansion of agriculture has ignited significant disputes and debates, as noted by various scholars (Yaffee, 1994; Angelstam, 1996; Lindenmayer and Franklin, 2003; Rudel et al., 2009). The primary threat to global biodiversity stems from land alterations, such as habitat conversion and fragmentation caused by human activities (Primack, 2001; Kerr and Deguise, 2004).

Large-bodied mammals, due to their extensive home-range needs, are particularly vulnerable to deforestation and fragmentation, as highlighted in studies (Kinnaird et al., 2003). Mammals, traditionally a focus of government funding for wildlife conservation, play a crucial role in land ecosystems, emphasizing the importance of understanding their response to changes in land use (Ceballos et al., 2005; Schipper et al., 2008; Redford et al., 2011; Ramesh & Downs, 2015).

In wildlife research, camera traps prove to be an invaluable tool, especially for secretive and cryptic mammal species (Rowcliffe and Carbone, 2008; Matsubayashi et al., 2011; Bernard et al., 2012). They are commonly utilized for collecting biological data on mammal species, including diversity, relative abundances, activity patterns, and the presence or absence of certain species (Kawanishi et al., 1999; Srbe-

Araujo and Chiarello, 2005; De Luca and Rovero, 2006; Grassman et al., 2006; Linkie et al., 2007; Rovero et al., 2013a). Moreover, camera traps have become a significant tool in occupancy estimation studies, contributing to conservation efforts (Linkie et al., 2007).

Managing the replanting cycle is crucial to prevent a subsequent wave of biodiversity loss, including the depletion of farmland species and their habitats (Ashton-Butt et al., 2019). Notably, large-scale industrial plantations, prevalent in Southeast Asia's leading producing countries like Indonesia and Malaysia, exhibit higher biodiversity loss compared to smallholdings (Bissonnette and De Koninck, 2017; Oon et al., 2019a). In Malaysia alone, large-scale industrial plantations and smallholdings encompass 4,232,294 ha and 1,667,863 ha, respectively (MPOB, 2019).

Moreover, predictions suggest that by 2100, approximately 21–48% of mammals in Southeast Asia will face extinction, underscoring the urgency of addressing the challenges posed by agricultural expansion (Brook et al., 2003).

## 1.2 Problem Statement

The extensive land use changes for agricultural expansion are the main problem in Southeast Asia (FAOSTAT, 2022), especially when it practices monoculture system. Owing to the sequences, this unsustainable practice has threatened the forest biodiversity when the plantations expanded into forested areas, causing biodiversity loss and habitat destruction (Balkanlou et al., 2020, Liang and Song, 2022, Shirmohammadi et al., 2020a).

Looking into monoculture rubber tree plantations, commonly associated with simplified habitat because it supports fewer faunal species. In addition, the applications of agrochemical such as pesticides and herbicides degrade the monoculture plantations and thus make available habitats within plantations inhospitable to biodiversity.

Lowland-hill dipterocarp forest is one of the crucial habitats for mammals. The remarkable rate of land conversion that occurs in Malaysia has cause the emerge of a land strategy called as land and land sparing. However, these strategies have not been seriously considered by conservation stakeholders in Peninsular Malaysia.

### **1.3 Research Objectives**

The purpose of this study is to investigate the effects of forest conversion into monoculture rubber tree plantations on mammalian biodiversity by:-

- 1) Quantifying species richness in monoculture rubber tree plantations.
- 2) Comparing mammal species composition between lowland dipterocarp forests & rubber tree plantations.
- 3) Determining the site occupancy of mammal species in lowland dipterocarp forests & rubber tree plantations.

### **1.4 Justification and Significance of Study**

The study on comparison of mammal community in relation to habitat structure between forest reserves and rubber tree plantations will contribute to updating the current survey data on various species, composition, site occupancy of mammals for future reference, management, and conservation. Thus, will help the forest and wildlife managers make an informed decision making with respect to habitat and wildlife conservation. Subsequently, this research can aid them to understand the effects of land use changes on biodiversity in the context of land sparing & sharing strategies.

## CHAPTER 2

### LITERATURE REVIEW

#### **2.1 Ecological Roles of Mammals**

Mammals exhibit a wide size range, from the tiny Etruscan shrew (< 2 g) to the colossal blue whale (almost 140,000 kg), with varying lifespans ranging from less than a year for certain shrews to over 200 years for bowhead whales (*Balaena mysticetus*). The most substantial herbivores and carnivores among mammals are energy-intensive organisms, holding significant roles in terrestrial and marine ecosystems. Understanding how community structure influences ecosystem processes (Morris et al., 1989) has facilitated more effective implementation of management and conservation strategies amidst anthropogenic landscape degradation (Hoffmann et al., 2010).

#### **2.2 Camera Trap**

In recent years, camera trapping has become an established non-invasive approach for wildlife monitoring in practically any soil or weather condition. It has proven to be successful not only in precisely identifying a wide range of species but also, with the proper setup (OConnell et al., 2011, Silveira, 2003), by thoroughly assessing variables such as age, sex, population composition, and density over broad areas (Zaragoz et al., 2015).

Nearly all of approaches for determining the number of wildlife species are predominantly concerned with the following key ecological characteristics of the species: (1) the scarcity of individuals, (2) the species' vast range, and (3) the secrecy of their behaviors (Karanth and Nichols, 1998). Whilst traditional survey is said to be efficient and inexpensive, but they do not methodically depend solely on the environment like camera trapping (Silveira, 2003). Camera trapping does not require strenuous fieldwork and is not adversely influenced by the researchers' inexperience (Silveira, 2003).

Moreover, adopting these methodologies facilitates the study of rare, endemic, threatened, or endangered species, even if authorities have tightened restrictions or even prohibited monitoring (Botello et al., 2007). The deployment of camera trapping techniques offers several intriguing benefits, but precaution should be given while managing the data. Following problems such as lack of systemization (Kelly, 2008; Barrueto et al., 2013), large volume of data, and lack of regular quality controls (Barrueto et al., 2013) may arise.

### 2.3 Lowland/Hill Dipterocarp Forest

The name of 'Dipterocarp Forest' exists because trees of the Dipterocarpaceae family mostly inhabit forests in Malaysia and the Dipterocarpaceae grows on dryland just above sea level at an elevation of around 900m (World Wildlife Fund, n.d.). This category of forest can be categorised by altitude into Lowland Dipterocarp Forest (LDF) up to 300 m over sea level and Highland Dipterocarp Forest (HDF) between 300 m and 750 m above sea level (World Wildlife Fund, n.d.).

Located in Rembau, Negeri Sembilan, the Angsi forest reserve is a pristine and contiguous lowland/highland dipterocarp forest, forming part of Peninsular Malaysia's Main Range. Spanning about 12,435.018 hectares, this area is recognized as a high conservation value zone, with an elevation of around 539 meters above sea level.

Lowland Dipterocarp Forest is among the richest ecosystems in the world with some more than 200 tree species per acre (Okuda et al., 2003). At present the lowland dipterocarp forest is known as an endangered habitat due to anthropogenic activities such as logging (Okuda et al., 2003) and land conversion for agricultural expansion (Benhin 2006). Unlike LDF, HDF contains low wildlife richness and undergrowth but small mammals like arboreal species and birds would prefer this type of habitat due to its elevation (World Wildlife Fund., n.d.).

## 2.4 Rubber Tree Plantations

Rubber (*Hevea brasiliensis*) is globally recognized as a lucrative commodity crop (Pridayarshan, 2017), cultivated extensively for its ability to produce natural rubber (Priyadarshan, 2017). Thriving in tropical regions with an annual rainfall of 1500-4000 mm and an average temperature of 28 °C, rubber trees have found ideal conditions in Southeast Asia, which has consequently become the leading supplier of rubber (Karim, 2006; Rao et al., 1998; Watson, 1989).

The roots of the Southeast Asian rubber industry trace back to 1877 when Henry Wickham planted around 70,000 rubber seeds in the Royal Botanic Garden at Kew, England (MRB, 2009). Subsequently, young rubber plants were transported to Sri Lanka in 1900 and distributed between Singapore and Malaysia, marking the initiation of Southeast Asia's development in the rubber sector (MRB, 2009). By the 1930s, the region contributed an astounding 98% of the world's rubber production, establishing its dominance in the industry (Hurley, 1981).

Presently, Thailand, Indonesia, Vietnam, China, India, Côte d'Ivoire, and Malaysia stand as leading rubber producers, collectively contributing over 90% to global rubber output (Fox and Castella, 2013; MRB, 2020). Malaysia, once the foremost rubber producer in the 1960s, currently ranks as the seventh-largest producer (Barlow, 1978; Barlow et al., 2014; MRB, 2020). The rubber industry remains a substantial contributor to the Malaysian economy, generating USD 10.2 billion, equivalent to 4.7% of the

national gross domestic product, from exports in 2013 (MRB, 2014; Sharib and Halog, 2017). The recent decline in production has become a major concern for the national economy, attributed to the escalating instability of worldwide rubber prices and an extended duration of reduced prices (Goh et al., 2016; Mdludin et al., 2016).

## **2.5 Land Use Management (Land sparing-land sharing)**

Biodiversity conservation strategies can be broadly categorized into two approaches based on their spatial allocation and management type (Phalan et al., 2011). The first approach, known as land-sparing, involves the spatial segregation of conservation areas from agricultural or forest production zones. The second approach, referred to as land-sharing, integrates multiple goals, such as production and conservation, within the same sites (Phalan et al., 2011). At a landscape scale, land-sparing entails a clear zonation, where specific areas are designated for intensive management or protection for conservation purposes. Conversely, land-sharing involves the distribution of conservation measures more evenly or randomly across the landscape.

The debate over which strategy is more beneficial for biodiversity persists (Kremen, 2015; Grass et al., 2021). Ecological theories suggest that a land-sparing strategy may promote biodiversity by creating larger habitat patches that can support larger populations, thereby reducing the risk of local extinctions (Hanski, 2000). Hanski (2011) introduces the concept of "Third-of-a-third," proposing that one-third of the managed landscape, in

addition to areas protected in reserves, should be dedicated to conservation. This concentration allows for the dispersal of individuals among set-aside areas, fostering viable populations.

Land-sharing may be preferable when the goal is both production and biodiversity maintenance across the entire landscape (Mell, 2017). The effectiveness of each approach also depends on the intensity of forest management in production stands. While the land-sparing/land-sharing framework was initially developed for agricultural land, its application in forest land is limited (Paul and Knoke, 2015; Betts et al., 2021). In forests, land-sharing may offer greater benefits than in agricultural landscapes because managed forests can closely resemble natural habitats. However, outcomes in forest land vary based on factors such as management history, climate, and social context (Sterling et al., 2017; Naumov et al., 2018).

## 2.5 Threats on Mammals in Malaysia's Forest

The rapid declination in the abundance of numerous mammal populations, coupled with a heightened risk of extinction, give rise to conservation apprehensions regarding mammals (Latcher et al., 2019).

Mammals face severe impacts from habitat loss, overexploitation, invasive species (Schipper et al., 2008), and an escalating threat from climate change (Pacifci et al., 2017). Current trajectories reveal a decline in mammalian populations (Ceballos et al., 2017), significant reductions in the range and population size of primates (Estrada et al., 2017), and a global collapse of carnivore (Ripple et al., 2014a) and herbivore (Ripple et al., 2015) populations, heightening the risk of extinction for numerous mammal species. This downturn further jeopardizes their ecological functions and the valuable ecosystem services they contribute.

The significant rise in human impacts on planetary biodiversity over the past century has led some conservationists to propose the advent of a defining epoch, the Anthropocene (Lewis & Maslin, 2015). Biodiversity declines, influenced by various threats such as habitat loss, fragmentation, climate change, and overconsumption, exhibit variations across taxa (Lacher & Roach, 2018). These factors interact to different extents, impacting species at diverse spatial and temporal scales and consequently altering crucial ecosystem functions (Lacher Jr et al., 2019). To effectively implement conservation actions and preserve essential ecosystem processes, a comprehensive understanding of threats at both local and

regional scales is necessary (Rands et al., 2010). There is a consensus that habitat loss due to human-induced land cover change currently stands as the foremost factor contributing to biodiversity declines in Earth's terrestrial ecosystems (Millennium Ecosystem Assessment, 2005; Newbold et al., 2015; Chaudhary & Mooers, 2018).



## CHAPTER 3

### METHODOLOGY

#### 3.1 Materials and Methods

Several tools and application will be utilised during the data collection of this study. Occurrence of wildlife especially ground-dwelling mammals were recorded using two types of camera trap which is Bushnell Trophy Cam HD & Suntek Trail camera HC800A. A total of 15



units of camera traps equipped with a 16 MP lens were used.

Figure1. Camera trap (Bushnell Trophy Cam HD & Suntek Trail Cam HC800A)

The deployment of each camera was set to a systematic sampling method where the cameras will operate for 24 hours per day for a month.

The camera traps' memory card and batteries were changed every two weeks because each sampling points are surveyed in a single cycle. Camera traps (Bushnell Trophy Cam HD & Suntek Trail camera HC800A) were strategically deployed at 44 locations within both lowland forests and rubber tree plantations.

All camera traps were affixed to the base of trees approximately 0.5 m above the ground, with the camera lenses facing outward. Triggered to capture three images with a one-second interval between them, the passive infrared motion sensor was set to a normal setting to detect any movement passing in front of the camera (Bernard et al., 2014; Mohd-Azlan and Sharma, 2003; Sasidhran et al., 2016). Equipped with night-vision capabilities, this camera trap setup has proven effective in studying the occurrence of elusive mammal species in tropical forests in previous research studies (Kawanishi and Sunquist, 2004; Azlan et al., 2006; Bernard et al., 2014; Sasidhran et al., 2016).



Figure 2. GPS

Each camera trap location will be geo-referenced using a Global Positioning System (GPS) device to attest each camera trap's sampling points.

### 3.2 Study Area

This study was conducted in Rembau, Negeri Sembilan, Malaysia. With a mean altitude of 59 m and covering an approximated 12,435.018 hectares, this forest is designated as a high conservation value area, with a terrain elevation of approximately 539 meters above sea level. Rembau exhibits a typical equatorial climate, characterized by year-round hot and humid conditions with daily temperatures ranging from 24 to 34°C and annual rainfall averaging 1500–2000 mm (MET, 2020). It is a semi-developed sub-urban area with a mosaic landscape of agricultural lands, settlements, and urbanized areas. A sizeable continuous forest reserve borders the north of the study area, while scattered secondary successional patches (<10 ha) exist within the district.

Agriculture represents the primary economic driver, with oil palm (*Elaeis guineensis*), rubber tree (*Hevea brasiliensis*), and various tropical fruit trees (e.g., durian, rambutan, mangosteen, jackfruit, petai) as the main commodities. Within the vicinity of studied area, large-scale, single-crop plantations of oil palm and rubber tree dominate, typically owned and managed by companies (private or government-controlled) and employing industrialized farming practices including agrochemical applications.

The study focused on 20 monoculture plantations, each comprised of a single species, specifically mature rubber trees aged around 6 years, ready for harvest. These rubber tree plantations exhibit uniform stand height and are scattered in patches near the Angsi Forest Reserve. It is noteworthy that these plantations were originally forested areas over 60 years ago. As of 2022, the total documented area of rubber tree plantations in Malaysia is approximately 1.1 million hectares (MRB).

### **3.3 Sampling Plot Design**

Systematic sampling with a random starting point (Morrison et al., 2008) was applied for this study. A random starting point within the sampling interval is chosen and followed by other plots with a fixed minimum distance of 300m or more between the plots. The significance is to inject an element of chance and ensuring that all members of the population have an equal probability of being selected and to minimize the double counts of individuals that are captured by the cameras.

Placement considerations included the availability of access routes, the presence of visible animal trails, and tree markings by wildlife, such as footprints and scars (Bernard et al., 2014; Sasidhran et al., 2016). Due to limited availability of camera traps, only 15 units were used simultaneously in forests and rubber tree plantations. The camera trapping survey was conducted from February 2023 to September 2023.

Data were gathered and aggregated from two habitat types, each comprising 24 plots of forested areas and 20 plots of rubber tree plantations. While Nichols and Karanth (2002) recommended a minimum sampling period of two weeks, each sampling point underwent a four-week camera deployment using Bushnell Trophy Cam HD or Suntek Trail camera HC800A that is equipped with 16 Megapixels lens and GPS tools. Each sampling points are surveyed in a single cycle.

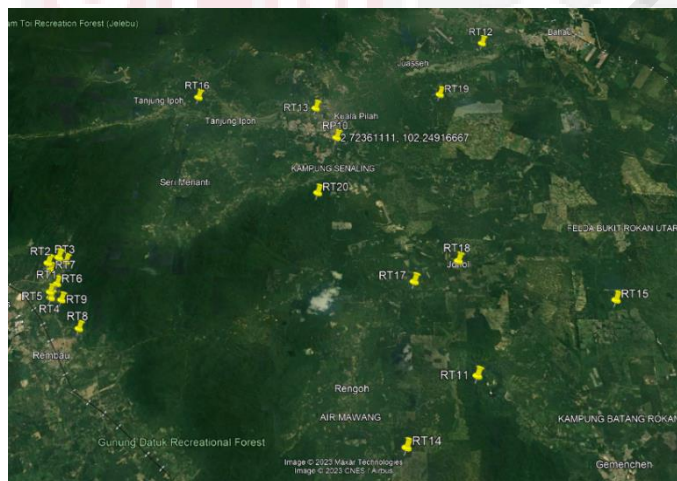


Figure 3. Sampling plots in rubber tree plantations

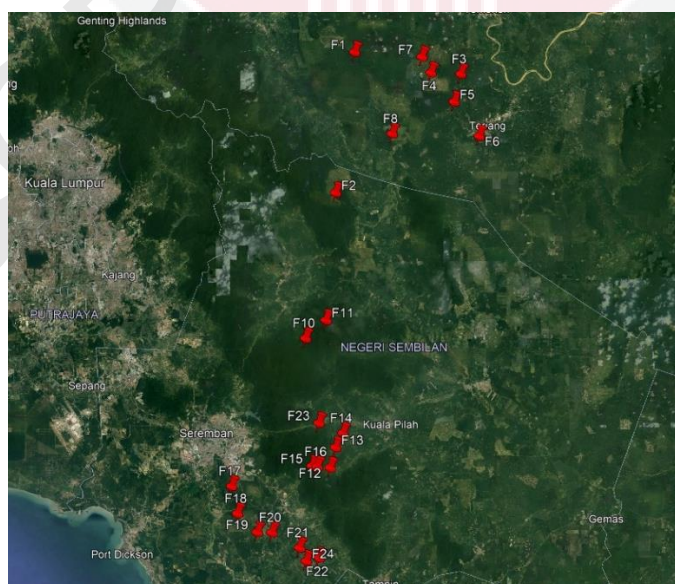


Figure 4. Sampling plots in forests

### 3.4 Statistical Analysis

In this study, paired t-tests was used to compare two key features of habitat quality: the number of trees and the average height of the trees between forest areas and rubber tree plantations. All images captured by our camera traps were examined meticulously, identifying the mammals in them using Francis's mammal guide from 2008. We didn't include any blank or unclear images, which were less than 1% of the total, in our analysis.

To understand how each mammal species contributed to the similarities or differences in our samples, we used SIMPER analysis. This analysis was based on the Bray-Curtis similarity measure, which helped us calculate the average similarity for each species between the lowland/hill dipterocarp forests and the rubber tree plantations. Additionally, we used ANOSIM analysis to identify if there were any differences in the species found in different locations. We conducted both SIMPER and ANOSIM analyses using the software PRIMER version 7.

To compare the variety of mammal species between the lowland/hill dipterocarp forests and rubber tree plantations, we used a two-sample Poisson test. We also compared the total number of animal images found in each habitat type. We then looked at how mammal species richness was related to various features of the environment using Generalized Linear Models (GLMs).

Wald's test helped us find out which factors were important for explaining the differences in mammal species richness. We checked for multi-collinearity among our variables, ensuring no two were too closely related (with a correlation higher than 0.7), as suggested by Dormann et al. in 2013. Our final model was chosen using a method that makes sure we accurately represent the biological processes and avoid including any misleading models, following the guidance of Johnson and Omland in 2004.

We made graphs using the software GenStat version 15 to show how the mammal species richness was related to different environmental factors."

## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Summary statistic

Throughout the research period, a total of 170 mammals belonging to 15 species across 9 families were captured, as outlined in Table 1. The predominant species recorded were Wild boar (*Sus scrofa*, 49 individuals), followed by Long-tailed macaque (*Macaca fascicularis*, 41 individuals), and Southern Pig-tailed macaque (*Macaca nemestrina*, 28 individuals). In the oil palm plantation, the prevalent species included Wild boar (*Sus scrofa*, 37 individuals), Long-tailed macaque (*Macaca fascicularis*, 21 individuals), and Asian palm civet (*Paradoxurus hermaphroditus*, 9 individuals). Conversely, in the forest, Pig-tailed macaque (*Macaca nemestrina*, 26 individuals) dominated the captures, followed by Long-tailed macaque (*Macaca fascicularis*, 20 individuals), and Leopard cat (*Prionailurus bengalensis*, 13 individuals).

Table 1. Conservation status of the recorded species in the study area

No	Common Name	Scientific Name	IUCN Status	Forest	Rubber plantations	Wildlife Act (2010)
1.	Asian Palm Civet	<i>Paradoxurus hermaphroditus</i>	LC	0	21	Protected
2.	Black Panther	<i>Panthera pardus</i>	CE	7	0	Totally Protected
3.	Common Palm Civet	<i>Paradoxurus musangus</i>	LC	0	1	Protected
4.	Large Indian Civet	<i>Viverra zibetha</i>	LC	1	0	Totally Protected
5.	Leopard Cat	<i>Prionailurus bengalensis</i>	LC	13	0	Totally Protected
6.	Long-tailed Macaque	<i>Macaca fascicularis</i>	EN	20	32	Protected
7.	Malayan Civet	<i>Viverra zibetha</i>	LC	2	4	Protected
8.	Malayan Sun bear	<i>Helarctos malayanus</i>	V	6	0	Totally Protected
9.	Lesser Mousedeer	<i>Tragulus kanchil</i>	LC	3	0	Protected
10.	Muntjac	<i>Muntiacus muntjak</i>	LC	1	0	Protected
11.	Sunda Pangolins	<i>Manis javanica</i>	CE	1	0	Totally Protected
12.	Pig-tailed Macaque	<i>Macaca nemestrina</i>	EN	26	16	Protected
13.	Sambar Deer	<i>Rusa unicolor</i>	V	2	0	Protected
14.	Tapir	<i>Tapirus indicus</i>	EN	2	0	Totally Protected
15.	Wild Boar	<i>Sus scrofa</i>	LC	12	61	Protected

## 4.2 Species composition of mammals in rubber plantation and forest

Table 2. Average species composition in rubber plantations.

Species	Average Abundance	Contribution (%)	Cumulative Contribution (%)
Wild boar	25.96	45.73	45.73
Long-tailed macaque	16.12	22.41	68.14
Pig-tailed macaque	16.26	21.05	89.19
Asian palm civet	10.08	10.81	100.00

Species composition in rubber plantations shows that Wild boar contributed up to (45.73 %) of mammal community, followed by Long-tailed macaque (22.41 %), Pig-tailed macaque (21.05 %), and Asian palm civet (10.81 %) forming a cumulative contribution of 100 % (Table 2) by four most dominant species of mammals recorded in rubber plantations.

Table 3. Average species composition in forest

Species	Average Abundance	Contribution	Cumulative contribution
Pig-tailed macaque	12.74	40.87	40.87
Long-tailed macaque	13.19	22.57	63.44
Wild boar	6.46	14.15	77.58
Leopard	5.11	9.85	87.43
Sunbear	3.78	4.82	92.25
Leopard cat	2.97	3.68	95.93
Tapir	2.27	1.37	97.30
Lesser mousedeer	2.10	1.37	98.66
Sambar deer	2.25	1.34	100.00

A cumulative distribution of 100% for species composition in forest is formed with the contribution of nine species of mammals. In forest, Pig-tailed macaque (40.87%) contributes the highest, followed by Long-tailed macaque (22.57%), Wild boar (14.15 %), Leopard (9.85 %), Sun bear (4.82 %), Leopard cat (3.68 %), Tapir (1.37 %), Lesser mousedeer (1.37 %) and Sambar deer (1.34 %).

The most dominant species recorded in the forest was pig-tailed macaque and the least dominant one was sambar deer.

### 4.3 Species Presence – Absence Analysis

#### 4.3.1 Mammals species in Forest

Table 4. Pig-tailed macaque (*Macaca nemestrina*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.3861	0.1461	0.1581-0.6780
Density	0.538	0.3129	0.1721-1.6822
Total Abundance	12.91	7.51	4.33- 40.37

Table 5. Leopard (*Panthera pardus*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.357	0.2882	0.0442-0.8662
Density	0.4968	0.6212	0.0428-5.7613
Total Abundance	11.92	14.91	1.03-138.27

Table 6. Wild boar (*Sus scrofa*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.27	0.1236	0.0976-0.5585
Density	0.3363	0.2014	0.1040-1.0875
Total Abundance	8.07	4.83	2.50-26.10

Table 7. Long-tailed macaque (*Macaca fascicularis*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.1747	0.0804	0.0663-0.3870
Density	0.1909	0.098	0.0697-0.5223
Total Abundance	4.58	2.35	1.67-12.53

Table 8. Malayan Sun bear (*Helarctos malayanus*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.1553	0.0924	0.0442-0.4224
Density	0.1687	0.1126	0.0456-0.6244
Total Abundance	4.05	2.7	1.09-14.99

Table 9. Leopard cat (*Prionailurus bengalensis*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.137	0.0757	0.0433-0.3577
Density	0.1591	0.0969	0.0483-0.5248
Total Abundance	3.82	2.33	1.16-12.60

In Angsi Forest Reserve, only six mammal species had a high sighting frequency: pig-tailed macaque, leopard, wild boar, long-tailed macaque, Malayan sun bear, and leopard cat. Using the PRESENCE software, we analysed data for these species. The most common one was the pig-tailed macaque, making up 38.61% of the forest with around 40 individuals. Leopards were next, covering 35.70% of the area with about 138 individuals. Wild boars ranked third, occupying around 27% of the forest with an estimated 26 individuals. The others like long-tailed macaque, Malayan sun bear, and leopard cat were present but less common, constituting 17.47%, 15.53%, and 13.70%, respectively. This means these three species are among the least common mammals in Angsi Forest Reserve.

### 4.3.2 Mammals species in Rubber plantations

Table 10. Wild Boar (*Sus Scrofa*)

	Estimate	Standard Error	95% Confident interval
Site Occupancy	0.4819	0.1218	0.2633 – 0.7076
Density	0.7572	0.2900	0.3574 – 1.6041
Total Abundance	15.14	5.80	7.15 – 32.08

Table 11. Long-tailed macaque (*Macaca fascicularis*)

	Estimate	Standard error	95% Confident interval
Site Occupancy	0.3602	0.1102	0.1806 - 0.5898
Density	0.4601	0.1820	0.2118 – 0.9992
Total Abundance	9.20	3.64	4.24 – 19.98

Table 12. Pig-tailed macaque (*Macaca nemestrina*)

	Estimate	Standard error	95% Confident interval
Site Occupancy	0.4762	0.1436	0.2273 – 0.7375
Density	0.7491	0.3709	0.2839 – 1.9770
Total Abundance	14.98	7.42	5.68 – 39.54

Table 13. Asian palm civet (*Paradoxurus hermaphroditus*)

	Estimate	Standard error	95% Confident interval
Site Occupancy	0.4223	0.1825	0.1444 – 0.7601
Density	0.6357	0.4578	0.1550 – 2.6078
Total Abundance	12.71	9.16	3.10 – 52.16

Table 14. Malayan civet (*Viverra zibellina*)

	Estimate	Standard error	95% Confident interval
±Site Occupancy	0.0548	0.0546	0.0073 – 0.3136
Density	0.0559	0.0574	0.0075 – 0.4184
Total Abundance	1.12	1.15	0.15 – 8.37

In rubber tree plantations, only five mammal species had a high sighting frequency: wild boar, long-tailed macaque, pig-tailed macaque, asian palm civet and malayan civet. PRESENCE software was used to run the analysis for these species. Species with the most sighting was wild boar, making up 48.19% of the rubber plantations with an estimated of (7–32) individuals. Followed by pig-tailed macaque, dominating almost 47.62% of the area with estimated individuals up to (5–39). Next is Long-tailed macaque, contributing 36.02% of the area with (4–19) individuals estimated. Asian palm civet makes up around 42.23% of the area with estimated individuals (3–52). The least common mammal in rubber tree plantations is malayan civet, as it only contributes up to 5.48% of the areas with estimated individuals being (1-8)

These results are one of the indicators that shows the significance of land use management because ecological theories suggest that implementing a land-sparing strategy may benefit biodiversity. This is because larger habitat patches can support larger populations, reducing the chances of local extinctions, as stated in Hanski's work in 2000.

#### **4.4 Summary statistics of three predictor variables in two different habitats**

The boxplots indicate that forests have higher diversity in tree number and height, crucial for wildlife niches and biodiversity. Larger trees contribute to biomass and carbon sequestration, vital for climate change mitigation. Forest variability suggests a healthy ecological succession, crucial for sustainability.

In contrast, uniformity in rubber plantations may impact species requiring varied habitats. Lower tree heights and reduced variability may not support needed complexity. Conservation could integrate biodiversity-friendly practices, like interspersing native trees for structural diversity. Agricultural practices in rubber plantations optimize production efficiency but may require additional inputs with environmental impacts.

The interplay between tree abundance, height, and image frequency informs how agricultural landscapes can support conservation. Policies promoting land-sharing could incentivize maintaining native forest in rubber plantations, fostering wildlife coexistence.

#### 4.4.1 Comparing number of images recorded in two habitats (forests and rubber plantations)

Table 15. Number of images by habitat

Habitat	Station	Mean	Median	Min value	Max value	Std.error of mean
Rubber plantations	20	7.3	3	0	36	2.330
Forests	24	4	1.5	0	31	1.367

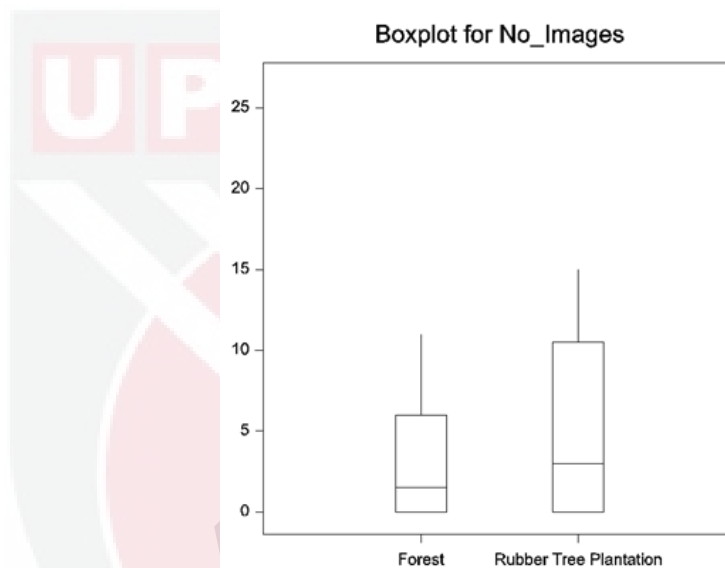


Figure 5. Number of mammals images recorded in two different habitats (forest and rubber plantations)

It is evident that forests exhibit a mean of 4 images with a standard error of mean of 1.367, indicating relative consistency, with few outliers that is highlighted by a maximum of 31 and a median of 1.5. Conversely, rubber plantations showcase a higher mean of 7.3 images, accompanied by a larger standard error of mean which is 2.330, suggesting increased variability, as denoted by a higher maximum (36) and a median of 3.

#### 4.4.2 Comparing number of trees measured in two habitats (forests and rubber plantations)

Table 16. Number of trees by habitat

Habitat	Station	Mean	Median	Min value	Max value	Std.error of mean
Rubber plantations	20	112.2	112.5	37	236	12.48
Forests	24	146.1	140	30	288	14.35

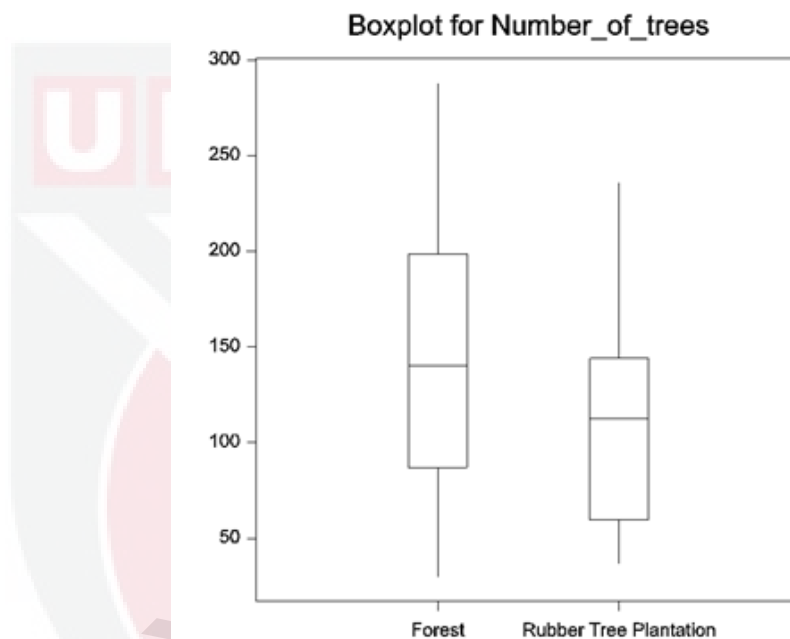


Figure 6. Number of trees measured in two different habitats (forests and rubber plantations)

Moving to the number of trees, forests exhibit a significantly higher mean (146.1) compared to rubber plantations (112.2). Although the standard error of mean are comparable (14.35 for forests and 12.48 for rubber plantations), implying consistency within each habitat, forests display a higher maximum number of trees (288) compared to rubber plantations (236).

#### 4.4.3 Comparing mean of tree height measured in two habitats (forests and rubber plantations)

Table 17. Mean of tree height by habitat

Habitat	Station	Mean	Median	Min value	Max value	Std.error of mean
Rubber plantations	20	10.13	10.15	5.83	13	0.432
Forests	24	15.19	14.65	7.4	29	1.122

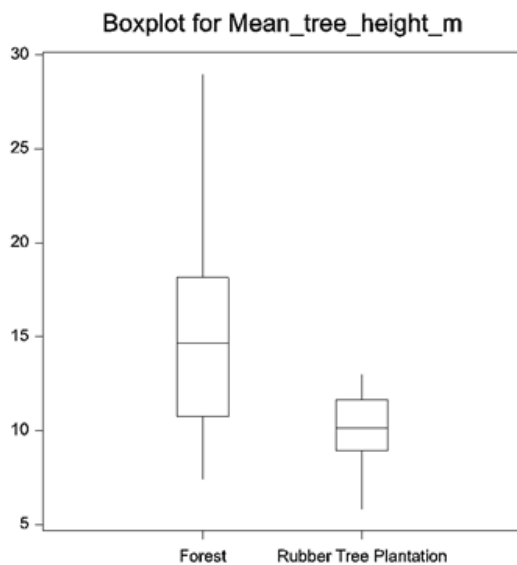


Figure 7. Mean of tree height in two different habitats (forests and rubber plantations)

Examining the mean of tree height, forests again outshine rubber plantations, boasting a mean height of 15.19 m, while rubber plantations lag at 10.13 m.

The standard error of mean for forests (1.122) indicates less variation in tree height, while rubber plantations (0.432) reflect more consistent heights. The maximum tree height in forests (29 m) significantly surpasses that in rubber plantations (13 m).

#### 4.5 Spearman's Rank Correlation Coefficient between two predictor variables (number of trees and mean tree height)

Table 18. Shows spearman's rank for two predictor variables.

Fixed term	N	t approximation	D.F	Fpr
Number of trees and Mean tree height	44	2.13	42	0.039

Correlation 0.313 adjusted for ties 0.313

Sample size 44

t approximation 2.13 on 42 d.f. probability 0.039

The Spearman Rank Correlation was employed to assess the strength and direction of the association between two ranked variables: number of trees and mean tree height. The obtained correlation coefficient from Table 18 is 0.313, close to +1, indicating a strong positive correlation between the two ranks.

#### 4.6 Wald test on three variables

Table 19. Wald Test for numerical data (number of trees, mean tree height) and categorical data (habitat)

Term	Wald statistic	d.f	Chi.pr
Number of trees	50.40	1	<0.001
Mean tree height	28.05	1	<0.001
Habitat	22.62	1	0.886

The Wald tests yielded highly significant results for the predictors in the model. The number of trees, mean tree height, and habitat type all displayed strong significance, suggesting their crucial role in explaining variability in the data. The best subsets analysis further supported their significance, with an R2 value of 23.42%. While modest, the adjusted R2 value of 17.67, considering predictors and sample size, accurately gauges the model's explanatory power.

These findings confirm the model's robustness and underscore the importance of the predictors. Conservation efforts and ecological assessments considering these factors are likely to be more informed and effective. In conclusion, the statistical evidence strongly advocates for including 'Number of Trees,' 'Mean Tree Height,' and 'Habitat' in the regression model for a comprehensive understanding of ecological systems.

## 4.7 Generalised Linear Model Analysis

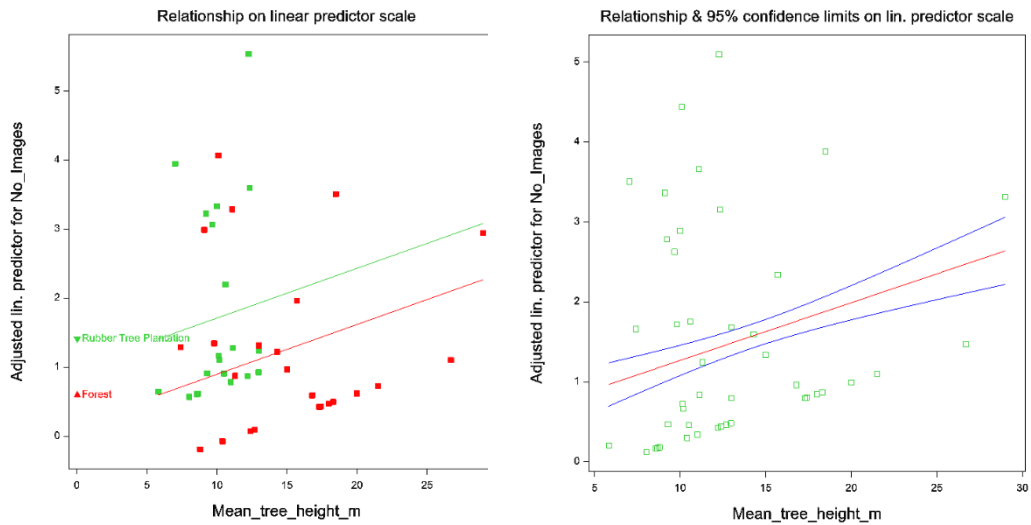


Figure 8. Relationship between mean tree height and categorical data (forest and rubber tree plantation)

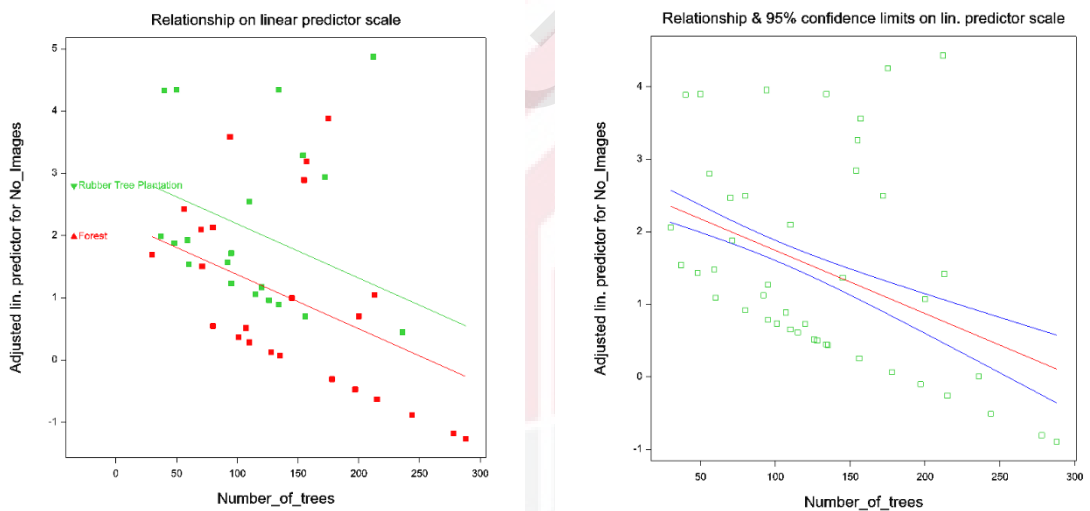


Figure 9. Relationship between number of trees and categorical data (forest and rubber tree plantation)

The data suggests that forests have a higher median number of trees than rubber tree plantations. This difference is indicative of the inherent variances between natural ecosystems and cultivated landscapes. Forests, typically rich in species diversity and structural complexity, offer a range of ecological niches

supporting diverse flora and fauna. Conversely, the cultivated nature of rubber plantations results in lower tree density, aimed at optimizing production. This disparity in tree numbers is significant as it underscores the potential trade-offs between biodiversity conservation and agricultural productivity.

Similarly, the mean tree height is substantially greater in forests compared to rubber tree plantations. This difference can be ascribed to the unmanaged growth patterns prevalent in natural forests, allowing trees to reach their full growth potential. In contrast, rubber plantations are regularly pruned and managed to facilitate latex extraction, resulting in lower mean heights. The height of trees is a critical factor in determining the stratification of habitats, which in turn affects biodiversity, especially of avian and arboreal species.

These findings contribute to a nuanced understanding of how human activities reshape habitat structures. For conservationists, the results emphasize the need to preserve natural forests, which support complex ecosystems. For agriculturists, the insights may lead to exploring sustainable plantation management practices that can mimic natural structures, such as integrating various tree species to enhance vertical stratification, which could improve ecological value without substantially compromising productivity.

The implications of these results for policy are profound. Conservation policies could be tailored to incentivize the preservation of forested lands, recognizing their ecological value in supporting biodiversity. Agricultural policies might focus on sustainable plantation management, promoting practices that increase the ecological complexity of these habitats while maintaining their economic viability.

To summarise, the graphical analysis provides clear evidence of the structural differences between natural forests and rubber plantations. These findings serve as a cornerstone for discussions on how to balance conservation with agricultural development, advocating for a landscape approach which is land sharing and land sparing that has the potential to harmonize ecological integrity alongside human livelihoods.

## CHAPTER 5

### CONCLUSION & RECOMMENDATION

#### 5.1 Conclusion

This study emphasizes the significance of preserving natural habitats such as lowland/hill dipterocarp forest to sustain biodiversity in agricultural areas like rubber plantations. Proven by the species richness in lowland dipterocarp forests being greater than in rubber tree plantations.

In the context of abundance, the wild boar was the most prevalent species in rubber tree plantations, whereas the pig-tailed macaque was the dominant species in forests. The site occupancy for forest having higher number (nine) of species than the rubber tree plantations (four).

Future land-use strategies should focus on incorporating these habitats into croplands, considering the distinct requirements of forested areas versus non-forested areas to tailor appropriate local solutions. Last but not least, forest conservation and forest biodiversity conservation is crucial in shaping landscape management.

## 5.2 RECOMMENDATION

Extend the duration of camera trap deployment to capture seasonal variations in wildlife activity. Some species may exhibit specific behaviors during specific times of the year, and a longer monitoring period can provide a more comprehensive understanding of the fauna in the study area.

Evaluate the existing sampling design, including the placement of camera traps, their density, and the duration of deployment. Ensure that the design aligns with the environmental characteristics of the study area. Consider adjusting sampling locations based on habitat types, animal movement patterns, and potential corridors.

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