



Faculty of Resource Science and Technology

**Forage Resources and Nutrient Content in Grazing Areas of Oil Palm
Plantation**

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Forage Resources and Nutrient Content in Grazing Areas of Oil Palm Plantation

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Elaeis guineensis Jacq. is one of the most important commodity crops due to its high oil content and increasing global demand for oil in the food, fuel, and cosmetic industries. The extensiveness of oil palm plantation in Malaysia and its luxuriant cover crops have been viewed as a potential avenue for promoting livestock-tree crop integration. The huge land areas of plantations have integrated livestock and crop production. The specific objectives of this study were to (i) determine the floristic diversity and carbon stock of weed species in an integrated oil palm plantation area, (ii) examine the forage recovery of selected forage species following livestock grazing, (iii) examine the forage preferred by livestock between cut and uncut forages, and (iv) determine the selected elements and toxic elements contained in the selected forage and weeds species. The study was conducted at an integrated oil palm plantation in Serian, Sarawak. Initial sampling showed that 10961 total individuals were recorded, belonging to 53 species of weeds. The second sampling carried out six months after the initial sampling recorded 9959 individuals consisting of 62 species and higher diversity than the initial sampling. The estimated carbon stock was 0.43 tonne ha⁻¹ for the initial sampling and 0.41 tonne ha⁻¹ for the second sampling. Recovery of *Axonopus compressus* showed the significant difference of mean height between grazed, cut, and ungrazed, in which the ungrazed was higher than grazed and cut. For cut *A. compressus* the recovery height was better in shaded than opened areas. The height recovery for grazed, cut, and ungrazed *Elaeis guineensis* seedlings differed significantly. The recovery of *E. guineensis* was higher in ungrazed than grazed. The difference was significant for grazed and cut and between cut and ungrazed. The cut *E. guineensis* showed a higher height recovery in opened than the shaded area. There was a significant difference in the recovery of new shoots for grazed and cut *Antrophyum reticulatum*. The mean percentage of forage

preferred by livestock showed that the uncut was higher than cut *A. compressus*. Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Sulphur (S), and Sodium (Na) were detected in *A. compressus*, *E. guineensis*, *A. reticulatum*, *Asystasia gangetica*, and *Scleromitrion verticillatum* in different concentrations. No heavy metals were detected in the consumed plants. Toxicity analyses of unconsumed plants; *Melastoma malabathricum*, *Miconia crenata*, *Diplazium esculentum*, *Taenitis blechnoides*, and *Torenia crustacea* did not contain hazardous elements such as Lead (Pb), Cadmium (Cd), Mercury (Hg), and Arsenic (Ar) except for Aluminium (Al). This study revealed that no cutting of forages is required provided that the rotation system incorporate forage recovery in the rotation schedule. Livestock did not adversely affect forage growth and development because grazed weeds are tolerant of grazing stress.

Keywords: Integrated oil palm plantation, weeds diversity, forage recovery, forage preferences, elements in forage

Sumber Makanan Ternakan dan Kandungan Nutrien di dalam Kawasan Ragut Ladang Kelapa Sawit

ABSTRAK

Elaeis guineensis Jacq. merupakan salah satu daripada komoditi tanaman terpenting disebabkan oleh kandungan minyak yang tinggi dan juga peningkatan permintaan global untuk penggunaan minyak sawit dalam industri makanan, bahan api dan kosmetik. Keluasan ladang kelapa sawit di Malaysia dan kekayaan tanaman penutup dilihat sebagai berpotensi untuk mempromosi integrasi di antara ternakan-tanaman pokok. Ladang yang mempunyai kawasan tanah yang luas sudah pun mengamalkan integrasi ternakan dengan penghasilan tanaman. Objektif-objektif spesifik kajian ini ialah untuk (i) menentukan diversiti floristik dan stok karbon spesies rumpai dalam kawasan ladang kelapa sawit bersepadu (ii) meneliti pemulihan foraj bagi spesies foraj yang terpilih setelah diragut oleh ternakan (iii) meneliti foraj yang disukai oleh ternakan sama ada foraj yang telah dipotong dan tidak dipotong, dan (iv) menentukan kandungan unsur dan unsur toksik yang terpilih dalam spesies tanaman ragut dan rumpai yang terpilih. Kajian telah dilakukan di ladang kelapa sawit bersepadu di Serian, Sarawak. Pensampelan awal menunjukkan sejumlah 10961 individu telah direkodkan terdiri dari 53 spesies. Pensampelan kedua dijalankan selepas enam bulan dari pensampelan awal merekodkan sejumlah 9959 individu terdiri daripada 62 spesies dan diversiti adalah lebih tinggi daripada pensampelan awal. Stok karbon dianggarkan 0.43 metrik tan ha⁻¹ untuk pensampelan awal dan 0.41 metrik tan ha⁻¹ untuk pensampelan kedua. Pemulihan *Axonopus compressus* menunjukkan perbezaan ketara bagi min tinggi diantara yang diragut, dipotong, dan tidak diragut di mana yang tidak diragut adalah lebih tinggi daripada yang diragut dan dipotong. Untuk *A. compressus* yang dipotong pemulihan ketinggian adalah lebih cepat di kawasan redup daripada terbuka. Pemulihan ketinggian

bagi anak pokok E. guineensis yang diragut, dipotong dan tidak diragut adalah berbeza dengan ketara. Pemulihan E. guineensis yang tidak diragut adalah lebih cepat dibandingkan dengan yang diragut dan perbezaan adalah ketara bagi yang diragut dan dipotong dan juga diantara yang dipotong dan tidak diragut. E. guineensis yang dipotong menunjukkan pemulihan ketinggian yang cepat dalam kawasan terbuka dibandingkan dengan kawasan redup. Terdapat perbezaan yang ketara di dalam pemulihan pucuk baru bagi Antrophyum reticulatum yang telah diragut dan dipotong. Min peratusan foraj yang disukai oleh ternakan menunjukkan A. compressus yang tidak dipotong adalah menjadi pilihan dari yang dipotong. Komposisi unsur Nitrogen (N), Fosforus (P), Kalium (K), Magnesium (Mg), Sulfur (S), dan Natrium (Na) bagi spesies yang dimakan oleh ternakan termasuk A. compressus, E. guineensis, A. reticulatum, Asystasia gangetica, dan Scleromitron verticillatum telah dikesan di dalam semua spesies tetapi dalam kandungan yang berbeza dan tiada logam berat telah dikesan. Analisis toksik yang dilakukan ke atas spesies terpilih yang tidak dimakan oleh ternakan termasuk Melastoma malabathricum, Miconia crenata, Diplazium esculentum, Taenitis blechnoides, dan Torenia crustacea menunjukkan bahawa Plumbum (Pb), Kadmium (Cd), Raksa (Hg), dan Arsenik (Ar) tidak dikesan di dalam semua spesies kecuali bagi Aluminium (Al). Kajian ini mendedahkan bahawa pemotongan foraj adalah tidak perlu dilakukan dengan syarat sistem giliran mengambilkira pemulihan foraj dalam merangka jadual giliran. Ternakan tidak memberi kesan buruk ke atas pertumbuhan dan perkembangan foraj kerana rumpai yang diragut adalah toleran terhadap tekanan akibat dari ragutan.

Kata kunci: Ladang kelapa sawit bersepadu, diversiti rumpai, pemulihan foraj, foraj pilihan, unsur dalam foraj

TABLE OF CONTENTS

	Page
DECLARATION	i
ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
ABSTRAK	v
TABLE OF CONTENTS	vii
LIST OF TABLES	xiii
LIST OF FIGURES	xv
LIST OF ABBREVIATIONS	xix
CHAPTER 1: INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	4
1.3 Objectives	5
1.4 Summary of Introduction	6
CHAPTER 2: LITERATURE REVIEW	7
2.1 Integrated Oil Palm Plantation	7
2.2 Some Studies on Integrated Oil Palm Plantation	8
2.3 Sustainability of Integrated Plantation Practices	9
2.4 Efficiency of Management in Integrated Plantation System	12
2.5 Rotational Grazing System of Livestock in Integrated Oil Palm Plantation	13
2.6 Forage Supply in Oil Palm Plantation	14

2.7	Evaluation of Forage	15
2.8	Diversity of Weeds Species in Oil Palm Plantation	16
2.9	Carbon Stock	18
2.10	Summary of Literature Review	18
CHAPTER 3: MATERIALS AND METHODS		20
3.1	Study Area	20
3.2	Sample Collection	21
3.2.1	Weeds Species Composition and Diversity	22
3.2.1.1	Summed Dominance Ratio (SDR)	23
3.2.1.2	Shannon - Wiener Diversity Index (H')	23
3.2.1.3	Species Diversity (Simpson's Index of Diversity, 1-D)	24
3.2.1.4	Species Richness (Margalef's Richness Index, R)	25
3.2.1.5	Pielou's Evenness Index (J')	25
3.2.1.6	Sorensen's Index (SI)	26
3.2.2	Classification of Plant	26
3.3	Estimation of Biomass and Carbon Stock	26
3.4	Determination of Forage Recovery	27
3.5	Forage Preferred by Livestock between Cut and Uncut	30
3.6	Elemental Analysis	31
3.7	Statistical Analysis	34
3.8	Summary of Material and Methods	35
CHAPTER 4: RESULTS		38
4.1	Species Composition of Weeds in the Integrated Oil Palm Plantation Area	38

4.1.1	Family Composition of Weeds during the Initial Sampling at the Integrated Oil Palm Plantation Area	38
4.1.2	Family Composition of Weeds in the Second Sampling at the Integrated Oil Palm Plantation Area	39
4.2	Species Diversity of Weeds	40
4.2.1	Species Dominance	40
4.2.1.1	Dominant Species in the Initial Sampling of the Integrated Oil Palm Plantation	40
4.2.1.2	Dominant Species in the Second Sampling of the Integrated Oil Palm Plantation	41
4.2.2	Species Diversity of Weeds in Two Different Periods of Sampling in the Integrated Oil Palm Plantation Area	44
4.2.3	Growth Development of Weeds Species in Integrated Oil Palm Plantation	48
4.3	Biomass and Carbon Stock of Weeds Species in Integrated Oil Palm Plantation	52
4.3.1	Biomass and Carbon Stock of Weeds Species in Initial Sampling at Integrated Oil Palm Plantation Area	52
4.3.2	Biomass and Carbon Stock of Weeds Species in Second Sampling at the Integrated Oil Palm Plantation Area	54
4.3.3	Estimated Biomass and Carbon Stock of Two Different Periods of Sampling	56
4.4	Forage Recovery of Selected Species	57
4.4.1	Forage Recovery of <i>Axonopus compressus</i>	57

4.4.1.1	Height of Grazed <i>Axonopus compressus</i> in Opened Area of Integrated Oil Palm Plantation	57
4.4.1.2	Height of Ungrazed <i>Axonopus compressus</i> in Opened Area of Integrated Oil Palm Plantation	58
4.4.1.3	Height of Cut <i>Axonopus compressus</i> in Opened Area of Integrated Oil Palm Plantation	59
4.4.1.4	Height of Cut <i>Axonopus compressus</i> in Shaded Area of Integrated Oil Palm Plantation	60
4.4.2	Forage Recovery for <i>Elaeis guineensis</i>	61
4.4.2.1	Height of Grazed <i>Elaeis guineensis</i> in Opened Area of Integrated Oil Palm Plantation	61
4.4.2.2	Height of Ungrazed <i>Elaeis guineensis</i> in Opened Area of Integrated Oil Palm Plantation	62
4.4.2.3	Height of Cut <i>Elaeis guineensis</i> in Opened Area of Integrated Oil Palm Plantation	63
4.4.2.4	Height of Cut <i>Elaeis guineensis</i> in Shaded Area of Integrated Oil Palm Plantation	64
4.4.3	Species Recovery for <i>Antrophyum reticulatum</i>	65
4.4.3.1	Total Number of <i>Antrophyum reticulatum</i> New Shoot After being Grazed for 27 days	65
4.4.3.2	Total Number of <i>Antrophyum reticulatum</i> New Shoot after 27 days Cutting Treatment	66
4.4.4	Comparison of Species Recovery for <i>Axonopus compressus</i> , <i>Elaeis guineensis</i> , and <i>Antrophyum reticulatum</i> in Different Factors	67

4.4.4.1	Comparison of Species Recovery for <i>Axonopus compressus</i>	67
4.4.4.1.1	Comparison of Recovery in the Opened Area between Grazed, Cut, and Ungrazed <i>Axonopus compressus</i>	67
4.4.4.1.2	Comparison of <i>Axonopus compressus</i> Recovery of Cut Treatment between Opened and Shaded Areas	68
4.4.4.2	Comparison Recovery for <i>Elaeis guineensis</i>	69
4.4.4.2.1	Comparison of Recovery for Grazed, Cut, and Ungrazed <i>Elaeis guineensis</i> in Opened Area	69
4.4.4.2.2	Comparison of <i>Elaeis guineensis</i> Recovery for Cut Treatment in Opened and Shaded Areas	70
4.4.4.3	Comparison Recovery for Grazed and Cut <i>Antrophyum reticulatum</i>	71
4.5	Forages Preferred by Livestock between Cut and Uncut <i>Axonopus compressus</i> in the Rotation Grazing System	72
4.5.1	Forage Preference for Cut Treatment	72
4.5.2	Forage Preference for Uncut	73
4.5.3	Comparison of Forage Preference for Cut and Uncut	74
4.6	Elemental Analysis for the Selected Forages Species and Toxicity Analysis for Selected Weeds Species Presented in the Area of Integrated Oil Palm Plantation	75
4.6.1	Elemental Analysis for Selected Forages Species	75
4.6.2	Toxicity Analysis for Selected Weeds Species	78
4.7	Summary of Results	79
CHAPTER 5:	DISCUSSION	82
5.1	Integration of Livestock in Oil Palm Plantation	82

5.1.1	Weeds Species in Oil Palm Plantation	83
5.2	Species Diversity	85
5.2.1	Species Richness	88
5.2.2	Species Evenness and Species Similarity	89
5.3	Weeds Species Growth Form	90
5.4	Biomass and Carbon Stock of Undergrowth in Integrated Oil Palm Plantation	91
5.5	Forage Species Recovery	92
5.6	Forage Preferred by Livestock	99
5.7	Elemental Analysis for Selected Consumed Species and Toxicity Analysis for Selected Unconsumed Species Presented in the Area of Integrated Oil Palm Plantation	101
5.7.1	Elemental Content of Selected Consumed Species	102
5.7.2	Toxic Elements in Selected Unconsumed Species	110
5.8	Summary of Discussion	114
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS		116
6.1	Conclusions	116
6.2	Recommendations	118
REFERENCES		119
APPENDICES		151

LIST OF TABLES

	Page
Table 4.1 Top five dominant weeds family of 100 quadrats (1 m ² each) during the initial sampling at integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) values.	38
Table 4.2 Top five dominant weeds family of 100 quadrats (1 m ² each) during the second sampling at integrated oil palm plantation represented by Summed Dominance Ratio (SDR) value.	39
Table 4.3 Top five dominant species in the initial sampling at the integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.	40
Table 4.4 Top five dominant species in second sampling at integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.	42
Table 4.5 Species diversity indices of initial and second samplings in the integrated oil palm plantation.	45
Table 4.6 Five highest biomass and carbon stock of weeds species in the initial sampling at integrated oil palm plantation area.	53
Table 4.7 Five highest biomass and carbon stock of weeds species in the second sampling at integrated oil palm plantation area.	55
Table 4.8 Total of biomass and estimated carbon in kg and total of estimated carbon stock and the estimated carbon stock per hectare of two different periods of samplings in an integrated oil palm plantation.	57

Table 4.9	Elemental composition of selected forages.	76
Table 4.10	Toxic element composition of the selected weeds species.	78

LIST OF FIGURES

	Page
Figure 3.1 Satellite map of Samarahan Plantations Sdn. Bhd. area. Source: Google Map.	20
Figure 3.2 Cattle grazing in the area of oil palm plantation.	21
Figure 3.3 The layout of forage recovery study in integrated oil palm plantation.	28
Figure 3.4 Establishment of two 5 m x 5 m for cut and uncut squares located at each other.	30
Figure 3.5 Cattle grazing in the fencing area of one of the selected forage species, <i>Axonopus compressus</i> .	32
Figure 3.6 <i>Melastoma malabathricum</i> (unconsumed species).	33
Figure 3.7 <i>Diplazium esculentum</i> (unconsumed species).	33
Figure 4.1 <i>Axonopus compressus</i> was one of the species that dominated the area in both initial and second sampling.	43
Figure 4.2 The dominant species in the area of both initial and second sampling, <i>Scleromitrium verticillatum</i> .	43
Figure 4.3 <i>Torenia crustacea</i> are one of the most dominant species in the area of the initial and second sampling.	44
Figure 4.4 The weeds composition recorded during the initial and second sampling in the integrated oil palm plantation area.	49

Figure 4.5	Mean height (cm) of grazed <i>Axonopus compressus</i> in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	58
Figure 4.6	Mean height (cm) of ungrazed <i>Axonopus compressus</i> in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	59
Figure 4.7	Mean height (cm) of <i>Axonopus compressus</i> following cut treatment in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	60
Figure 4.8	Mean height (cm) of <i>Axonopus compressus</i> following cut treatment in the shaded area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	61
Figure 4.9	Mean height (cm) of grazed <i>Elaeis guineensis</i> in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	62
Figure 4.10	Mean height (cm) of ungrazed <i>Elaeis guineensis</i> in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	63
Figure 4.11	Mean height (cm) of cut <i>Elaeis guineensis</i> in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	64

Figure 4.12	Mean height (cm) of cut <i>Elaeis guineensis</i> in the shaded area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	65
Figure 4.13	Total number of new shoots of <i>Antrophyum reticulatum</i> on oil palm trunk after being grazed for 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	66
Figure 4.14	Total number of new shoots of <i>Antrophyum reticulatum</i> after 27 days cutting treatment. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.	67
Figure 4.15	Mean height of recovery in the opened area for grazed, cut, and ungrazed <i>Axonopus compressus</i> .	68
Figure 4.16	Comparison of the mean height of cut <i>Axonopus compressus</i> between opened and shaded area.	69
Figure 4.17	Comparison of the mean height of grazed, cut, and ungrazed <i>Elaeis guineensis</i> in the opened area.	70
Figure 4.18	Comparison of the mean height of <i>Elaeis guineensis</i> for cut treatment in the opened and shaded areas.	71
Figure 4.19	Comparison of new shoots between grazed and cut <i>Antrophyum reticulatum</i> .	71
Figure 4.20	Mean percentage (%) of forage grazed by livestock with cut treatment.	73

Figure 4.21	Mean percentage (%) of forage grazed by livestock without treatment in the total day of forage left.	74
Figure 4.22	Comparison of the mean percentage of forage preferred by livestock for cut and uncut samples of <i>Axonopus compressus</i> .	75
Figure 4.23	The percentage of the selected elements (Nitrogen as N, Phosphorus as P, Potassium as K, Magnesium as Mg, Sulphate as S, and Sodium as Na) was detected in five preferred forage species; <i>Axonopus compressus</i> , <i>Elaeis guineensis</i> , <i>Antrophyum reticulatum</i> , <i>Asystasia gangetica</i> , and <i>Scleromitrium verticillatum</i> .	77
Figure 4.24	Aluminium content in <i>Melastoma malabathricum</i> , <i>Miconia crenata</i> , <i>Diplazium esculentum</i> , <i>Taenitis blechnoides</i> , and <i>Torenia crustacea</i> .	79

LIST OF ABBREVIATIONS

1-D	Simpson's Index of Diversity
3P	People, Planet, Profit
AAS	Atomic Absorption Spectrometry
Asymp. Sig.	Asymptotic significance
cm	centimetre
CO ₂	Carbon dioxide
CPO	Crude palm oil
D	Density
DM	Dry matter
DVS	The Department of Veterinary Services
ESPEK	Sistem Maklumat Pekebun Kecil
EU	European Union
F	Frequency
FELDA	Federal Land Administration Authority
g	gram
GHGs	Greenhouse Gases
GNI	Gross national income
ha	Hectare
ha ⁻¹	per hectare
H'	Shannon-Wiener Diversity Index
IAEA	International Atomic Energy Agency
IPM	Integrated pest management

IPNI	International Plant Names Index
IV	Inportant Value
J'	Pielou's Evenness Index
kg	kilogram
m	metre
Mmtons	Million metric tons
MPOB	Malaysia Palm Oil Board
MSPO	Malaysian Palm Oil Sustainable
MYR	Malaysian Ringgit
NRC	National Research Council
PAR	Photosynthetically Active Radiation
PgC	Petagram of Carbon
PINTAR	The Malay acronym for Ruminant Tree Crop Integration Project
R	Coefficient correlation
R'	Margalef's Richness Index
RD	Relative Density
RF	Relative Frequency
RISDA	Rubber Industry Smallholders Development Authority
RSPO	Roundtable on Sustainable Palm Oil
SDR	Summed Dominance Ratio
SI	Sorensen's Similarity Index
Sig.	Significance
TAC	Targeted Area Concentration
TDN	Total Digestible Nutrient

t	tonne
ton	tonne
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Research Background

The oil palm plantation area in Malaysia had shown dramatic growth from about 55 000 ha in 1960 to 193 000 ha in 1970, and the development was remarkably rapid, with the area of planted oil palm reaching 1.02 million ha in 1980. It then continually expanded to 2.03 million ha in 1990, then added to 5.74 million ha in 2016 (MPOB, 2017; Nambiappan et al., 2018) and recently reached 5.87 million ha in 2020 (MPOB, 2021). In recent years, mostly Sabah and Sarawak contributed to expanding oil palm planted areas because of the decreasing availability of suitable land in Peninsular Malaysia. As of 2016, about 47% of the planted area was in Peninsular Malaysia, 27% in Sabah and 26% in Sarawak (Nambiappan et al., 2018). Meanwhile, both Malaysia and Indonesia produced approximately 85% of the total palm oil production. The demand is rapidly spreading globally because China and India are the main import countries next to the EU (USDA, 2012; Ferdous et al., 2015).

Oil palm plays a vital role in providing food to more than 3 billion people in more than 200 countries, and it will be a great challenge to supply an additional 2 billion people by 2050 with limited arable land. As compared to the other oil crops, oil palm requires less land to produce the same amount of oils. For example, oil palm only needs 0.26 hectares (ha) to produce 1 tonne (t) of oil compared to 2.2, 2.0 and 1.5 ha for soybean, sunflower, and rapeseed, respectively (Wahid et al., 2011; Nambiappan et al., 2018). The palm oil industry has brought significant economic benefits to Malaysia, and the current production of 19 million metric tons (Mmtons) of crude palm oil (CPO) adds 8% to the country's gross

national income (GNI). The production is expected to increase with the achievement of planting commercial higher yields that could rise to 6.0 tons of CPO and 0.70 tons palm kernel oil per hectare per year when they are grown in suitable agro-ecological conditions, good rainfall, and with good management (Sharma, 2013).

This commodity puts pressure on the producers of plantation management. The cost-effective and sustainable process includes minimising the impact that could cause the unwanted vegetation of weed growth in oil palm cultivation through competition for water, nutrients, and sunlight (Rutherford et al., 2011). As weeds may turn more resistant towards herbicides along with the time, thus it increases the usage of herbicides (Green, 2014; Heap, 2014). However, in response to this issue, green management practices are crucial for oil palm growers to meet the benefit of both oil palm weeds control and maintain farmland biodiversity. There is still a lack of research that details the ecological aspects of integrating cattle farming and oil palm plantation (Kamil et al., 2017). The potential of integrating livestock and crop commodity should be emphasized in the future to encourage green management practices in the 5.8 mill ha of Malaysia oil palm plantation.

The concept of integrating animals with oil palm plantations is a feasible and practical proposition, as demonstrated by many studies conducted in Malaysia over the past two decades. The oil palm industry offers two opportunities to promote animal products with various products and by-products. Firstly, the products and by-products from the industry are valuable feed resources that can expand animal production. Secondly, the forages in the inter-rows can be consumed by ruminants. Meanwhile, integrating animal production with oil palm plantations should consider all the available resources, such as the products and by-products of the industry and the forages grown in the inter-rows. This study is focused on

the forages in the plantation area. There is no reason why a viable animal production system cannot be developed in conjunction with the oil palm plantation. The oil palm industry is the only basis for animal production in the tropics since conventional grazing alone is uneconomic (Jalaluddin, 1996). The under-storey of natural vegetation can be divided into species that are consumed by ruminants, and the species that are unpalatable the consumed vegetation species are called 'forage'. Categorically, some plantation managers refer to these plants as weeds (Stür & Shelton, 1991).

Even though the meat and milk demands are increasing in Malaysia, cattle products are static (Najim et al., 2015). Thus, Malaysia imported approximately 88% of beef requirements from different countries due to the slower growth of beef production in fresh, chilled and frozen meat and living animals to meet the local beef demand (Yasmin et al., 2003). This can be observed by the increasing trend from 14% (919 tonnes) in 1960 to 88% (117 800 tonnes) in 2000 of the total imported beef (Yasmin et al., 2003). About 75-80% of the beef requirement are currently imported from various countries to satisfy the domestic demand (Zainalabidin et al., 2013). In plantations, there are several weed management methods, including the cultural, mechanical, and integrated, productive system of using livestock to control the weeds or chemicals (herbicides) (Rosli et al., 2010). Large quantities of chemical fertilizers are used in the primary commodities to support high yield production (Faridah, 2001).

1.2 Problem Statement

High demands of meat and milk in South East Asia contribute to improving meat production systems. This is because the production level of meat and milk from ruminants is relatively low in this region, and the products are managed for self-sufficiency. Any increase in demand would increase imports at high costs, and increased costs can trigger higher commodity prices associated with a solid global market (Devendra, 2011). The marked trend for keeping more ruminants to increase meat production in Southeast Asia requires considerable expansion of the forage supply from currently under-utilised sources. The land used for plantation crops is alternatively the primary source with considerable potential for integrating forages and livestock. Coconut, rubber and oil palm plantations already supply some naturally occurring forages, and this land could support increased forage production.

Thus, it is important to know the diversity of the forages and provide a better understanding of the plant resources that are suitable to be consumed by ruminants in the integrated oil palm plantation. The quantitative plant diversity inventories are the fundamental tools for conservation and management and plan efficient control measures. It is necessary to identify the weeds, know their distributions and understand the factors which affect their distributions (Essandoh et al., 2011).

As forages are the major source of nutrients for livestock nutrition and health, forage toxicity in livestock is caused by the consumption of forage that contains high toxic compounds found in different forages such as grazing crops, hay, silage, or weeds. The importance of examining the nutrients and their toxicity of the forages that animals

potentially consume cannot be denied. Some of the weeds that were not consumed need to be analysed to determine the presence of toxic elements.

In the integrated oil palm plantations, the biomass of the forages is used to estimate the amount of resources fed by the livestock and be used in estimating the forages carbon stock as a contribution to the environment. Estimating the accumulated biomass in one ecosystem is important for assessing the ecosystem's productivity and sustainability, such as plantation. Typically, the carbon storage data can be used to estimate the total current storage of carbon in the area of study as the results contribute to understanding the role and importance of the global carbon cycle (Fan et al., 2007).

1.3 Objectives

The specific objectives of this study were to:

- i. Determine the floristic diversity and carbon stock of weed species in an integrated oil palm plantation area;
- ii. Examine the forage recovery of selected forage species following livestock grazing;
- iii. Examine the forage preferred by livestock between cut and uncut forages; and
- iv. Determine the selected toxic elements contained in the chosen forage and weeds species.

1.4 Summary of Introduction

The introduction chapter presented the background information on the oil palm industry in Malaysia and the integrated farming practices of livestock in oil palm plantations. The benefits of the integrated plantation can be seen in the synergetic effect between the livestock and the plantation. Due to the high demand for beef and livestock products in Malaysia, the large area of oil palm plantation provided the alternative to optimise the use of the plantation and yield of livestock production. The importance of examining forage found in the plantation that is consumed by livestock was also highlighted. There were specific four objectives in this study, and the main aims were to determine the species diversity and carbon stock of weed in an oil palm plantation. It also aims to determine the preferred weed consumed and its recovery following grazing. Finally, it determined the composition and toxicity of forage in an oil palm plantation.

CHAPTER 2

LITERATURE REVIEW

2.1 Integrated Oil Palm Plantation

The range is from the forages grown in the inter-rows and by-products from the oil palm such as palm kernel cake and oil palm fronds, which contain high nutrients proven for high-quality feeds (Jalaludin, 1996). The benefits of integrating the animals in oil palm plantations ensure the long-term profitability and sustainability of the agriculture industry, which is provided in a competitive environment (Jalaludin, 1996).

However, many plantation managers still have lingering doubts about the damaging effects of livestock on oil palm growth, fruit yield, and soil compaction. Damage on oil palms occurs either directly or indirectly through soil compaction and puddling by animal treading. The fear of upsetting the delicate balance of the plantation ecosystem through cattle integration is evident because of higher economic returns from the crop. The planters believe that grazing goats and buffaloes on estate land are a menace as they trample and chew up saplings, resulting in harmful weed invasion and damage to old trees. The herds also cause soil compaction by their sheer body weights, adversely affecting palm root growth and subsequent fruit yield.

Unlike chemical herbicides, targeted cattle grazing created necessary results for weed control in oil palm plantations by reducing understory vegetation cover and height without exposing too much of the ground to avoid erosion. The outcomes of the practices are compatible with the Integrated Pest Management (IPM) and RSPO's standards, followed by the oil palm industry from the major producing countries of Malaysia and Indonesia (Kamil

et al., 2017). The Department of Veterinary Services (DVS) initiated the program of Target Area Concentration (TAC) to develop the potential of local beef production due to the possibility of beef cattle integration under plantation crops (Tapsir et al., 2008). Integrating ruminant with plantation in Malaysia also identified in the National Agricultural Policy (1992-2010) as an important strategy that aims to increase beef production (Mohd. Zamri & Azhar, 2015).

The integration of livestock such as cattle, goats, and sheep in the tree crop plantations like oil palm (*Elaeis guineensis*), *Citrus* spp., Mango (*Mangifera indica*) and coconut (*Cocos nucifera*) promote good practice (Ebenezer et al., 2012). The synergistic interactions produced by the integration of the crops and animals provide more excellent additive and total contributions than their practices (Edwards et al., 1988). benefits of integration of livestock in plantation establishments such as the total farm productivity and sustainable agriculture in terms of efficient natural resource management along with the advantages of weeding and fertilizer cost-efficiency increased soil fertility through the return of animal waste and value addition to the tree crop (Devendra, 2004; Ebenezer et al., 2012).

2.2 Some Studies on Integrated Oil Palm Plantation

The advantages are undeniable, and many countries are attracted to this practice and research and development to create the best yield for plantation and farming. The studies of sheep grazing under rubber and cattle grazing under oil palm showed a saving of 17 to 36% and 20 to 40% accordingly, based on the total cost of weed control besides the enhancement of product of the animals by the utilization of undergrowth and crop by-products such as oil palm fronds, palm oil mill effluent, palm kernel cake, copra, and rubber seed meal (Ahmad Salihin et al., 1998).

Furthermore, past studies show that weeding labour replaced by cattle as much as 150 cows can replace four men for weeding. Thus, it saved the cost of weeding from RM 30 to RM 50 per hectare a year (Rosli, 2000). About 400 ha is required for 100 cows for the systematic rotational grazing in oil palm plantation showed that the practice is suitable for the estate. For smallholding of 10 ha, an intensive management system is recommended where cattle are stall-fed in the cattle house. This system is popular for fattening before slaughtering, and the intensive system is implemented to breed cattle (Kamil et al., 2012).

Compared to the conventional, mono-culture animal production systems, the integration system showed that the forages grown in such plantations of oil palm, rubber, acacia, and coconut provide the most critical factor in ruminant production lowest cost (Dahlan & Kamal, 2014). Chemical weed control costs were reduced in systematically grazed plantations (MYR 107.9 ± 19.69 per ha) compared to non-systematically grazed (MYR 163.2 ± 14.19 per ha) (Kamil et al., 2017).

2.3 Sustainability of Integrated Plantation Practices

The integrated farming system has benefited from high productivity of the resources recycling in the approach and utilizing the concept of ecological soundness that ensures sustainable agriculture (Majunatha et al., 2014). There are four primary goals of integrated farming systems: maximization of the yield of all component enterprises, providing steady and stable income, rejuvenating or ameliorating the system's productivity, and achieving agro-ecological equilibrium (Majunatha et al., 2014). It also avoids the build-up of insect pests, diseases, and weed populations through natural cropping system management by keeping them at a low level of intensity and reducing the use of chemicals (fertilizers and pesticides) to provide chemical-free healthy produce and environment to society.

The biotic and abiotic habitat characteristics to form species distribution must be examined by an essential preliminary step to have an overview in situ and landscape biodiversity level resulting from oil palm expansion (Luskin & Potts, 2011). Keeping the animals on land used simultaneously for the production of the crops is known as an integrated or 'zero land' live-stock production system (Dahlan & Kamal, 2014), where the process optimizes the livestock industry. In contrast, no new land for farming is established. Although the high potential exists in the industry, it is being slowly realized. Some advantages in the system, including improved soil fertility of the soil through the return of the dung and urine, control of waste herbage or weed growth and reduced use of weedicides, provides easier management of the crop and distinct possibilities of increased crop yields per unit area (Jusoh & Mohd Noor, 2002; Dahlan & Kamal, 2014).

A significant concern about health hazards due to chemical fertilizers seems to be an issue in recent years. To avoid this, the use of fertilizers needs to be reviewed. An efficient effort also needs to be replaced with the use of organic fertilizers. This effort will produce the recycling of organic waste and by-products to be helpful and reduce the disposal or burning of waste products that contribute to soil, water, and air pollution (Faridah, 2001). The integrated farming system has always involved components like crops and animals in which the products and by-products bring benefits to each component. It is clearly stated that integrated farming and mixed farming are more profitable than mono-crop (Jaishankar, 2014).

The profits from the systems derive from the sale of animals and their products apart from their plantation products using the resources more efficiently. In Malaysia, some livestock production systems have been studied, including open-improved pasture land,

intensive feed-lotting systems and an extensive system of small-holders (Dahlan et al., 1992; Dahlan, 2002). The promising returns from integrating livestock with plantation crops like oil palm, rubber, acacia, and coconut are increased (Dahlan & Kamal, 2014).

The advantages of dual land use include better use of scarce land resources; increased and diversified income; soil stabilization; the potential for increased plantation crop yield through better weed control, nutrient cycling, and nitrogen accretion; and better weed-control management. The sustainability of the livestock-crops integrated production systems depends on the balance of economic, community, and ecological development. The rest of the three most important factors that must be accounted for are people, planet and profit (3P) in the industries to demonstrate the green business and become sustainable in the long run. Understanding the significant components of the interactions is the crucial task for the value of sustainability of the production system (Dahlan & Kamal, 2014).

Apart from the various benefits of the integration practices, some disadvantages that affect both animals and crops should be a great concern. The study included the growth of the plants (Tan & Abraham, 1981), weed control by animals (Tan & Abraham, 1981), damage by the grazing animals (Tan & Goh, 1988) and economies of combined grazing and chemical control (Ani Arope & Chong, 1985). As such, some limitations and the decision to implement the practices depends on factors including capital investment, labour costs, natural predators, soil quality for the cultivation of improved fodder and the irrigation systems of the plantation to lower the risk of flooding (Ahmad Salihin et al., 1998).

2.4 Efficiency of Management in Integrated Plantation System

Nothing is wasted in an integrated farming system as the by-product of one system is beneficial for the rest of the system. The integrated farming system with efficient soil, water crop, and pest management practices are considered environmentally friendly and cost-effective for sustainable development (Walia and Kaur, 2013). The management efficiency in the integrated farming system is usually taken as less risky and more environmentally friendly. Integrated system benefits include reducing erosion, increasing crop yields, soil biological activity, and nutrient recycling, helping in efficient use of water, reducing pests and diseases, intensifying land use, improving profits, helping reduce poverty malnutrition, and strengthening environmental sustainability (Walia and Kaur, 2013).

The negative impacts in oil palm plantations occur in such situations due to the improper control of the cattle. Therefore, the integration of oil palm cattle, such as the cattle system, is well-established in Malaysia. Organizations such as the Federal Land Administration Authority (FELDA settlers, Felda Farm Products Sdn. Bhd and the ESPEK division of RISDA developing cattle are rearing under oil palm cattle integration (Najim et al., 2015). Another view is that animal faeces necessarily used to be well managed to reduce odour, nutrient losses and emissions. Otherwise, it contributes to pollution and affects the aquifers and surface waters (Burton & Turner, 2003) can also directly affect the health of humans and livestock (IAEA, 2008).

The oil palm cattle integration system is widely known, and it has been established in various numbers of oil palm plantations. The sources provided in the area of practices include forages grown and fronds for feed and the return of the faeces from cattle under organic fertilizer for the crop (Nurhayati et al., 2015). The limits of labour and rising labour

costs are severe issues for the plantation sector. Biological control of weeds by cattle showed positive results after the appropriate strategy. Less use of the herbicides created environmental sounds in the plantation and sustained the development of the resource. The grazing system under the oil palm area minimized the cost of weeding problem where grazing by rotation is one of the systems in oil palm plantations. Several plants consist of grasses, legumes, and other narrow and broad leaves, whereas some of the plants are palatable and some are unpalatable or toxic to cattle (Nurhayati et al., 2015).

2.5 Rotational Grazing System of Livestock in Integrated Oil Palm Plantation

The systematic integration of livestock in oil palm plantations is applied with the help of an electric fence which is used to control the livestock, especially the rotational grazing system, a practical method (Rosli, 2000). Rearing cattle in oil palm plantations using a portable electric fence gives the advantage in weed control. Then it reduces the use of chemical herbicide, environmental pollution and labour required. It also contributed to a well-integrated weed management program (Rosli, 2000).

The grazing area was all under systematic control with schedule and strategically construct (diseases free cattle are crucial and productive cattle to rear live-stock for an optimum production). The grazing area must be encircled with a portable electric fence before the cattle enter the plot. Mineral salt was also provided by the management and enough supply of water resources for the requirement of better health for cattle. Three blocks of oil palm areas can accommodate more than 110 cattle and buffaloes at one time in the duration of 1 to 3 days based on the total area of grazing, where the more extensive area provided for more days for cattle to feed. The next paddock must be ready by encircling an electric fence next to the grazed area to make workers at ease to move the cattle to the

adjacent paddock. The rotation was repeated to the initial paddock at about 30 days, depending on the forages sufficient in one paddock. In flood-prone areas, the cattle need to move to higher or the site not affected by the flood. The use of portable electric fences to control the cattle proved workable. The rotational grazing system for weed control can contribute to integrated pest management.

2.6 Forage Supply in Oil Palm Plantation

The integration system with major crops was not a new concept and was practised when the coconut was introduced in Malaysia (Sani et al., 1993). Since establishing the plantation crop in the country, cattle in the oil palm have existed. Cattle production was traditionally managed through open grazing and the cut and carry system using coconut by-product, tapioca waste, banana waste, and *Imperata cylindrica* and weeds have been practised earlier (Ayob & Kabul, 2009).

Vegetation under palm oil plantations is a potential for ruminant feed by grazing or cut and carry because it can provide an abundant amount of nutritious forage biomass. Forage production under oil palm plantations depends on the degree of shade. The age of the plant, the height of the plant, the distance between plants, soil condition, and canopy characteristics are the factors that influence the degree of shade (Martono et al., 2019). Also, the shade will affect the photosynthesis process, affecting plant morphology, production, and nutrient quality from forage. In the meantime, the chemical composition and forage digestibility are affected by species and plant age, climate (temperature, radiation, and rainfall) and forage management such as nitrogen fertilization (Martono et al., 2019).

About 60 to 70 species of undergrowth under oil palm plantation consist of planted leguminous cover crop, naturally growing grasses, broad leaves, and ferns considered weeds,

need to be controlled with some methods such as chemical spray or manual slashing. The potential food source as the yields, palatability and nutritional values are sufficient for cattle. Under appropriate conditions and systematic management, cattle can be efficiently used for weed control, producing a harmonious relationship between cattle, undergrowth, and oil palm (Ayob and Kabul, 2009).

2.7 Evaluation of Forage

A sufficient food supply is essential to secure the people in any situation. It may become the resilience factor of an independent country to survive when facing challenges either externally or internally. It depends on the sufficiency levels of the food commodities in the country. Significant improvements in the self-sufficiency levels for beef and mutton have been discovered (Kamil et al., 2014). The uprising trend in self-sufficiency was estimated at 29.5% and 12.9% of beef and mutton, respectively, in 2012 (Department of Veterinary Services, 2013). However, the percentage is still low compared to 1970 records of 86.9% for beef and 24.8% for mutton (Tan & Ahmad Tajuddin, 1988). In Malaysia, ruminant products are significant sources of protein (Kamil et al., 2014).

The study suggested that the accurate laboratory testing of feed and forage is needed to deliver the information essential to formulate animal rations. Analysis of forage represents the average quality of the material being analysed. Only a few grams of material conclude tons of forage, and the importance of finding a representative sample is crucial (Ball et al., 2001). As the potential of forage intake decreases, the concentration of Neutral Detergent Fibre (NDF) increases with plants age due to the difficulties in digestion than the non-fibre parts of forage and the slow rate to digest fibre the plants mature. It can be concluded that the digestion becomes slow as plants get older accordingly. The indigestible and gradually

becomes digestible components represented by the NDF in plant cell walls: cellulose, hemicellulose, lignin, and ash (Ball et al., 2001).

In animal production, two normal terms used to define the quality or value of forage are feeding and nutrition (Ulyatt, 1973). Feeding value is animal production response when feed is available, and nutritional value is the response of animal production per unit of intake. The mechanism of livestock is considered choosy among forages in their feeding behaviour, which is still not well understood. Forage evaluation must be highlighted as the components of both intensive and extensive farming systems. The need to improve the characterisation of forages by recognizing the factors for better livestock production (Dynes, 2003).

2.8 Diversity of Weed Species in Oil Palm Plantation

The inter-row spaces found in all oil palm plantations promote the growth of at least 60 plant species usually considered weeds (Chen & Dahlan, 1995). An intensive oil palm plantations, chemicals are used regularly to control weed growth so that the competition for plant nutrients is minimal. The cost of weeding is quite substantial and can be easily eliminated if the forages in the inter-rows are utilized for animal production. Besides, soil and environmental pollution are minimized. Integrating animals into the plantation can also reduce fertilizer application since the nutrients returned to the soil from the animals are quite substantial. In the long run, reducing chemical fertilisers will not only reduce production costs but, more importantly, minimize further deterioration in soil fertility. It is a known fact that the consistent application of chemicals will alter the ecological profile of the soil. With reduced biodiversity in the soil, plant growth can be affected.

The canopy from the crops will also provide a comfortable environment due to the shade for the animal than an open pasture land system where the heat stress has naturally reduced the problems that occurred with the animal in the tropic (Dahlan, 2002). As the palm matures, the canopy increases and limits light penetration, which will reduce forage production in the inter-rows (Jalaluddin, 1996). Some of the factors for the native species that were adapted in the plantation were tolerable for microclimate conditions, leaf litter depth and coverage, the structure, composition and complexity of the herbaceous understory, and canopy (Luskin & Potts, 2011). The potential of native species to adapt within plantations or to use plantations for foraging or other resources can be increased by lowering the differences between forest and plantations' conditions (Brockerhoff et al., 2008).

The light penetration under the oil palm plantation can provide forages or weeds to grow, and there are more than 50 species identified (Wong & Chin, 1998). Malaysia's common weeds and natural forage included *Ottochloa nodosa*, *Axonopus compressus*, and *Asystasia intrusa* (Ayob and Kabul, 2009). A study reported that *Chromolaena odorata*, *Aspillia africana*, and *Melanthera scandens* dominated Ghana's mature oil palm plantation. The high diversity of weeds species was found in mature plantations (5-15 years) with Simpson's (0.98) and Shannon's (3.80) indices, and the Evenness index (0.78) of oil palm plantation in Ghana were also reported (Essandoh et al., 2011). Different composition of weeds was found in a different stage of crop plantation. A wide range of broadleaved is found on newly opened land, a mixture of grassy and broadleaved weeds in young plantations while a predominance of grasses in well-established plantations (Chee et al., 1991; Essandoh et al., 2011).

2.9 Carbon Stock

Southeast Asia is considered a hot spot of land-use changes as one of the main contributors to establishing oil palm (*Elaeis guineensis*) plantations from forests (Stibig et al., 2014; Niharika et al., 2018). The increasing and extensive land-use changes have made tropical forests a net carbon source and an estimated 1.1 ± 0.7 PgC is emitted from these forests per year because of the forests clearing for extraction of timber and agriculture such as plantations and pasture (Pan et al., 2011).

Many international energy producers and users agree that carbon sequestration is a new idea that plays an essential role in assuring affordable energy for the nations and the global economy. A challenging goal can be achieved if large-scale sequestration is inexpensive and environmentally friendly (Haggerty, 2004). The monitoring and estimation of carbon stock of the global vegetation show the capability of plants to release or absorb carbon. Estimating the net carbon flux from soils in a time series is also needed and constrain other methods. For any project interested in carbon measurements, the initial carbon stock on the project lands must be quantified. Carbon stocks measurement is the baseline to determine the effect of the ongoing project activities and serve as the main indicator of the state of the resources (Pearson et al., 2005).

2.10 Summary of Literature Review

This chapter provides an overview of the integrated oil palm plantation industry and the feed sources for the livestock. The advantages of integrated livestock in oil palm plantations are proven. Integrated and mixed farming is not just profitable than mono-crop but also ecologically sound, ensuring sustainable agriculture. However, some constraints include capital investment, labour cost, natural predators, soil quality, and the irrigation

system to lower the risk of flooding must be overcome before successful implementation can be realised.

A systematic, integrated farming practice in oil palm plantations is usually established by using an electric fence to control the livestock, especially in a rotational grazing system. Each grazing area is under systematic control and scheduling. All grazing areas are strategically constructed, encircled with an electric fence with sufficient mineral salts and water before the cattle enter a grazing area. The undergrowth in oil palm plantations has the potential as the feed source for ruminants by grazing or cut and carry due to the ability to provide the amount of nutritious forage biomass.

Inter-row spaces in an oil palm plantation can grow at least 60 weeds species. The cost of weeding can be reduced if the forage in the inter-row is fed by livestock. Soil and environmental pollution can be minimized, and the fertilizer application is diminished due to the nutrients returned to the soil from an animal. In the long run, reducing chemical fertilisers will reduce production costs and minimize further deterioration in soil fertility. The canopy increases as the mature palm limits light penetration, reducing forage production in rows. Besides, the canopy formed by the palm will also develop a comfortable environment with shade for the livestock compared to an open pasture land system where the heat stress is reduced.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

The study was conducted in an integrated oil palm plantation at Samarahan Plantations Sdn Bhd. (Incorporated in Sarawak), Samarahan Estate, Jalan Ensegei, Off 32nd Mile, Kuching/ Serian Road in the division of Serian, Sarawak (Figure 3.1) with GPS location 1.303122, 110.546798.

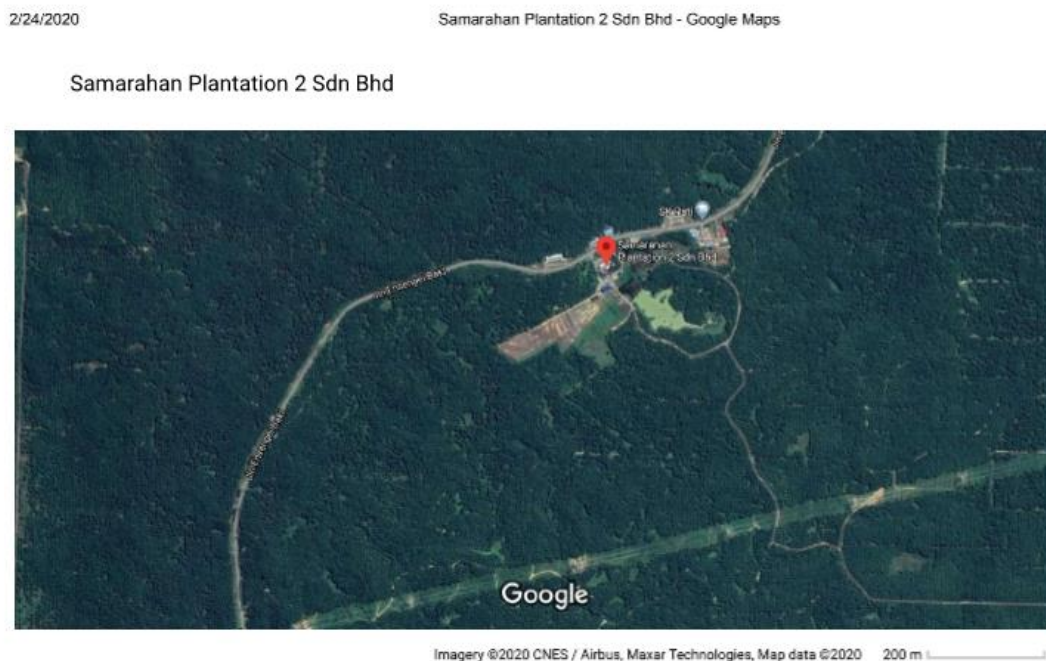


Figure 3.1: Satellite map of Samarahan Plantations Sdn. Bhd. area. Source: Google Map.

The total area of the plantation is 1569 ha. It has alluvial and kaolin grey soil. Generally, the land is flat with a few undulating terrains at about 10%. In 2018, the rainfall per month was in the range of 260-1013mm. The plantation is certified with Malaysian Sustainable Palm Oil (MSPO) certification (Appendix A1). Currently, they practice the integration of

livestock grazing-palm oil with 110 cattle and 60 buffaloes. However, only cattle integration was highlighted in this study (Figure 3.2) as the buffaloes were actually for transportation within the plantation area at the time of harvesting. The integration only involved part of the total plantation area. Before establishing the oil palm plantation, various crops had been planted, such as coffee, cocoa, paddy, and other crops. The study site implemented the systematic rotation grazing practices with the areas of the portable electrical fence (Appendix A2 and A3). Each grazing plot is approximately three blocks of oil palm trees area (3 ha) and took one to three days before the cattle were moved to another plot. The duration of grazing periods in each plot depends on the availability of forages to be grazed by cattle.



Figure 3.2: Cattle grazing in the area of oil palm plantation.

3.2 Sample Collection

Sampling was carried out using list or census quadrat methods using 1m x 1m quadrat (Kim and Moody, 1983). In this method, the weeds species are recorded, and the

number of individuals of each species is counted. One hundred (100) quadrates were established within the areas of integrated farming (Appendix B1 and B2). The quadrates were established based on simple random sampling. Weeds within each quadrate were cut at ground level (MacDicken, 1997) to ensure that each sample was cut at the almost same height (Appendix B3). All living weeds were identified with the help of the experts of Universiti Malaysia Sarawak, and references from the book included Barnes and Chan (1990) and from websites such as The Plant List and IPNI. The samples were then counted individually (Appendix B4 to B6). The weeds samples were placed in the labelled plastic bag and brought to the plant ecology laboratory before oven-drying at 60⁰C for seven days. Subsequently, all oven-dried samples were weighed to obtain their dry biomass. The dry biomasses were then used to estimate the study areas' above-ground biomass and carbon stock. Sample collection was done in two different periods on the same plot, where the first sampling was carried out on 27th December 2016 and the second sampling was done on 5th July 2017. The sampling at two different periods was conducted to determine the species diversity after months of grazing.

3.2.1 Weed Species Composition and Diversity

According to the International Plant Names Index (IPNI) (International Plant Names Index, n.d.), all species recorded were identified and confirmed. All weeds collected from the initial and second sampling were calculated to obtain species diversity indices. It included the Summed Dominance Ratio, Shannon-Wiener Diversity Index, Simpson's Index of Diversity, Margalef's Richness Index, Pielou's Evenness Index, and Sorensen's Similarity Index. The details of the analyses are listed below:

3.2.1.1 Summed Dominance Ratio (SDR)

Summed Dominance Ratio (SDR) determines the dominant or major weeds species found in the study area. It was calculated based on Kim and Moody (1983) method:

$$\text{Relative density (RD)} = \frac{\text{Absolute density (D)}}{\text{Total number of plants for all species}}$$

Absolute density (D) = The total number of plants for given species in all quadrates

$$\text{Absolute frequency (F)} = \frac{\text{Total number used in which given species occurs}}{\text{Total number of quadrates used}}$$

$$\text{Relative frequency (RF)} = \frac{\text{Absolute frequency of a species (F)}}{\text{Total of the absolute frequency for all species}}$$

Important value (IV) = Relative density (Rd) + Relative frequency (Rf)

$$\text{Summed dominance ratio (SDR)} = \frac{\text{Important value}}{2}$$

3.2.1.2 Shannon - Wiener Diversity Index (H')

The diversity of weeds at each study was determined by using the Shannon-Weiner Diversity Index (Shannon, 1948). Shannon - Wiener Diversity Index was calculated using the formula below:

$$H' = - \sum_{i=1}^S p_i \ln p_i \quad \text{Equation 3.1}$$

S = the number of species

n_i = the number of individuals in species i

N = the total number of all individuals

p_i = the relative abundance of each species, calculated as the portion of individuals of a given species to the total number of individuals in the community: n_i/N

3.2.1.3 Species Diversity (Simpson's Index of Diversity, 1-D)

The Simpson's Index (Simpson, 1949) is used to measure the species diversity of an area. This is used to measure the possibility that two individuals randomly selected in a sample will belong to the same species. With the formula in Equation 3.2, 0 indicates infinite diversity while 1 no diversity:

$$D = \Sigma(n(n - 1) / (N(N - 1))) \quad \text{Equation 3.2}$$

D = Simpson's Index

n = the number of individuals in each species

N = the total sample sizes

To make the result more comparable, Simpson's Index of Diversity has used the value between 0 to 1 in which the closer the value to 1, the greater the diversity of the area. The index represents the possibility that two individuals randomly selected from a sample belonged to different species (Bibi & Ali, 2013). The formula had been explained by Peet (1974), as mentioned in Equation 3.3 below.

$$\text{Simpson's Index of Diversity (1-D)} = 1 - (\Sigma(n(n - 1) / (N(N - 1)))) \quad \text{Equation 3.3}$$

3.2.1.4 Species Richness (Margalef's Richness Index, R)

Margalef's Richness Index measure the species richness of the sample (Margalef, 1958) represented as R in this study. The formula for Margalef's Index can be counted as in Equation 3.4 below:

$$R = (S - 1)/(\ln N) \quad \text{Equation 3.4}$$

S = Number of species

N = Number of individuals

3.2.1.5 Pielou's Evenness Index (J')

The distribution of individuals among the species is given by Pielou's Evenness Index (Pielou, 1966) J' while J' is constrained between 0 and 1, J' can range from close to 0, where most species are rare. Just a few are abundant, whereas when the value is closer to 1, the potential evenness between species ($H'_{\max}$) is equal to that observed (H'). The Shannon-Weiners index is a quantitative expression that incorporates both species richness and species evenness of species abundance and considers two independent characteristics of biological communities that contributed to the diversity (Heip et al., 1998). The formula of species evenness is given as in Equation 3.5:

$$J' = H'/H'_{\max} \quad \text{Equation 3.5}$$

$$H'_{\max} = \ln S$$

(Maximum level of diversity possible within a given community)

3.2.1.6 Sorensen's Index (SI)

The similarity in weed species in all areas was compared using the Sorensen's Index similarity (Sorensen, 1948). The index was calculated as follows:

$$SI = 2C/(A + B) \quad \text{Equation 3.6}$$

C = number of species common to both communities

A = total number of species in community A

B = total number of species in community B

3.2.2 Classification of Plant

The collected undergrowth was classified into grass, sedges, broadleaved, and ferns, according to Barnes and Chan (1990). However, broadleaved were classified into climber or creeper or vine, herbaceous, shrub, and tree.

3.3 Estimation of Biomass and Carbon Stock

All plant materials within the quadrates were separated according to species and determined their dry weight. The plant materials were dried for seven days at 60°C to obtain the constant weight of three consecutive days. The carbon stock estimation was referred to the default value of 47% as the carbon content. Carbon stock was estimated by multiplying biomass density by 0.47, which confirmed the standards used by The European Commission, 2010 (Sanquetta et al., 2015) and used by Khasanah et al. (2015). The dry weight of the dry matter was multiplied by 0.47 to obtain the carbon stock of each species.

The carbon stock of each pool was estimated by multiplying the biomass of each pool with the assumed organic carbon content was assumed to be 0.47 for palm biomass and

under-storey vegetation, 0.5 for necromass (deadwood) and 0.4 for the standing litter stock) (Khasanah et al., 2015). Biomass and carbon stock of weeds were calculated in terms of kg ha⁻¹ with the calculations below (Equation 3.7):

$$\text{Biomass density (kg ha}^{-1}\text{)} = \text{Biomass (kg m}^{-2}\text{)} \times \text{Expansion factor} \quad \text{Equation 3.7}$$

$$\text{Expansion factor} = \frac{10000\text{m}^2}{\text{Area of quadrates (m}^2\text{)}}$$

$$\text{Carbon stock (kg ha}^{-1}\text{)} = 47\% \text{ of Biomass Density}$$

3.4 Determination of Forage Recovery

Forage recovery is the time taken for the selected forage species to recover after it had been grazed and cut. Three species were mostly preferred by cattle based on the observation of the study area and information provided by the management of the oil palm plantation. The selected species included *Axonopus compressus*, *Elaeis guineensis* Jacq (oil palm grown freely on the ground and considered weeds in oil palm plantation), and *Antrophyum reticulatum* (Appendix D1 to D3). The parameter for forage recovery used was the height of growing shoots. Forage recovery evaluations of the three species were conducted after there have been grazed and cut. The ungrazed plant acts as a control. Forage recovery of grazed, cut, and ungrazed where for cut, it were subjected to two different conditions, namely opened area and shaded area were done for *Axonopus compressus* and *Elaeis guineensis*. For *Antrophyum reticulatum* only two evaluations were done to compare new shoot growth after cut and grazed. Each sample has 20 replicates. The height of the samples was measured every three days from day 0 until day 27. Figure 3.3 shows the layout of a forage recovery study.

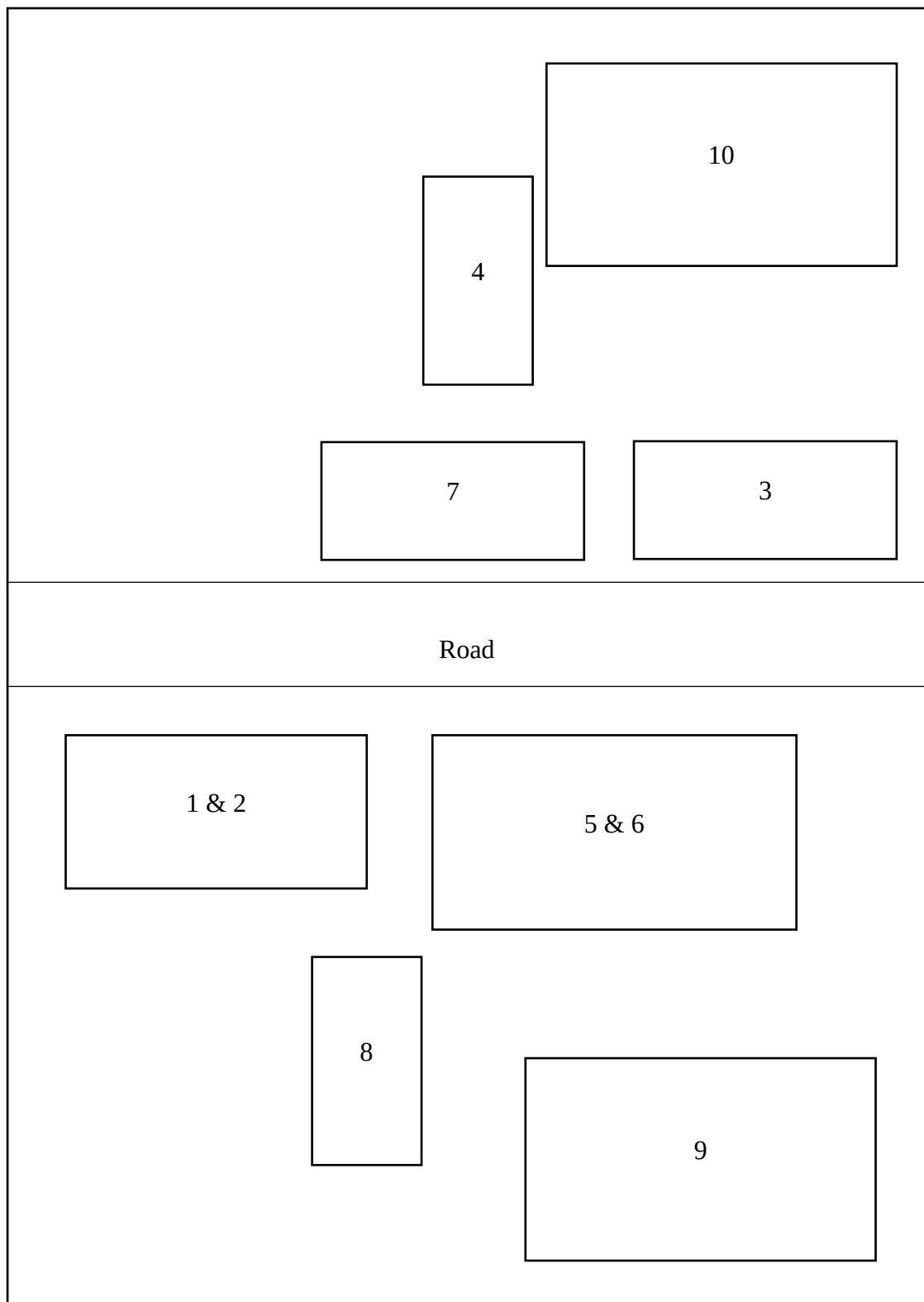


Figure 3.3: The layout of forage recovery study in integrated oil palm plantation.

The numbers in Figure 3.3 represent:

1. *Axonopus compressus*, grazed samples in the opened area.
2. *Axonopus compressus*, not grazed samples in the opened area.
3. *Axonopus compressus*, cut samples in the opened area.
4. *Axonopus compressus*, cut samples in the shaded area.
5. *Elaeis guineensis*, grazed samples in the opened area.
6. *Elaeis guineensis*, not grazed samples in the opened area.
7. *Elaeis guineensis*, cut samples in the opened area.
8. *Elaeis guineensis*, cut samples in the shaded area.
9. *Antrophyum reticulatum*, grazed samples.
10. *Antrophyum reticulatum*, cut samples.

The initial height was recorded for 20 clumps of *Axonopus compressus* and *Antrophyum reticulatum* and 20 seedlings for *Elaeis guineensis*. For *Axonopus compressus* and *Elaeis guineensis*, they were subjected to three conditions. Firstly, they were in the open area for both grazed and ungrazed samples. Secondly, the samples in the open area for grazed and cut samples. Thirdly, the samples were cut in both the open and shaded areas. The comparison of grazed and cut *Antrophyum reticulatum* were done to determine the difference between the growth pattern of new shoots.

For the cut treatment of *Axonopus compressus* the samples were cut at 80%, *Elaeis guineensis* was cut at 50%, and *Antrophyum reticulatum* was cut at 100% of the total height. The different percentage of cut was based on the total area of the forage that was grazed by livestock from the tip of forage that was different for each species. The height of *Axonopus compressus* and *Elaeis guineensis* samples were measured in centimetres (cm), and the

number of new shoots for *Antrophyum reticulatum* was counted. The data were recorded every three days until the next rotation took place on the same plot after a total of 27 days.

3.5 Forage Preferred by Livestock between Cut and Uncut

For the study of forage preferred by livestock, the selected forage species was *Axonopus compressus*. This species was selected because it is the most preferred forage based on observation and information provided by the management of the oil palm plantation it can be found in abundance within the study area. Each square of 5 m x 5 m was located close to each other for both cut and uncut forage due to the available grazing area mostly found in the study area. The photos for this study are shown in Appendix E1 to E8. A total of 5 squares of cut forage and five squares of uncut forage were established in every 11 plots that underwent the rotational system during this study (Figure 3.4). In total, there were 55 squares for each cut and uncut forage.

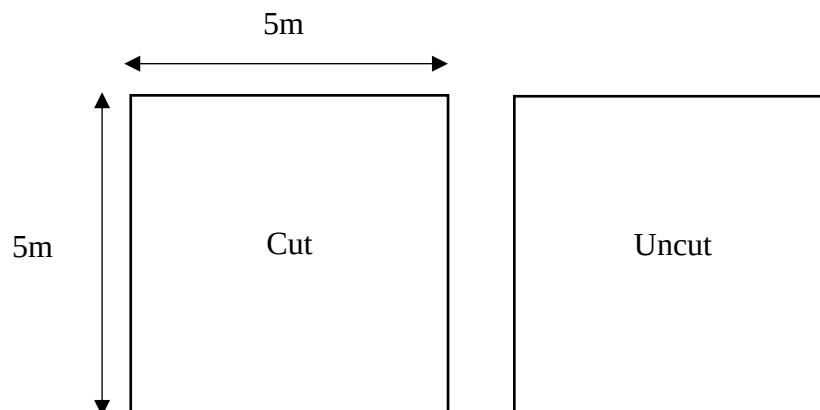


Figure 3.4: Establishment of two 5 m x 5 m for cut and uncut squares located at each other.

The samples were cut approximately 2.5 cm high for cut treatment, while the uncut samples were left with no treatment. The squares established and let the cattle roam and grazed in the plot. The total number of days the cattle roam and grazed were recorded. The

percentage of consumed forages were estimated after the cattle had moved to the next plot. For this study, the percentage of forage consumed was estimated by using the grids with the size of each grid was about 5 cm x 5 cm. The number of grids grazed was counted against the total number of grids.

$$\text{Percentage of grazed forage} = \frac{\text{Total number of grids grazed}}{10000 (\text{Total number of grids})} \times 100 \quad \text{Equation 3.8}$$

3.6 Elemental Analysis

Quantification of selected elements and their toxicity were conducted to determine the number of micronutrients in plants and the presence of heavy metals. The elemental analysis was done on five forage chosen species that are considered the most preferred forage species, based on the observation and information provided by the management of the plantation: *Axonopus compressus*, *Elaeis guineensis*, *Antrophyum reticulatum*, *Asystasia gangetica*, and *Scleromitron verticillatum*. The GPS location of samples was *Axonopus compressus* collected at N 01° 17.579' E 110° 33.052', *Elaeis guineensis* at N 01° 17.593' E 110° 33.047', *Antrophyum reticulatum* at N 01° 17.603' E 110° 33.055', *Asystasia gangetica* N 01° 17.602' E 110° 33.042' and *Scleromitron verticillatum* at N 01° 17.606' E 110° 33.067'. The selected species for elemental analysis are shown in Appendix C1 to C5.

Figure 3.5 shows the cattle are grazing in one of the selected forage species, *Axonopus compressus*. The selected elements analysed were based on the elements listed in Mineral Nutrition of Livestock 4th Edition by Suttle (2010). There were six plant macronutrients include Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Sulphur (S), and Sodium (Na).

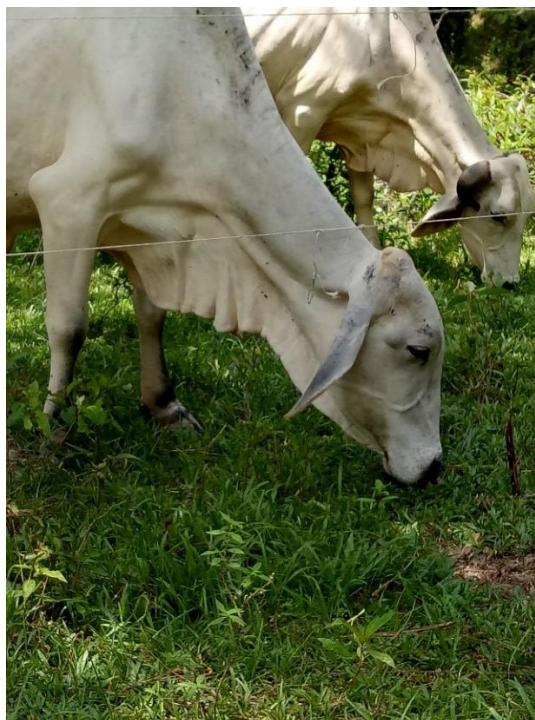


Figure 3.5: Cattle grazing in the fencing area of one of the selected forage species, *Axonopus compressus*.

The potential toxic elements that were tested in this study are the hazardous heavy metals found in the plant, which are Lead (Pb), Cadmium (Cd), Arsenic (As), Aluminium (Al), and Mercury (Hg). These elements were analysed to determine whether the selected species contained the toxic elements that could put livestock at risk as the species were commonly found in the area. The non-forage plants analysed for toxic elements were *Melastoma malabathricum*, *Miconia crenata*, *Diplazium esculentum*, *Taenitis blechnoides*, and *Torenia crustacea* which were selected because these species were unconsumed by cattle based on observation while commonly available in the study area. The GPS location for samples collected was recorded as *Melastoma malabathricum* at N 01° 17.606' E 110° 33.068', *Miconia crenata* at N 01° 17.609' E 110° 33.029', *Diplazium esculentum* at N 01° 17.599' E 110° 33.037', *Taenitis blechnoides* at N 01° 17.602' E 110° 33.018' and *Torenia*

crustacea at N 01° 17.573' E 110° 33.049' as the species are included in Appendix C6 to C10. Two of the selected unconsumed species are shown in Figures 3.6 and 3.7.



Figure 3.6: *Melastoma malabathricum* (unconsumed species).



Figure 3.7: *Diplazium esculentum* (unconsumed species).

Different methods analyzed different elements. N was analyzed with MS 677: Pt. III: 1980 method, results expressed through %; P analyzed by MS 677: Pt. IV: 1980 method, result expressed with the help of %; K analyzed by MS 677: Pt. V: 1980 method, result expressed through %; Magnesium Mg analyzed by MS 677: Pt. VII: 1980 method, result expressed as a %; S analyzed by Gravimetry method, result expressed as a %; while Sodium Na, Pb, Cd, As and Al were analyzed by the AAS method with mg/kg unit as well as Hg was also analyzed by Cold Vapor AAS method through mg/kg unit.

3.7 Statistical Analysis

Statistical analysis was performed to determine the recovery differences of *Axonopus compressus*, *Elaeis guineensis* and *Antrophyum reticulatum*. The differences in height in each species from day 0 to 27 were analysed. For the regular and homogenous data, One-Way ANOVA was used to analyse the recovery differences of *Axonopus compressus*, *Elaeis guineensis* between grazed, ungrazed, and cut in opened and shaded areas and for *Antrophyum reticulatum* between grazed and cut. Tukey HSD post hoc tests were carried out for multiple mean comparisons between grazed, cut, and ungrazed *Axonopus compressus* and *Elaeis guineensis* in the opened area as well as between opened and shaded areas of cut *Elaeis guineensis*. For *Antrophyum reticulatum* mean comparisons of number of shoots were made between grazed and cut.

The Independent Sample Kruskal Wallis was used to analyse non-normal data. It was used to analyse each recovery of *Axonopus compressus* among grazed in the opened area, cut in the opened area, and cut in the shaded area. The recovery of *Elaeis guineensis* between grazed in opened area was also analysed. The test was also used to analyse the percentage of preferences for both grazed and cut *Antrophyum reticulatum*. Dunn-Bonferroni post hoc

tests were carried out for all mean comparisons following Kruskal-Wallis tests. All statistical analyses were conducted using IBM SPSS Statistics 26.

3.8 Summary of Materials and Methods

This chapter explained how the research was conducted. It started with a selection of study areas, then samples collection, the study's parameters, and the analysis of the data collected. The study was conducted in the integrated oil palm plantation at Samarahan Plantations Sdn. Bhd. It was located at Serian, Sarawak. There were about 110 cattles and 60 buffaloes within the area, and the plantation implemented systematic rotation grazing practices with the use of the portable electric fence. The fence encircled the area of about, 3 blocks at one time, for the duration of 1 to 3 days depended on the area and availability of forage.

The sampling of weeds was done using the quadrature method that was randomly established for 100 quadrates. The sample weeds were cut, the living weeds were identified and counted individually for species diversity determination, and it was placed in labelled plastic for a subsequent experiment. All weed samples were oven-dried for seven days and weighed to obtain the dry biomass and carbon stock estimation. The sampling was carried out for initial and second sampling, which was done after six months after the initial sampling. The samples for elemental and toxicity analyses were collected in the area of the plantation, and the location of the collected samples was recorded with GPS.

All the plant samples were identified, and the names of the species were confirmed from the IPNI website. Weed species dominance was determined based on Summed Dominance Ratio. Weed species diversity indices were calculated for the Shannon-Wiener Diversity Index, Simpson's Index of Diversity, Margalef's Richness Index, Pielou's

Evenness Index, and Sorensen's Similarity Index. Carbon stock for each species was estimated by multiplying the biomass by 0.47.

Three selected species, *Axonopus compressus*, *Elaeis guineensis*, and *Antrophyum reticulatum* were carried out for forage recovery determination. There were three evaluations used for *Axonopus compressus*, and *Elaeis guineensis*: grazed, cut, and ungrazed. Further evaluations, were conducted on cut samples placed at two different shades pattern, which was opened and shaded areas. Only two assessments were done for *Antrophyum reticulatum*, a fern that grows on an oil palm trunk that was grazed and cut. The height was recorded for *Axonopus compressus* and *Elaeis guineensis*, and the number of new shoots was recorded for *Antrophyum reticulatum* from day 0 to 27.

Forage preferred by livestock determination was done for cut and uncut *Axonopus compressus*. Each square of 5 m x 5 m for cut and uncut *Axonopus compressus* was established adjacent to each other. A total of five squares for each cut and uncut forage were established. The percentage of consumed forage were determined after the cattle were moved to the next plot.

The elements of N, P, K, Mg, S, and Na were analysed for each of the selected consumed species that include *Axonopus compressus*, *Elaeis guineensis*, *Antrophyum reticulatum*, *Asystasia gangetica*, and *Scleromitrium verticillatum*. The unconsumed weeds such as *Melastoma malabathricum*, *Miconia crenata*, *Diplazium esculentum*, *Taenitis blechnoides*, and *Torenia crustacea* were analysed for toxicity elements, namely Pb, Cd, As, Al and Hg.

Statistical analysis was used to determine the differences in forage recovery. Parametric analysis (One-way ANOVA) was conducted for normally distributed data, and a

non-parametric test (Kruskal-Wallis test) was used for non-normal data. Tukey HSD and Dunn-Bonferroni post hoc tests were carried out for One-way ANOVA and Kruskal-Wallis test, respectively.

CHAPTER 4

RESULTS

4.1 Species Composition of Weeds in the Integrated Oil Palm Plantation Area

4.1.1 Family Composition of Weeds during the Initial Sampling at the Integrated Oil Palm Plantation Area

A total of 27 weed families were recorded in the initial sampling based on 100 quadrats (1 m² each). The top five dominant weed families are listed in Table 4.1.

Table 4.1: Top five dominant weeds family of 100 quadrats (1 m² each) during the initial sampling at integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) values.

Rank	Family	Number of Species	D	F	RD	RF	IV	SDR
1	Poaceae	6	5186	2.82	0.47	0.30	0.77	0.39
2	Rubiaceae	5	3810	1.05	0.35	0.11	0.46	0.23
3	Melastomataceae	2	464	1.19	0.04	0.13	0.17	0.08
4	Scrophulariaceae	1	421	0.61	0.04	0.07	0.10	0.05
5	Euphorbiaceae	3	214	0.52	0.02	0.06	0.08	0.04
	Others							
	Total	53	10961	9.35	1.00	1.00	2.00	1.00

Note. D= Absolute density, F= Absolute frequency, RD= Relative density, RF= Relative frequency and IV= Important value.

Poaceae was the most dominant family in the initial sampling, followed by Rubiaceae, Melastomataceae, Scrophulariaceae, and Euphorbiaceae. Summed Dominance Ratio values

showed that Poaceae has a value of 0.39 due to high species number with the high total number of individuals and frequency recorded in the area. The least dominant families include Actinidiaceae, Blechnaceae, Clusiaceae, Gleicheniaceae, Hypoxidaceae, Loganiaceae, and Vittariaceae recorded. The other families in the initial sampling were Asteraceae, Acanthaceae, Cyperaceae, Lamiaceae and Schizaeaceae. The full listing of weed families recorded during the initial sampling is given in Appendix F1.

4.1.2 Family Composition of Weeds in the Second Sampling at the Integrated Oil Palm Plantation Area

The dominant weeds family within the integrated oil palm plantation area after 6 months of the initial sampling is listed in Table 4.2.

Table 4.2: Top five dominant weeds family of 100 quadrats (1 m² each) during the second sampling at integrated oil palm plantation represented by Summed Dominance Ratio (SDR) value.

Rank	Family	Number of Species	D	F	RD	RF	IV	SDR
1	Poaceae	8	4326	2.51	0.43	0.27	0.71	0.35
2	Rubiaceae	6	3605	1.06	0.36	0.12	0.48	0.24
3	Melastomataceae	2	433	1.28	0.04	0.14	0.18	0.09
4	Scrophulariaceae	1	425	0.69	0.04	0.08	0.12	0.06
5	Cyperaceae	8	162	0.55	0.02	0.06	0.08	0.04
	Others							
	Total	62	9959	9.17	1.00	1.00	2.00	1.00

Note. D= Absolute density, F= Absolute frequency, RD= Relative density, RF= Relative frequency and IV= Important value.

A total of 30 families were recorded in 100 quadrates with 9959 individuals. The top 5 dominant families were Poaceae, Rubiaceae, Melastomataceae, Scrophulariaceae, and Cyperaceae. The least dominant families recorded were Leeaceae, Malvaceae and Piperaceae, with only one species was found in each family in the study area. The other species were Euphorbiaceae, Lamiaceae, Leguminosae, Moraceae and Schizaeaceae and the complete listing of weed families in the second sampling (Appendix F2). Results showed that four dominant weed families (Poaceae, Rubiaceae, Melastomataceae, and Scrophulariaceae) were recorded with similar SDR values in both sampling periods.

4.2. Species Diversity of Weeds

4.2.1 Species Dominance

4.2.1.1 Dominant Species in the Initial Sampling of the Integrated Oil Palm Plantation

The composition of weeds species listed based on species dominance as represented by Summed Dominance Ratio is shown in Table 4.3.

Table 4.3: Top five dominant species in the initial sampling at the integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.

Rank	Species	D	F	RD	RF	IV	SDR
1	<i>Scleromitrium verticillatum</i> (L.) R.J.Wang	3780	0.97	0.34	0.10	0.45	0.22
2	<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2198	0.83	0.20	0.09	0.29	0.14
3	<i>Centotheca lappacea</i> Desv.	1761	0.95	0.16	0.10	0.26	0.13

Table 4.3: continued

4	<i>Axonopus compressus</i> P.Beauv.	1160	0.91	0.11	0.10	0.20	0.10
5	<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	421	0.61	0.04	0.07	0.10	0.05
	Others						
	Total	10961	9.35	1.00	1.00	2.00	1.00

Note. D= Absolute density, F= Absolute frequency, RD= Relative density, RF= Relative frequency and IV= Important value.

Analyses showed that SDR ranged from 0.00 to 0.22, where the complete list is furnished in Appendix G1. The dominance of *Scleromitrium verticillatum* was evident due to its abundance with the value of SDR 0.22 followed by *Cyrtococcum patens* var. *latifolium*, *Centotheca lappacea*, *Axonopus compressus*, and *Torenia crustacea*. By contrast, there were 13 least dominant species in the area, including *Antrophyum reticulatum*, *Dicranopteris linearis*, *Lygodium microphyllum*, *Oldenlandia corymbosa*, and *Saurauia glabra*.

4.2.1.2 Dominant Species in the Second Sampling of the Integrated Oil Palm Plantation

The dominant species during the second sampling are shown in Table 4.4.

Table 4.4: Top five dominant species in second sampling at integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.

Rank	Species	D	F	RD	RF	IV	SDR
1	<i>Scleromitrium verticillatum</i> (L.) R.J.Wang	3593	0.96	0.36	0.10	0.47	0.23
2	<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2256	0.78	0.23	0.09	0.31	0.16
3	<i>Axonopus compressus</i> P.Beauv.	1052	0.77	0.11	0.08	0.19	0.09
4	<i>Centotheca lappacea</i> Desv.	928	0.84	0.09	0.09	0.18	0.09
5	<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	425	0.69	0.04	0.08	0.12	0.06
	Others						
	Total	9959	9.17	1.00	1.00	2.00	1.00

Note. D= Absolute density, F= Absolute frequency, RD= Relative density, RF= Relative frequency and IV= Important value.

The SDR values of weed species in the second sampling at integrated oil palm plantation ranged between 0.00 and 0.23. The highest SDR value recorded was *Scleromitrium verticillatum* with 0.23, *Cyrtococcum patens* var *latifolium*, *Axonopus compressus*, *Centotheca lappacea*, and *Torenia crustacea*. There were 12 species in the area with the least SDR value, which indicated uncommon within the area. *Callicarpa longifolia*, *Hyptis brevipes*, *Leea aculeata*, *Mallotus leucodermis*, *Sida rhombifolia*, and the complete list for species dominance can be seen in Appendix G2. Results showed that both samplings' top

five dominant weed species are similar. Three dominant species for both initial and second sampling are shown in Figures 4.1 to 4.3.



Figure 4.1: *Axonopus compressus* was one of the species that dominated the area in both initial and second sampling.



Figure 4.2: The dominant species in the area of both initial and second sampling, *Scleromitrium verticillatum*.



Figure 4.3: *Torenia crustacea* are one of the most dominant species in the area of the initial and second sampling.

4.2.2 Species Diversity of Weeds in Two Different Periods of Sampling in the Integrated Oil Palm Plantation Area

Species diversity indices for the two samplings exercise are summarized in Table 4.5. In initial sampling, the total number of individuals found was 10961, with 53 species. During the second sampling, which was conducted six months after the initial sampling, the number of individuals was lesser at 9959. However, the total number of species increased to 62. Shannon-Wiener Diversity Index (H') was higher in second sampling with an H' value of 2.11 than initial sampling with an H' value of 2.06 (Table 4.5). Results indicated that species diversity has increased after six months from the initial sampling. Even though the community in the initial sampling had a higher number of individuals, the number of species was lesser than the second sampling, where the number of individuals was lower, but the number of species was higher. Thus, the value of diversity H' differ. However, both H'

values are considered to show moderate community complexity (Bibi and Ali, 2013). The value of H' contributed by each species for both samplings was fully recorded in Appendix H1 and H2.

Table 4.5: Species diversity indices of initial and second samplings in the integrated oil palm plantation.

Sampling	Initial	Second
Number of Species	53	62
Number of Individuals	10961	9959
Shannon-Wiener's Diversity Index (H')	2.06	2.11
Simpson's Index of Diversity (1-D)	0.80	0.79
Margalef's Richness Index (R)	5.59	6.63
Pielou's Evenness Index (J')	0.52	0.51
Sorensen's Similarity Index (SI)	0.68	

For Simpson's Index of Diversity (1-D), initial sampling had the higher species diversity with a value of 0.80 compared to 0.79 for the samples collected in the second sampling at the same area of integrated oil palm plantation. As the value of 1-D for both samplings was closer to 1, it indicated that the area was considered high in species diversity. The higher the Simpson's Index value, the greater the sample diversity (Ghosh & Biswas, 2015). The index also represented the high possibility of two individuals randomly selected from a sample belonging to different species. Even though the Shannon-Wiener Diversity Index and Simpson's Index of Diversity are not similar in terms of diversity value, the function of both methods was used to explain the different parts of species diversity. Appendix H3 and H4 show the Simpson's Index (D) calculation for both sampling periods.

Margalef's Richness Index (R) estimated the species richness in both samplings. The species richness was higher in the second sampling than in the initial sampling at the same area of integrated oil palm plantation with an R-value of 6.63, which was different from the initial sampling with only 5.59.

The Pielou's Evenness Index (J') shows how evenly the individuals are distributed in a community. The initial sampling and second sampling showed the same distribution pattern with J' values at 0.52 and 0.51, respectively. Pielou's Evenness Index value ranged between 0 and 1. A value of 0 corresponded to a community of one species meant total dominance or no diversity. A value of 1 to a community indicated that all species were equally abundant (Izquierdo et al., 2009).

By species, results in the initial sampling showed that *Scleromitrium verticillatum* had the highest value of relative abundance, P that was 0.3449, followed by *Cyrtococcum patens* var. *latifolium* ($P = 0.2005$), *Centotheca lappacea* ($P = 0.1607$), *Axonopus compressus* ($P = 0.1058$), and *Torenia crustacea* ($P = 0.0384$) as can be seen in Appendix H1. The smallest value of P was 0.0001, shared by 13 species including *Antrophyum reticulatum*, *Blechnum orientale*, *Dicranopteris linearis*, *Cyrtophyllum fragrans*, *Ficus auriculata*, *Fimbristylis quinquangularis*, *Lygodium microphyllum*, *Macaranga* sp., *Curculigo latifolia*, *Oldenlandia corymbosa*, *Ploiarium elegans*, *Saurauia glabra*, and *Struchium sparganophorum*.

In the second sampling, the P-value of each species was also shown in Appendix H2 as the highest relative abundance was *Scleromitrium verticillatum* with relative abundance, (0.3608), next ranked with *Cyrtococcum patens* var. *latifolium*, *Axonopus compressus*, *Centotheca lappacea* and *Torenia crustacea* with P values 0.2265, 0.1056, 0.0932 and

0.0427, respectively. The least relative abundance value from 12 species with the same P-value of 0.0001 include *Callicarpa longifolia*, *Ficus aurata*, *Hyptis brevipes*, *Cyperus brevifolius*, *Lasianthus* sp., *Leea aculeata*, *Mallotus leucodermis*, *Piper betle*, *Rhynchospora corymbosa*, *Sacciolepis indica*, *Sida rhombifolia*, and *Urophyllum* sp.

The Sorensen's Similarity Index (SI) estimated was 0.68 and considered as a high similarity. It indicated high similarity between the initial and second sampling. Sorensen's Similarity Index measure the similarity between samples which accounted for composition only but not species abundance. It increases when two communities are similar in species composition and are limited between 0 and 1 (Jaunatre et al., 2013). A total of 76 species were enumerated for both initial samplings and after six months of initial sampling combined. There were 39 species similarly found in both samplings, including *Ageratum conyzoides*, *Axonopus compressus*, *Cyperus compressus*, *Diplazium esculentum*, *Ficus fulva*, and *Lygodium circinatum*, *Melastoma malabathricum*, *Miconia crenata*, *Scleromitrium verticillatum* and *Taenitis blechnoides*.

Fourteen species were recorded in initial sampling: *Antrophyum reticulatum*, *Blechnum orientale*, *Crassocephalum crepidioides*, *Exallage auricularia*, *Ficus auriculata*, *Fimbristylis quinquangularis*, *Flagellaria indica*, *Macaranga* sp., *Mikania micrantha*, *Oldenlandia corymbosa*, *Ploiarium elegans*, *Scleria sumatrensis*, *Timonius flavescens*, and *Vitex pinnata*. While, a total of 23 species were only found after six months of initial sampling, which saw an addition of nine species. The difference was due to the different times of sampling attributed to the grazing area by livestock, thus resulting in the addition of 9 species after six months. The species recorded include *Axonopus* sp., *Callicarpa longifolia*, *Camonea umbellata*, *Clerodendrum chinense*, *Commelina diffusa*, *Cyperus*

brevifolius, *Cyperus rotundus*, *Ficus aurata*, *Hedyotis* sp., *Hyptis brevipes*, *Leea aculeata*, *Mallotus leucodermis*, *Oenanthë javanica*, *Paederia foetida*, *Piper betle*, *Polytrias indica*, *Ramirezella strobilophora* var. *pubescens*, *Rhynchospora corymbosa*, *Sida rhombifolia*, *Smilax* sp., *Stenochlaena palustris*, *Uncaria elliptica*, and *Urophyllum* sp.

4.2.3 Growth Development of Weeds Species in Integrated Oil Palm Plantation

The species of weeds found in both sampling periods were grouped into seven groups based on their growth forms. Barnes and Chan (1990) produced the book *Common Weeds of Malaysia and Their Control* and divided the species into four sections, namely grass, sedges, broadleaved weeds, and ferns. However, in more detail in this study, the broadleaved weeds were divided into four groups to explicitly classify them into climber or creeper or vine, herbaceous, shrub, and tree. The result of this classification is summarized in Figure 4.4.

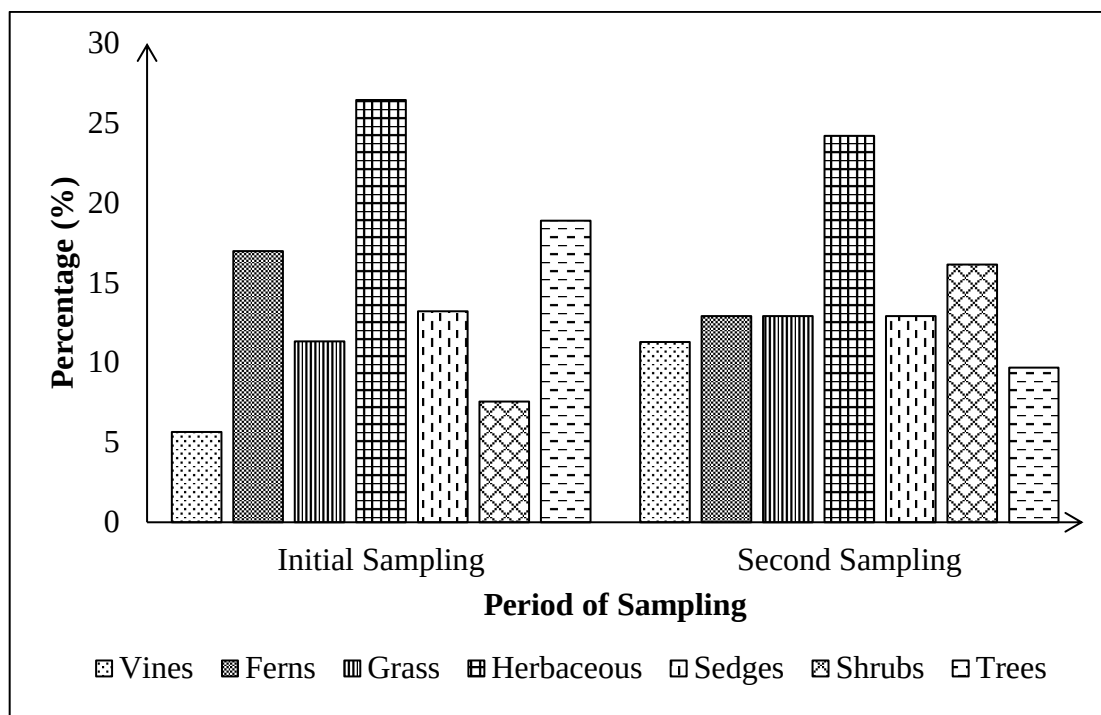


Figure 4.4: The weeds composition recorded during the initial and second sampling in the integrated oil palm plantation area.

Figure 4.4 showed that the herbaceous weeds recorded the highest percentage during the initial sampling with 26.42% or 14 species in total. Trees species ranked second in terms of composition with 18.87% or 10 species followed by ferns with 16.98% or nine species, sedges 13.21% or seven species, grasses 11.32% or six species followed by shrubs 7.55% or four species and vines with 5.66% a total number of 3 species.

Nine families with Asteraceae represented herbaceous plants with the highest species number, including *Ageratum conyzoides*, *Crassocephalum crepidioides*, and *Struchium sparganophorum*. Rubiaceae was represented by *Exallage auricularia*, *Oldenlandia corymbosa*, and *Scleromitron verticillatum*. Acanthaceae (*Asystasia gangetica* and *Asystasia* sp.), Commelinaceae (*Murdannia nudiflora*), Euphorbiaceae (*Phyllanthus amarus*), Hypoxidaceae (*Curculigo latifolia*), Lamiaceae (*Hyptis capitata*), Leguminosae (*Grona triflora*) and Scrophulariaceae (*Torenia crustacea*).

Trees species showed the second-high percentage found in the area and represented by eight families. It consisted of Moraceae (*Ficus auriculata* and *Ficus fulva*) and Euphorbiaceae (*Cleistanthus collinus* and *Macaranga* sp.) which 2 species contributed each family. Other families with only one species recorded include Actinidiaceae (*Saurauia glabra*), Arecaceae (*Elaeis guineensis*), Lamiaceae (*Vitex pinnata*), Loganiaceae (*Cyrtophyllum fragrans*), Rubiaceae (*Timonius flavescens*) and Theaceae (*Adinandra dumosa*).

Ferns recorded 7 families such as Schizaeaceae (*Lygodium circinatum*, *Lygodium flexuosum*, and *Lygodium microphyllum*), followed by Adiantaceae (*Taenitis blechnoides*), Blechnaceae (*Blechnum orientale*), Gleicheniaceae (*Dicranopteris linearis*), Oleandraceae (*Nephrolepis biserrata*) Vittariaceae (*Antrophyum reticulatum*) and Woodsiaceae (*Diplazium esculentum*). The sedges are represented by seven species of *Cyperus compressus*, *Cyperus distans*, *Cyperus* sp., *Eleocharis parvula*, *Fimbristylis dichotoma*, *Fimbristylis quinquangularis*, and *Scleria sumatrensis* all from Cyperaceae family.

The grasses recorded 6 species of Poaceae that showed the presence of *Axonopus compressus*, *Centotheca lappacea*, *Cyrtococcum oxyphyllum*, *Cyrtococcum patens* var. *latifolium*, *Paspalum conjugatum*, and *Sacciolepis indica*. The initial sampling also recorded three Melastomataceae with two species of *Miconia crenata* and *Melastoma malabathricum*. *Ploiarium elegans* (Clusiaceae), classified as a shrub or small tree, also recorded and the presence of *Lasianthus* sp. from Rubiaceae, a shrub that can be classified as a small tree. The least percentage recorded was from the vines group with three families, of which two families were climbers, Asteraceae (*Mikania micrantha*) and Flagellariaceae (*Flagellaria indica*) and one creeper from Mimosaceae (*Mimosa pudica*).

The herbaceous group dominated the sampling area in the second sampling, with 24.19% or 15 species of the 62 species. Shrubs formed 16.13% or 10 species enumerated. Ferns, grasses, and sedges are represented by 12.90% (8 species) each. Vines comprised 11.29% (7 species) and small trees composed of 9.68% or six species.

In terms of family, the herbaceous group is composed of 10 families, namely Acanthaceae (*Asystasia gangetica* and *Asystasia* sp.), Commelinaceae (*Commelina diffusa* and *Murdannia nudiflora*), Asteraceae (*Ageratum conyzoides* and *Struchium sparganophorum*), Lamiaceae (*Hyptis brevipes* and *Hyptis capitata*), Rubiaceae (*Scleromitron verticillatum* and *Hedyotis* sp.), Apiaceae (*Oenanthe javanica*), Euphorbiaceae (*Phyllanthus amarus*), Hypoxidaceae (*Curculigo latifolia*), Leguminosae (*Grona triflora*), and Scrophulariaceae (*Torenia crustacea*). The shrub group comprises seven families, such as Melastomataceae (*Miconia crenata* and *Melastoma malabathricum*) and Malvaceae (*Sida rhombifolia*). Lamiaceae with two species namely, *Clerodendrum chinense* and *Callicarpa longifolia*. Rubiaceae *Lasianthus* sp. and *Urophyllum* sp. Leeaceae with *Leea aculeata*. Euphorbiaceae with *Mallotus leucodermis* and Moraceae with *Ficus aurata*.

Ferns recorded six families with Schizaeaceae (*Lygodium circinatum*, *Lygodium flexuosum*, and *Lygodium microphyllum*), Adiantaceae (*Taenitis blechnoides*), Blechnaceae (*Stenochlaena palustris*, Gleicheniaceae (*Dicranopteris linearis*), Oleandraceae (*Nephrolepis biserrata*), and Woodsiaceae (*Diplazium esculentum*). Grass group or Poaceae family consisted of six species of *Axonopus compressus*, *Axonopus* sp., *Centotheca lappacea*, *Cyrtococcum oxyphyllum*, *Cyrtococcum patens* var. *latifolium*, *Paspalum conjugatum*, *Polytrias indica*, and *Sacciolepis indica*.

The sedges were from Cyperaceae family consisted of *Cyperus brevifolius*, *Cyperus compressus*, *Cyperus distans*, *Cyperus rotundus*, *Cyperus* sp., *Eleocharis parvula*, *Fimbristylis dichotoma*, and *Rhynchospora corymbosa*. The vines comprised of five families of climbers and creepers. For climbers, it is represented by five families that were Rubiaceae consisted of two species of *Paederia foetida*, and *Uncaria elliptica*, Convolvulaceae (*Camonea umbellata*), Leguminosae (*Ramirezella strobilophora* var. *pubescens*), Piperaceae (*Piper betle*), and Smilacaceae (*Smilax* sp.). There was only one creeper recorded which was Mimosaceae represented by *Mimosa pudica*.

4.3 Biomass and Carbon Stock of Weeds Species in Integrated Oil Palm Plantation

4.3.1 Biomass and Carbon Stock of Weeds Species in Initial Sampling at Integrated Oil Palm Plantation Area

The carbon stock was estimated by first estimating the biomass, then multiplying dry weight biomass with 0.47. The top five weed species with greatest values of biomass, carbon stock and carbon per ha is given in Table 4.6. The complete list of weed species and their estimated biomass carbon content is provided in Appendix I1.

Table 4.6: Five highest biomass and carbon stock of weeds species in the initial sampling at integrated oil palm plantation area.

Rank	Species	Total Biomass Sampled in 100 Quadrates (kg)	Carbon Stock in 100 Quadrates (kg) (Biomass × 0.47)	Estimated of Carbon (kg/ha)
1	<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3.70	1.74	174.01
2	<i>Miconia crenata</i> (Vahl) Michelang.	0.81	0.38	38.15
3	<i>Centotheca lappacea</i> Desv.	0.77	0.36	36.30
4	<i>Axonopus compressus</i> P.Beauv.	0.70	0.33	33.04
5	<i>Taenitis blechnoides</i> (Willd.) Sw.	0.68	0.32	31.82
	Others			
	Total	9.10	4.28	427.68
				0.43 tonne/ha

In initial sampling, the total weed samples accounted for about 9.10 kg of dry weight biomass with 4.28 kg of carbon. In one ha, it was estimated that the biomass accumulated 427 kg or 0.43 tonne of carbon. In terms of species, the highest dry biomass obtained was

by *Scleromitron verticillatum*, with a total of 3.70 kg. *Miconia crenata* was the second highest with 0.81 kg, followed by *Centotheca lappacea*, *Axonopus compressus*, and *Taenitis blechnoides* with a total of 0.77, 0.70, and 0.68 kg, respectively. The least amount of biomass was obtained by *Struchium sparganophorum*, *Oldenlandia corymbosa*, *Curculigo latifolia*, *Fimbristylis quinquangularis*, and *Dicranopteris linearis*.

Although shrubs were small in numbers, they recorded high biomass values. For instance, *Adinandra dumosa* and *Lasianthus* sp. with only three individuals recorded dry biomass of 37.81 g and 24.15 g, respectively.

4.3.2 Biomass and Carbon Stock of Weeds Species in Second Sampling at the Integrated Oil Palm Plantation Area

The top five highest biomass and carbon stock according to species in the second sampling is given in Table 4.7. The complete list of species with their respective biomass and carbon stock is given in Appendix I2.

Table 4.7: Five highest biomass and carbon stock of weeds species in the second sampling at integrated oil palm plantation area.

Rank	Species	Total Biomass Sampled in 100 Quadrates (kg)	Carbon Stock in 100 Quadrates (kg) (Biomass × 0.47)	Estimated of Carbon (kg/ha)
1	<i>Scleromitrion verticillatum</i> (L.) R.J.Wang	3.68	1.73	172.74
2	<i>Taenitis blechnoides</i> (Willd.) Sw.	0.78	0.37	36.61
3	<i>Miconia crenata</i> (Vahl) Michelang.	0.62	0.29	29.15
4	<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	0.60	0.28	28.26
5	<i>Melastoma malabathricum</i> L.	0.55	0.26	25.95
	Others			
	Total	8.79	4.13	412.89
				0.41 tonne/ha

The total of weed species contributed a total of 8.8 kg of dry biomass. They represent about 4.13 kg of estimated carbon, and in one ha, they contain approximately 412 kg or 0.41 tonne of carbon. In terms of species, *Scleromitron verticillatum* recorded total biomass of 3.68 kg followed by *Taenitis blechnoides* with 0.78 kg, *Miconia crenata*, *Cyrtococcum patens* var. *latifolium*, and *Melastoma malabathricum* with total biomass 0.62 kg, 0.60 kg, and 0.55 kg, respectively. The least biomass was *Axonopus* sp. followed by *Fimbristylis dichotoma*, *Rhynchospora corymbosa*, *Saurauia glabra* and *Sacciolepis indica*.

Although vines and shrubs had few individuals, they recorded high biomass. For instance, tropical vine *Uncaria elliptica* recorded only three individuals, but the total biomass was 49.58 g. Shrub species of *Leea aculeata* recorded 7.75 g of biomass with just a single individual. Another shrub *Adinandra dumosa* weighed 30.38 g for four individuals, and *Hyptis capitata* at 46.05 g for seven individuals.

4.3.3 Estimated Biomass and Carbon Stock of Two Different Periods of Sampling

Table 4.8 below shows the comparison of biomass, estimated carbon stock, and estimated carbon stock per hectare between the two different sampling periods in an integrated oil palm plantation.

Table 4.8: Total of biomass and estimated carbon in kg and total of estimated carbon stock and the estimated carbon stock per hectare of two different periods of samplings in an integrated oil palm plantation.

Biomass and Carbon Stock	Sampling period	
	Initial	Second
Total Biomass Sampled in 100 Quadrates (kg)	9.10	8.79
Carbon Stock in 100 Quadrates (kg) (Biomass × 0.47)	4.28	4.13
Estimated of Carbon (tonne/ha)	0.43	0.41

Results indicated that the initial sampling recorded a higher biomass and carbon stock than the second sampling. However, the differences are not significantly different. (Table 4.8)

4.4 Forage Recovery of Selected Species

There were three preferred plant species forage by livestock in the integrated oil palm plantation area. *Axonopus compressus*, *Elaeis guineensis* (growth freely on the ground) and *Antrophyum reticulatum*.

4.4.1 Forage Recovery of *Axonopus compressus*

4.4.1.1 Height of Grazed *Axonopus compressus* in Opened Area of Integrated Oil Palm Plantation

The recovery of *Axonopus compressus* in the opened area in terms of growth in height due to livestock grazing is presented in Figure 4.5. *Axonopus compressus* began to

t from day 0 to 3 after grazing, where the highest increase of the mean height can be seen with a total increment of 0.9 cm. Sprouting started to slow down on day 12. Complete data of *A. compressus* sprouting after grazing in the open area is given in Appendix J1. The statistical analysis showed significant differences in the height of samples with the day observed. A significant difference was found between days 0 and 9, 0 and 12, 0 and 15, 0 and 18, 3 and 12, and 3 and 15.

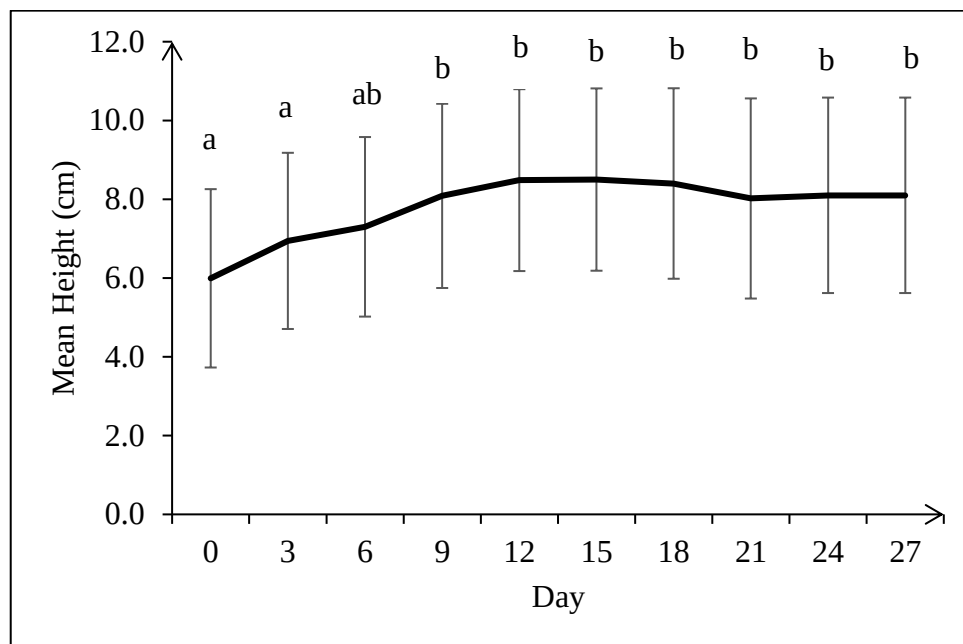


Figure 4.5: Mean height (cm) of grazed *Axonopus compressus* in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.1.2 Height of Ungrazed *Axonopus compressus* in Opened Area of Integrated Oil Palm Plantation

The mean height of *Axonopus compressus* recovery in the opened area for ungrazed samples is presented in Figure 4.6. Significant growth was observed from day 0 to 3 with about 3 cm of growth, and the growth continued until day 21. Details of growth data of ungrazed *Axonopus compressus* is provided in Appendix J2. In this study, the difference was

significant for the height of samples in day observed it was found on days 0 and 9, 0 and 12, 0 to 15, 0 and 18, 0 and 21, 0 and 24, 3 and 12, 3 and 15, 3 and 18, 3 and 21, 3 and 24, and 6 and 21.

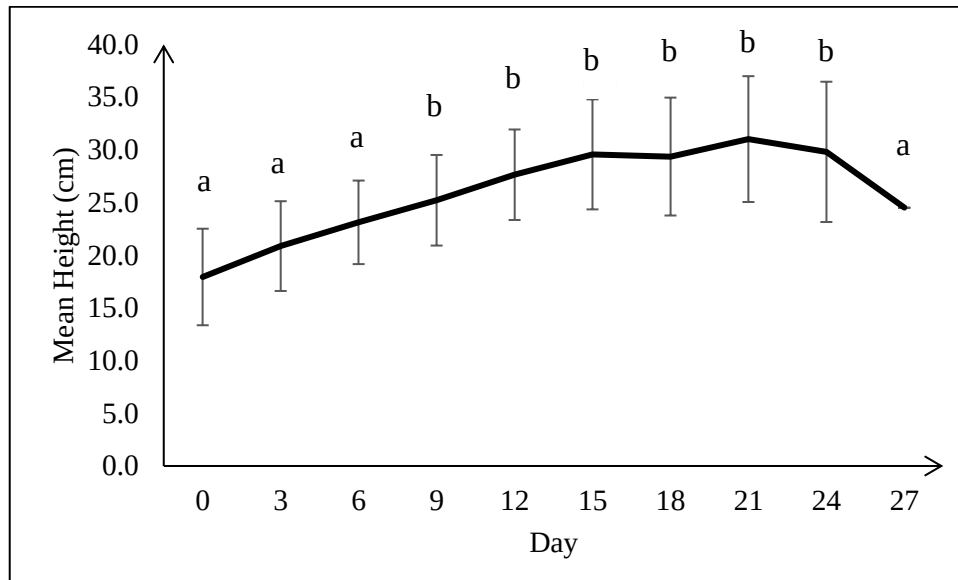


Figure 4.6: Mean height (cm) of ungrazed *Axonopus compressus* in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.1.3 Height of Cut *Axonopus compressus* in Opened Area of Integrated Oil Palm Plantation

The recovery of *Axonopus compressus* in the opened following cut treatment is presented in Figure 4.7. The highest mean height increase was at days 3 and 6 from 4.7 cm and 6.4 cm with 17 cm increment. The increase in height continued until day 21. Overall, there was a 60.4% increase in size from day 0 and day 27. Appendix J3 provides the detail of *Axonopus compressus* height growth in the opened following cut treatment. There were significant differences in the height of samples on the day of observation. Statistical analyses showed that the significant difference of height was found in the sample on day 0 and 6, 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 6, 3 and 9, 3 and 12,

3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 12, 6 and 15, 6 and 18, 6 and 21, 6 and 24, and 6 and 27.

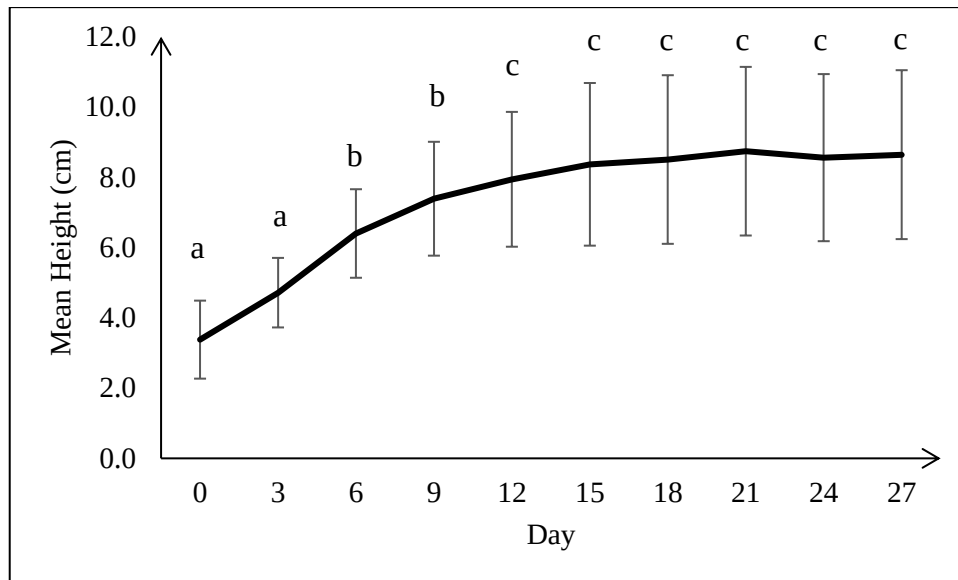


Figure 4.7: Mean height (cm) of *Axonopus compressus* following cut treatment in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.1.4 Height of Cut *Axonopus compressus* in Shaded Area of Integrated Oil Palm Plantation

The recovery of *Axonopus compressus* in the shaded area for cut treatment is shown in Figure 4.8. Mean height showed a rapid increase from day 0 and 3, from 3.0 and 5.1 cm with a 2.1 cm increment. It then continued to increase until day 24 and up to day 27. Complete observation of this study is attached in Appendix J4. The total increment of mean height from day 0 and 27 was about 72.4%. Statistical analyses showed that there were differences in mean with respect to day. Height of sample was significantly different on day 0 and 6, 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 6, 3 and 9, 3 and 12, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 15, 6 and 18, 6 and 21, 6 and 24, and 6 and 27.

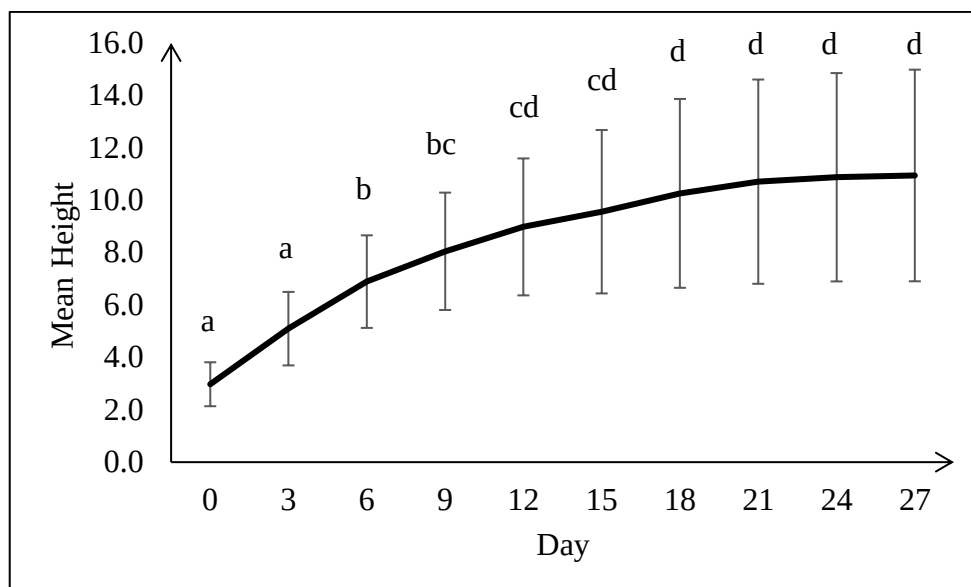


Figure 4.8: Mean height (cm) of *Axonopus compressus* following cut treatment in the shaded area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.2 Forage Recovery for *Elaeis guineensis*

4.4.2.1 Height of Grazed *Elaeis guineensis* in Opened Area of Integrated Oil Palm Plantation

Recovery of *Elaeis guineensis* in the opened area that was grazed by livestock is presented by Figure 4.9. The recovery pattern of *Elaeis guineensis* shows that the mean height increased from day 0 to 27. The largest height growth was from day 0 to 3 and day 6 to 9 by mean height 7.0 to 8.2 cm and 9.2 to 10.4, respectively, with 1.2 cm increment. Mean height from day 9 to 27 showed a gradual increase. Appendix J5 shows the full results of grazed *Elaeis guineensis*. The percentage of the increased mean height from day to 0 to 27 was 43.55%. There were significant differences between mean height among that among the days observed. Statistical analyses showed that there were significant differences for height between day 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 9, 3

and 12, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 15, 6 and 18, 6 and 21, 6 and 24 and 6 and 27.

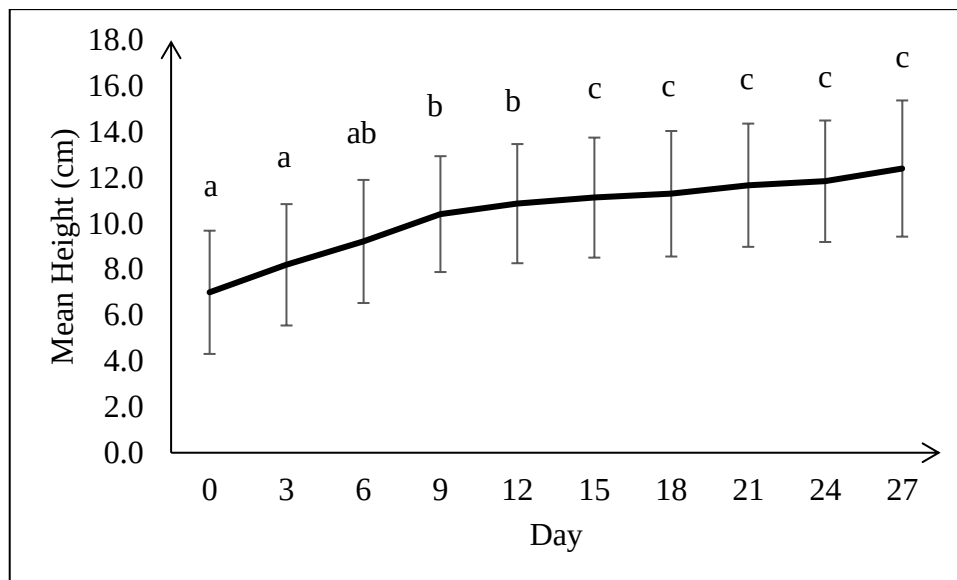


Figure 4.9: Mean height (cm) of grazed *Elaeis guineensis* in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.2.2 Height of Ungrazed *Elaeis guineensis* in Opened Area of Integrated Oil Palm Plantation

Mean height of ungrazed *Elaeis guineensis* in the opened area is shown in Figure 4.10. Mean height increased from day 0 to 27. The highest increase was from day 0 to 3 and day 6 to 9 by mean height 7.0 to 8.2 cm and 9.2 to 10.4, respectively, with 1.2 cm increment. Mean height increment was small from day 9 to 27. The mean height increased from day 0 to 27 was 43.55%. Complete data is given in Appendix J6. There was a significant difference between the height of samples in days observed. The statistical analysis showed that there was a significant difference for height in the sample that was observed on days 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 27.

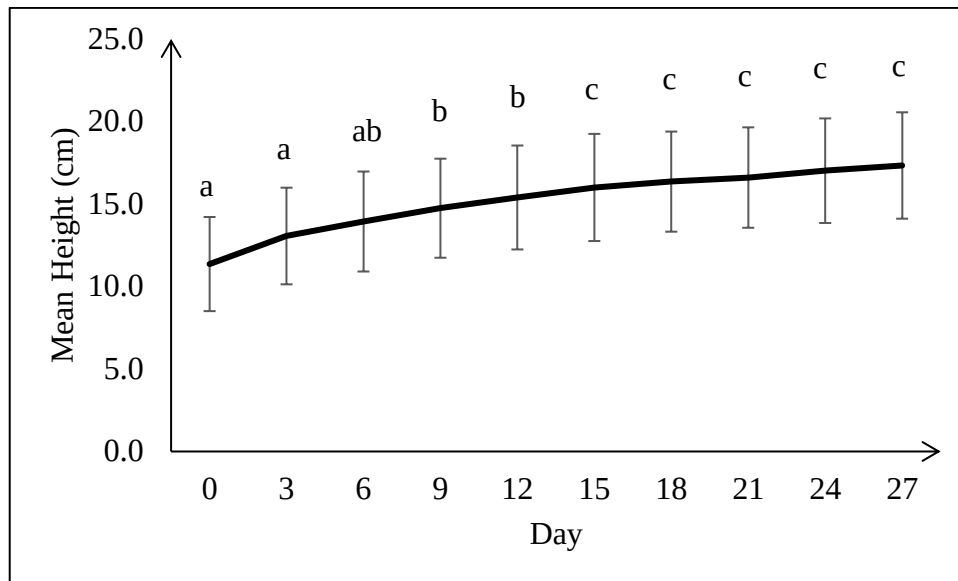


Figure 4.10: Mean height (cm) of ungrazed *Elaeis guineensis* in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.2.3 Height of Cut *Elaeis guineensis* in Opened Area of Integrated Oil Palm Plantation

Recovery of cut *Elaeis guineensis* in the opened area in 27 days is presented in Figure 4.11. The mean height gradually increased from day 0 until day 27, and the highest mean height increased was at day 0 to 3, 3 to 6 and 15 to 18 with 9.1 to 10.5 cm, 10.5 to 11.9 cm and 14.8 to 16.2 cm, respectively. Complete growth data is provided in Appendix J7. Significant differences of height were observed between day 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 12, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 18, 6 and 21, 6 and 24, 6 and 27, 9 and 18, 9 and 21, 9 and 24, 9 and 27, 12 and 24, and 12 and 27.

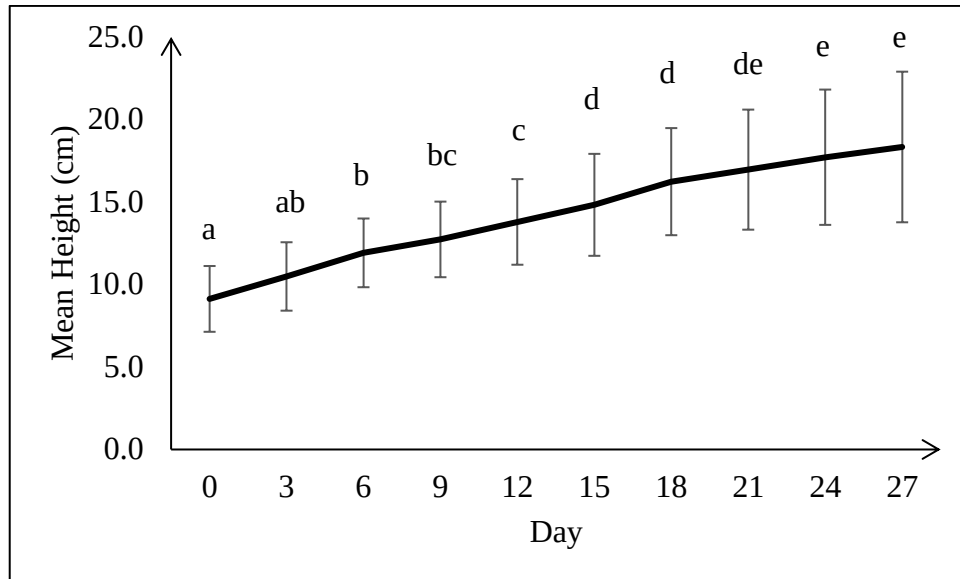


Figure 4.11: Mean height (cm) of cut *Elaeis guineensis* in the opened area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.2.4 Height of Cut *Elaeis guineensis* in Shaded Area of Integrated Oil Palm Plantation

The species recovery of cut *Elaeis guineensis* in the shaded area is shown in Figure 4.12. The mean height was increasing with days, and the highest increment was on day 3 to 6 from 9.3 to 10.3 cm. The full result is in Appendix J8. The statistical analysis showed that the height of samples was significantly different between day 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 24, 6 and 27, 9 and 24, and 9 and 27.

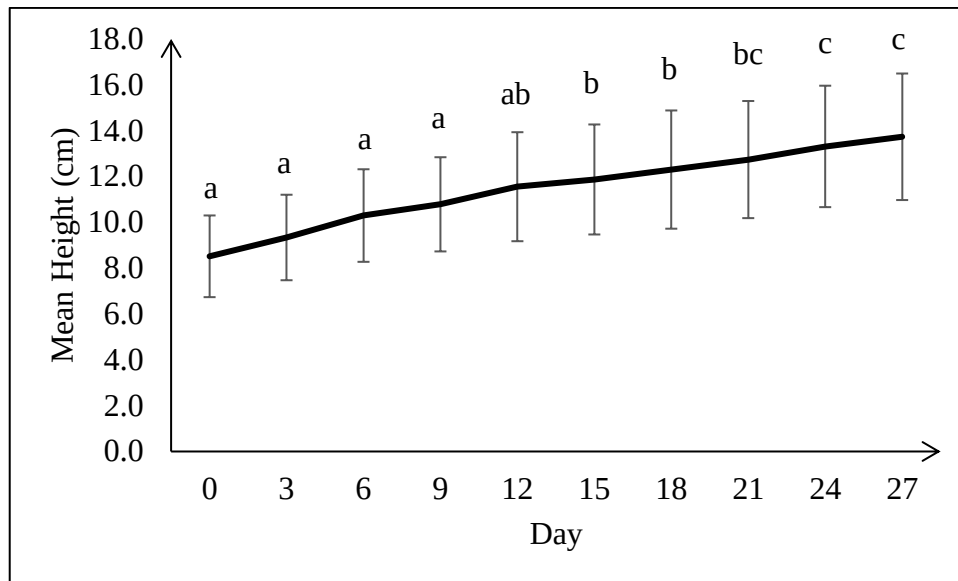


Figure 4.12: Mean height (cm) of cut *Elaeis guineensis* in the shaded area in 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.3 Species Recovery for *Antrophyum reticulatum*

A fern species, *Antrophyum reticulatum*, that grow on oil palm trunk, was one of the preferred weed species consumed by cattle. After being grazed by cattle and cut, this species' recovery in 27 days is presented in Figure 4.13 and Figure 4.14, respectively. It was observed that some of the shoots were damaged, and the samples were recorded until the final day of observation before it damaged.

4.4.3.1 Total Number of *Antrophyum reticulatum* New Shoot After being Grazed for 27 days

Antrophyum reticulatum is an epiphytic fern that lives on an oil palm trunk is a forage source for livestock. The recovery of this fern species in terms of sprouted new shoots after being grazed is presented in Figure 4.13. Complete data is provided in Appendix J9. Analyses showed that were significant differences in the number of new shoots between

days 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 21, 6 and 24, 6 and 27, 9 and 24, 9 and 27, and 12 and 27.

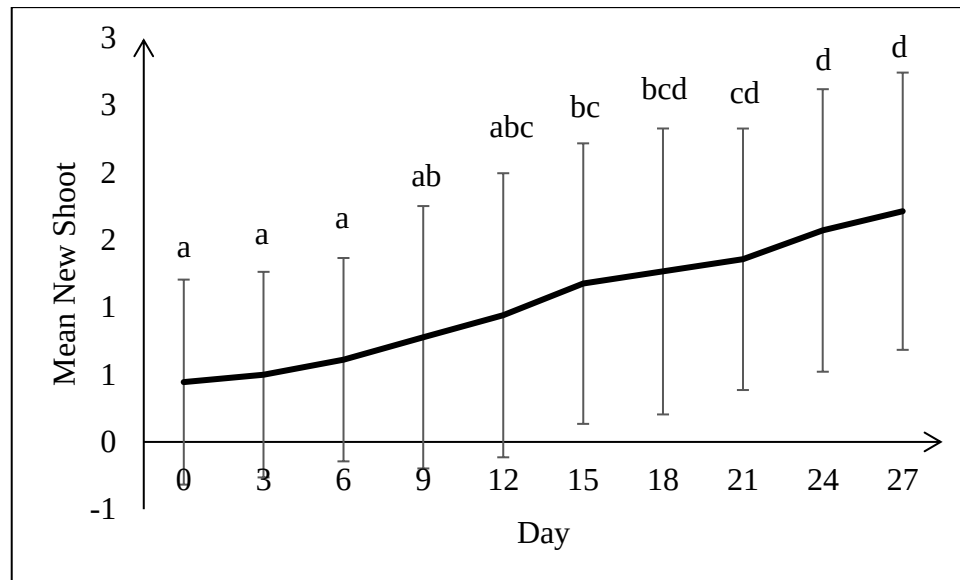


Figure 4.13: Total number of new shoots of *Antrophyum reticulatum* on oil palm trunk after being grazed for 27 days. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.3.2 Total Number of *Antrophyum reticulatum* New Shoot after 27 days Cutting Treatment

The recovery of the *Antrophyum reticulatum* 27 days after cutting is shown in Figure 4.14. The number of new shoots increased over time. Appendix J10 shows the complete results of *Antrophyum reticulatum* recovery 27 days after cutting. The statistical analysis showed significant differences in the number of new shoot between day 0 and 6, 0 and 9, 0 and 12, 0 and 15, 0 and 18, 0 and 21, 0 and 24, 0 and 27, 3 and 6, 3 and 9, 3 and 12, 3 and 15, 3 and 18, 3 and 21, 3 and 24, 3 and 27, 6 and 18, 6 and 21, 6 and 24, 6 and 27, 9 and 24, and 9 and 27.

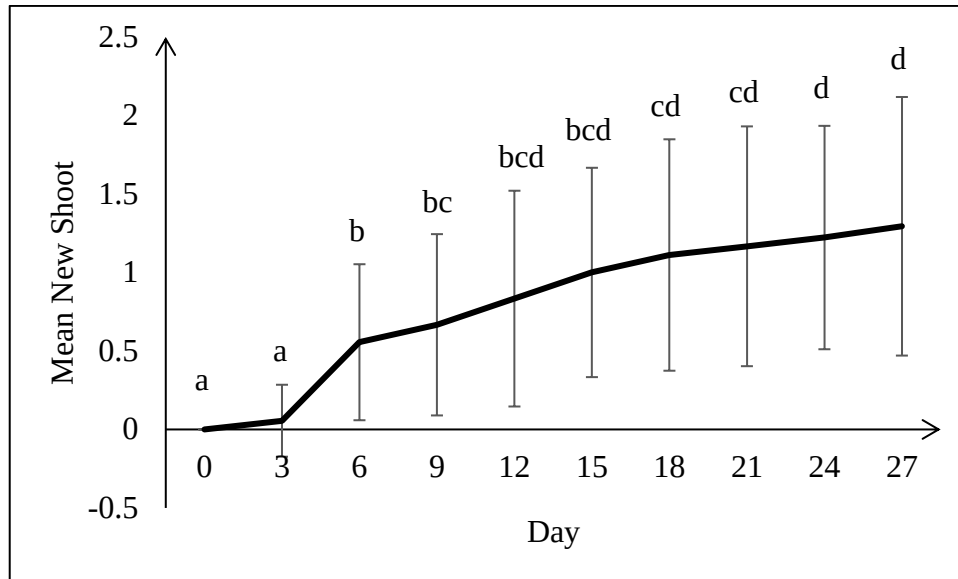


Figure 4.14: Total number of new shoots of *Antrophyum reticulatum* after 27 days cutting treatment. Means with the same letter are not significantly different. Error bar represents the standard deviation of the mean.

4.4.4 Comparison of Species Recovery for *Axonopus compressus*, *Elaeis guineensis*, and *Antrophyum reticulatum* in Different Factors

4.4.4.1 Comparison of Species Recovery for *Axonopus compressus*

The comparisons of species recovery were demonstrated in the graphs as provided in Figure 4.15 and 4.16.

4.4.4.1.1 Comparison of Recovery in the Opened Area between Grazed, Cut, and Ungrazed *Axonopus compressus*

The recovery of *Axonopus compressus* in terms of height for grazed, cut, and ungrazed samples are shown in Figure 4.15. The pattern of mean height increase was similar, but the difference in height recovery was different for grazed, cut, and ungrazed significantly. Furthermore, statistical analysis showed no significant difference in height between grazed and cut *Axonopus compressus* in the opened area. This indicates that the

recovery of *Axonopus compressus* do not differ between grazed and cut treatment. While the height of ungrazed *Axonopus compressus* was higher from day 0 to day 27 than the grazed sample. Statistical analysis showed that the height of ungrazed *Axonopus compressus* is significantly higher than the grazed samples. The cut and ungrazed *Axonopus compressus* differed in height recovery, whereas in statistical analysis, ungrazed was higher compared to cut significantly.

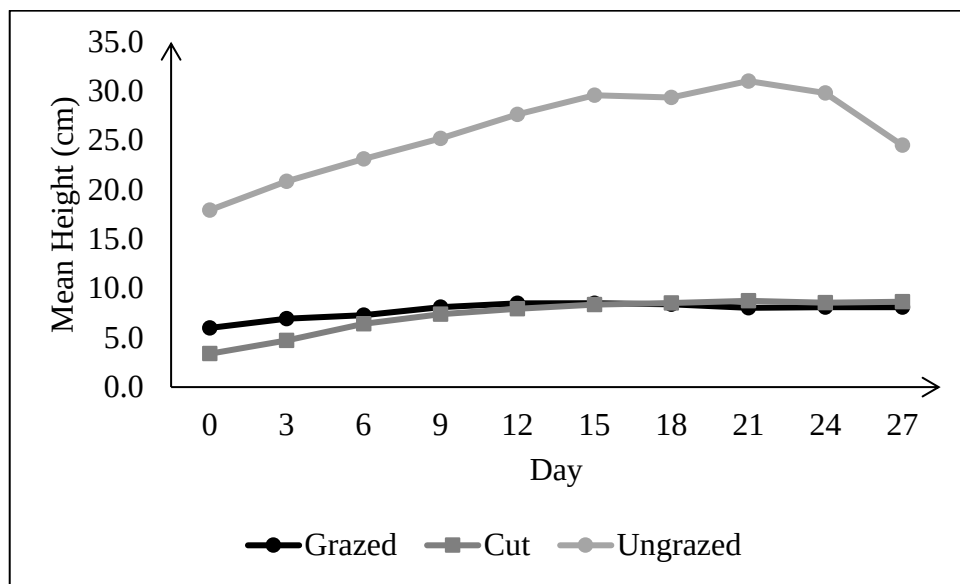


Figure 4.15: Mean height of recovery in the opened area for grazed, cut, and ungrazed *Axonopus compressus*.

4.4.4.1.2 Comparison of *Axonopus compressus* Recovery of Cut Treatment between Opened and Shaded Areas

Figure 4.16 shows growth in the height of cut *Axonopus compressus* in shaded and open areas. The increased height of cut *Axonopus compressus* between open and the shaded regions was similar for the first 12 days. From day 15 onwards, *Axonopus compressus* in the shaded areas continued to grow; however, no further growth was observed in the opened

areas. Overall, cut *Axonopus compressus* in shaded is significantly higher in terms of height recovery rather than opened area.

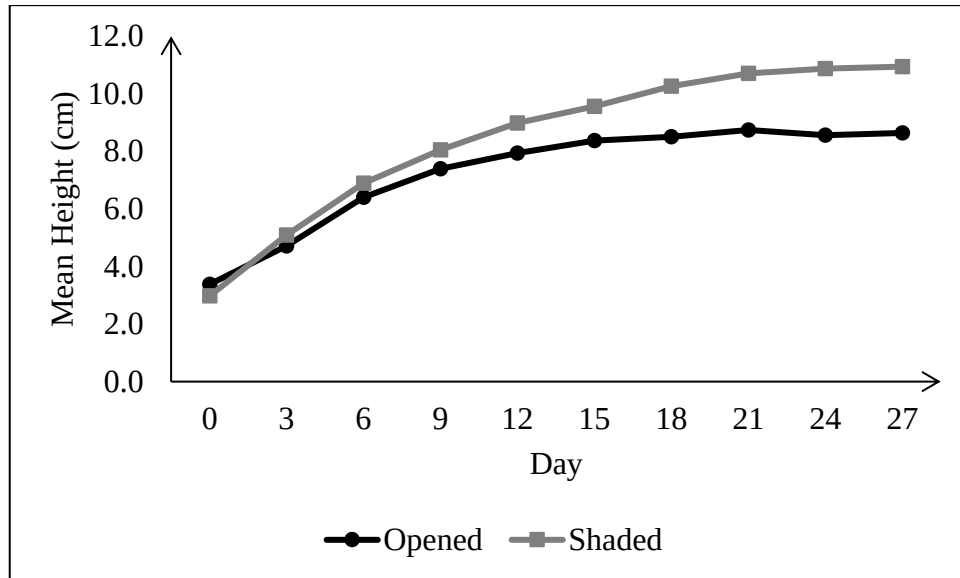


Figure 4.16: Comparison of the mean height of cut *Axonopus compressus* between opened and shaded area.

4.4.4.2 Comparison Recovery for *Elaeis guineensis*

The recovery comparisons for *Elaeis guineensis* were presented in Figures 4.17 and 4.18.

4.4.4.2.1 Comparison of Recovery for Grazed, Cut, and Ungrazed *Elaeis guineensis* in Opened Area

The mean height of grazed and ungrazed *Elaeis guineensis* in the opened area, as shown in Figure 4.17, indicated the same growth trend with the increase of height. The height of recovery for grazed, cut, and ungrazed differ significantly. From day 15 to day 27, the growth rate of cut was more rapid than the grazed *Elaeis guineensis*. Statistical analysis showed a significant difference in height between grazed and cut *Elaeis guineensis* in the

opened area. This result indicated that recovery was affected by how *Elaeis guineensis* was cropped in extended areas. Recovery is slower for grazed than cut *E. guineensis* in opened areas.

Statistical analysis showed that ungrazed *Elaeis guineensis* height was significantly higher than grazed *E. guineensis*. This result indicated that the growth in height was affected by cattle grazing. The statistical analysis also showed that the ungrazed *Elaeis guineensis* difference significantly with cut in height recovery.

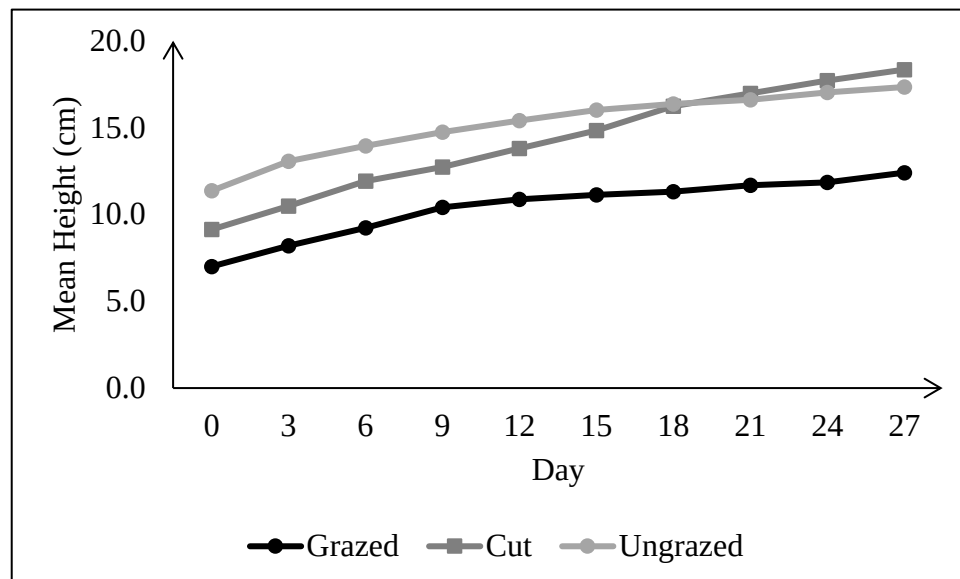


Figure 4.17: Comparison of the mean height of grazed, cut, and ungrazed *Elaeis guineensis* in the opened area.

4.4.4.2.2 Comparison of *Elaeis guineensis* Recovery for Cut Treatment in Opened and Shaded Areas

Figure 4.18 shows the mean height of *Elaeis guineensis* that were cut in opened and shaded areas. The growth rate in the opened area showed a faster increase in height than the shaded area, and statistical analysis showed that opened area significantly resulted in higher height.

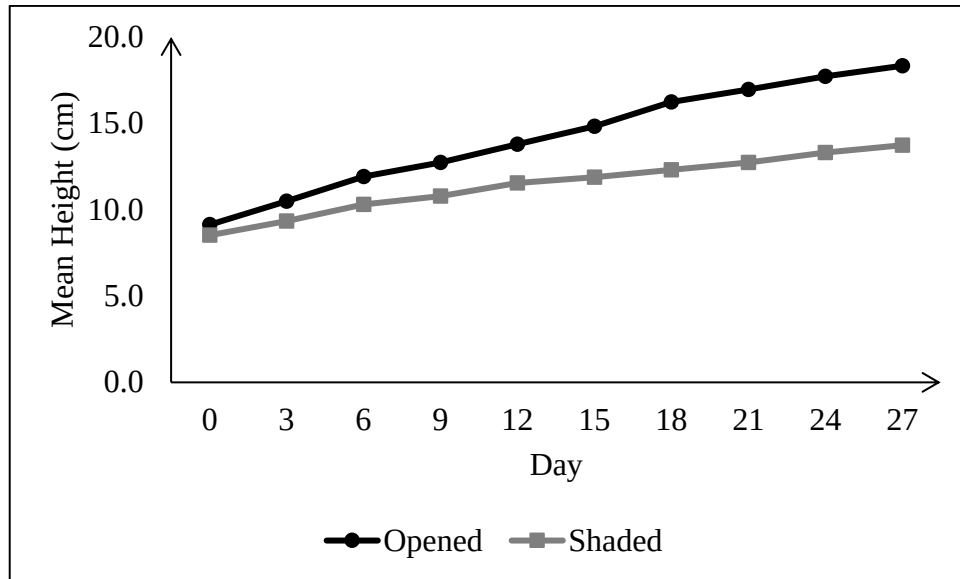


Figure 4.18: Comparison of the mean height of *Elaeis guineensis* for cut treatment in the opened and shaded areas.

4.4.4.3 Comparison Recovery for Grazed and Cut *Antrophyum reticulatum*

Based on the observation of new shoots growth, the recovery of *Antrophyum reticulatum* was compared between grazed and cut treatment samples (Figure 4.19).

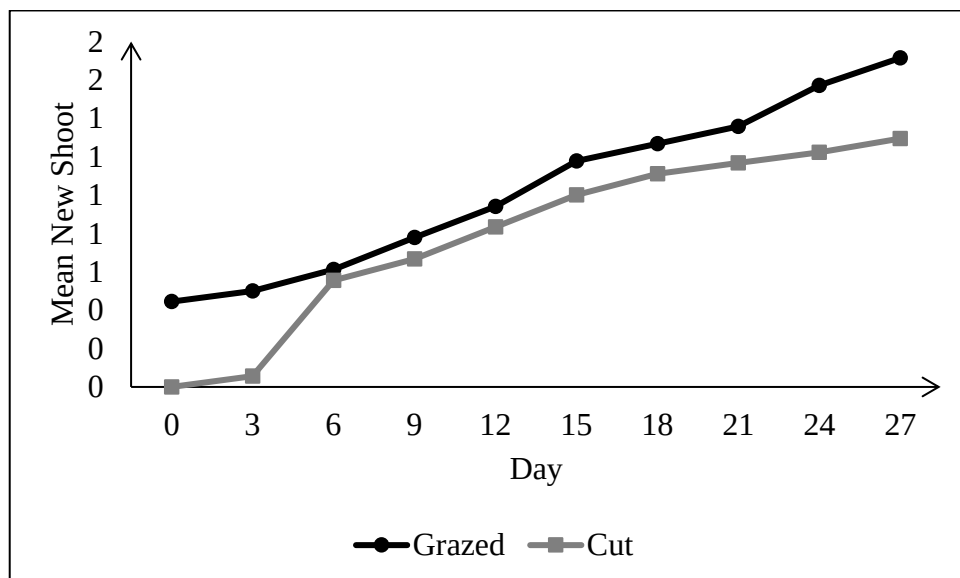


Figure 4.19: Comparison of new shoots between grazed and cut *Antrophyum reticulatum*.

The recovery of *Antrophyum reticulatum* trend between grazed and cut look similar. However, statistical analysis showed a significant difference between new shoots between grazed and cut *Antrophyum reticulatum*. This suggests that grazed and cut differed in *Antrophyum reticulatum* recovery in producing new shoots.

4.5 Forages Preferred by Livestock between Cut and Uncut *Axonopus compressus* in the Rotation Grazing System

4.5.1 Forage Preference for Cut Treatment

Figure 4.20 shows the mean percentage of cut forage that was grazed by livestock in 30 days. The highest mean rate was from day 30 to 32. The mean percentage started to increase from day 18 to 20 until the end of the day observed. There was a sharp increase on day 13 to 15; then it dropped from day 15 to 20. Subsequently, from day 23, the percentage increased gradually and reached the maximum on days 30 to 32. Statistical analysis showed that the percentage of forage grazed by livestock in days observed was significantly different and from statistical analysis, the percentage of forage grazed was significantly different on day (0 to 1) to (13 to 15), (0 to 1) to (28 to 30), (0 to 1) to (30 to 32), (4 to 5) to (13 to 15), (4 to 5) to (28 to 30), (4 to 5) to (30 to 32), (8 to 10) to (30 to 32), (9 to 12) to (30 to 32), and (18 to 20) to (30 to 32).

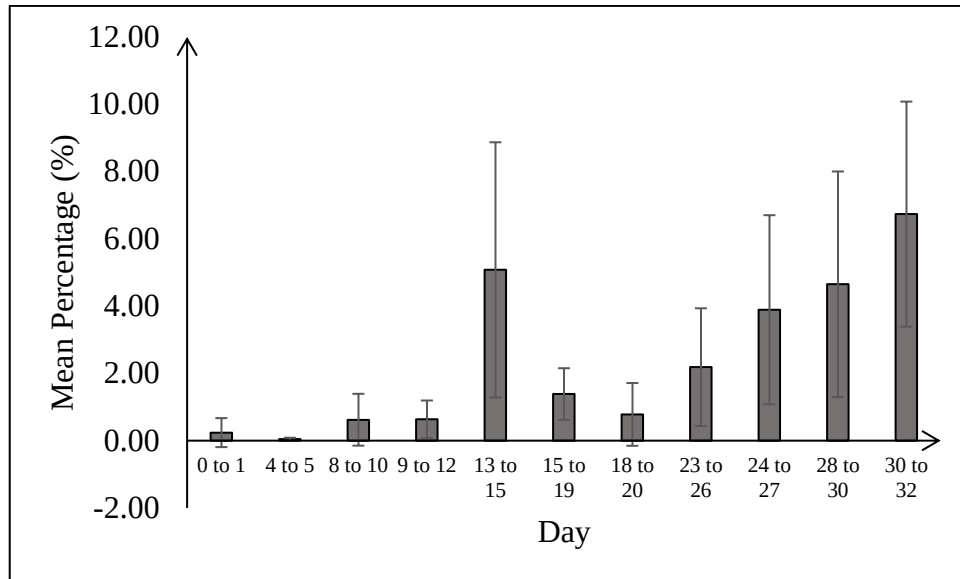


Figure 4.20: Mean percentage (%) of forage grazed by livestock with cut treatment.

4.5.2 Forage Preference for Uncut

Figure 4.21 shows the mean percentage of forage grazed by livestock with uncut forage. The highest mean rate was from day 13 to 15. Then, it decreased at day 15 to 19 and gradually increased from day 23 until day 32. Statistical analysis does not show any significant differences among the percentage of forage grazed in days observed. Figure 4.21 is presented the mean percentage of forage grazed by livestock without treatment (uncut).

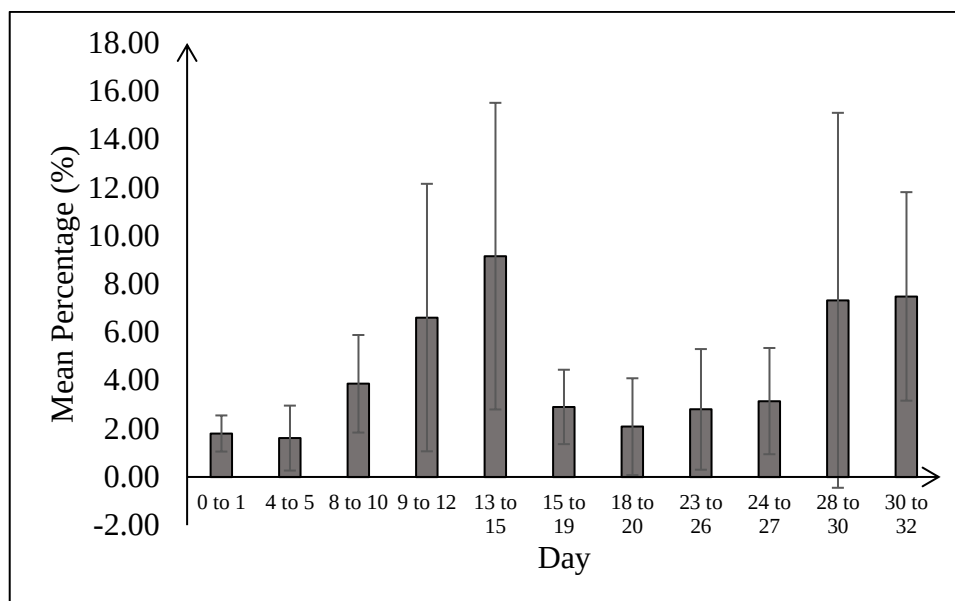


Figure 4.21: Mean percentage (%) of forage grazed by livestock without treatment in the total day of forage left.

4.5.3 Comparison of Forage Preference for Cut and Uncut

This study showed the response of the cattle to the cut and uncut *Axonopus compressus*. The percentage for each square was recorded in Appendix K1. Overall, the forage of *Axonopus compressus*, which was preferred by livestock, is clearly shown in Figure 4.22 below. Visually, the control or uncut forages were more favoured by livestock based on the percentage of grazing. The mean percentage of samples grazed by livestock was higher in uncut forages except for day 24 to 27. It shows the mean percentage had increased on day 0 to 1 until day 13 to 15 and suddenly decreased from day 13 to 15 until day 18 to 20 before it started to increase again until the end of the day observation period on day 30 to 32. Statistical analysis based on the results of percentages recorded for each square of cut and uncut forages showed a significant difference for a percentage of forage grazed by livestock between cut and uncut forage at day 0 to 1, day 4 to 5, day 8 to 10. Meanwhile,

there was no significant difference in the percentage of forage grazed by livestock at day 9 to 12, 13 to 15, 15 to 19, 18 to 20, 23 to 26, 24 to 27, 28 to 30 and 30 to 32.

Statistical analysis of the percentages of cut and uncut forage grazed by livestock showed a significant difference in the cut and uncut forage of *Axonopus compressus*. Results showed that the rate of uncut forage was higher than the cut forage, which suggests that forage preferred by livestock was affected by the uncut and cut treatment.

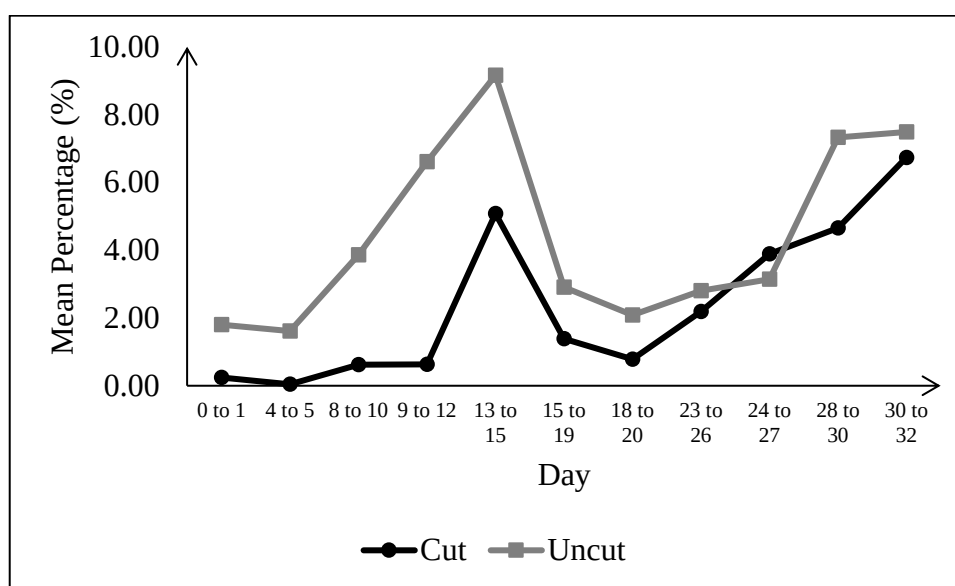


Figure 4.22: Comparison of the mean percentage of forage preferred by livestock for cut and uncut samples of *Axonopus compressus*.

4.6 Elemental Analysis for the Selected Forages Species and Toxicity Analysis for Selected Weeds Species Presented in the Area of Integrated Oil Palm Plantation

4.6.1 Elemental Analysis for Selected Forages Species

This study was intended to show the amounts of elements contained in the selected species of forages that were consumed by livestock. Table 4.9 shows the results of the elemental analysis.

Table 4.9: Elemental composition of selected forages.

Parameter	<i>Axonopus compressus</i> P.Beauv.	<i>Elaeis guineensis</i> Jacq.	<i>Antrophyum reticulatum</i> (Forst.) Kaulf.	<i>Asystasia gangetica</i> (L.) T.Anderson	<i>Scleromitrium verticillatum</i> (L.) R.J.Wang
Nitrogen (N%)	1.4	1.3	1.4	1.5	1.5
Phosphorus (as P%)	0.1	0.1	0.4	0.3	0.2
Potassium (K%)	1.1	1.8	4.2	1.7	3.6
Magnesium (Mg%)	Not Detected (<0.1)	0.3	0.4	0.3	0.7
Sulphate (S%)	0.05	0.04	0.32	0.06	0.05
Sodium (Na%)	0.02	0.03	0.03	0.03	0.09

The species include *Axonopus compressus*, *Elaeis guineensis* (grow freely on the ground), *Antrophyum reticulatum*, *Asystasia gangetica*, and *Scleromitrium verticillatum*. The six elements chosen include N, P, K, Mg, S and Na. The amount of elements detected in per cent in the selected species is shown in Figure 4.23.

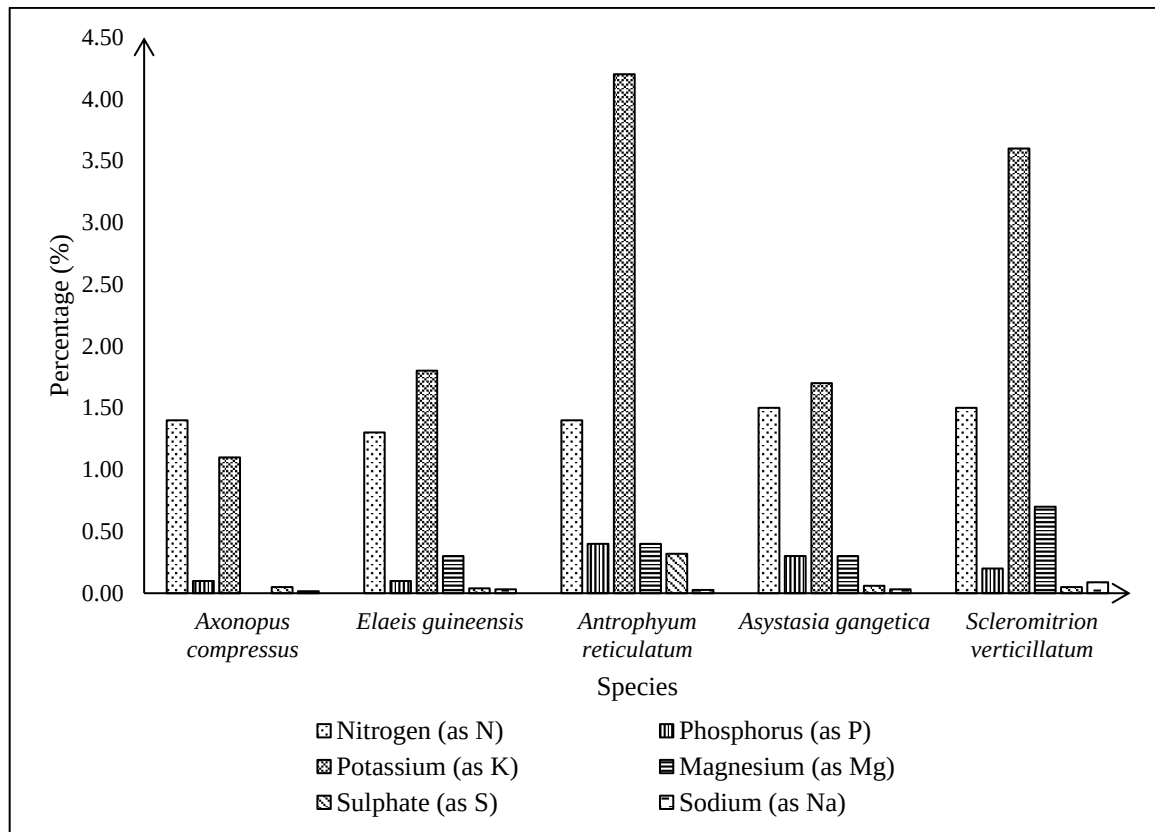


Figure 4.23: The percentage of the selected elements (Nitrogen as N, Phosphorus as P, Potassium as K, Magnesium as Mg, Sulphate as S, and Sodium as Na) was detected in five preferred forage species; *Axonopus compressus*, *Elaeis guineensis*, *Antrophyum reticulatum*, *Asystasia gangetica*, and *Scleromitrium verticillatum*.

There were insignificant differences in the percentage of elements detected in the five forages (Figure 4.23). Potassium (K) were found as the highest quantities in *Antrophyum reticulatum* and *Scleromitrium verticillatum*, *Elaeis guineensis* and *Asystasia gangetica* except for *Axonopus compressus*. N content was the second-highest found in all species except for *Axonopus compressus*, which is the highest. The other elements of P, Mg, S, and Na were found in small quantities for all of the species.

4.6.2 Toxicity Analysis for Selected Weeds Species

The heavy metals t in the selected weeds species were unconsumed by livestock.

Elemental analysis of selected unconsumed weeds species is listed in Table 4.10.

Table 4.10: Toxic element composition of the selected weeds species.

Parameter	<i>Melastoma malabathricum</i> L.	<i>Miconia crenata</i> (Vahl) Michela ng.	<i>Diplazium esculentum</i> (Retz.) Sw.	<i>Taenitis blechnoides</i> (Willd.) Sw.	<i>Torenia crustacea</i> (L.) Cham. & Schltdl.
Lead (Pb mg/kg)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)
Cadmium (Cd mg/kg)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)
Mercury (Hg mg/kg)	Not Detected (<0.1)	Not Detected (<0.1)	Not Detected (<0.1)	Not Detected (<0.1)	Not Detected (<0.1)
Arsenic (As mg/kg)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)	Not Detected (<1.5)
Aluminium (Al mg/kg)	9600	5760	103	195	1790

Toxic elements, namely Pb, Cd, Hg and As, were not detected for all species. Al was detected in all species with the different amounts (Figure 4.21).

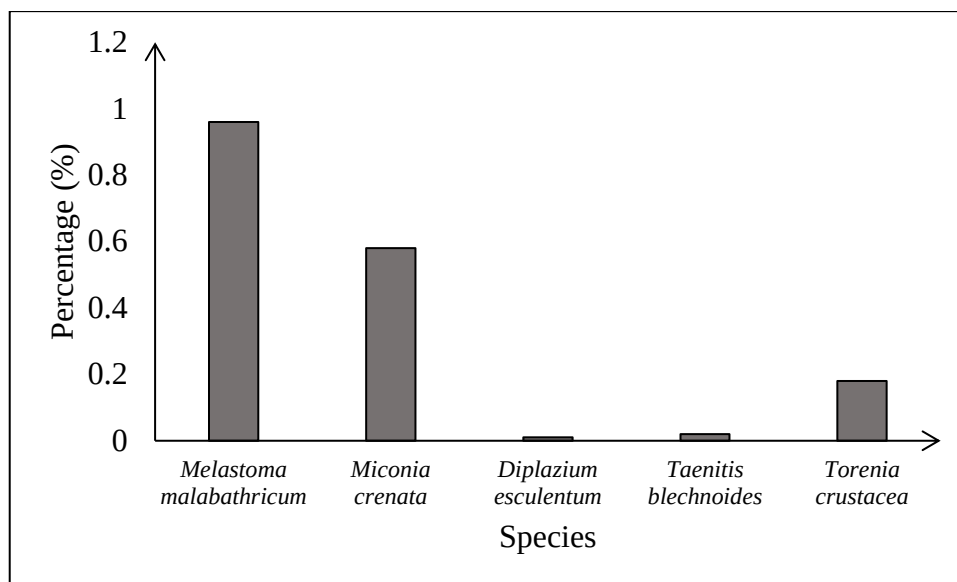


Figure 4.24: Aluminium content in *Melastoma malabathricum*, *Miconia crenata*, *Diplazium esculentum*, *Taenitis blechnoides*, and *Torenia crustacea*.

The value of Al content as in Figure 4.24 was represented by *Melastoma malabathricum* with 0.96% (9600 mg/kg) followed by *Miconia crenata* with 0.58% (5760 mg/kg), *Torenia crustacea* with 0.18% (1790 mg/kg), *Taenitis blechnoides* with 0.02% (195 mg/kg) and the lowest from *Diplazium esculentum* with 0.01% (103 mg/kg). Since most of the toxicity elements were not detected except Al content, no further statistical analysis was done.

4.7 Summary of Results

This chapter presented the results of this study. The most dominant weeds species found in both samplings were similarly based on SDR values for both initial and second samplings. These species, arranged in descending order of dominance, include *Scleromitrium verticillatum*, *Cyrtococcum patens* var *latifolium*, *Centotheca lappacea*, *Axonopus*

compressus, and *Torenia crustacea*. The total number of individuals was found more in initial sampling but a lower number of species than second sampling. For species diversity, initial sampling had lower H' and R but higher in 1-D and SI than the second sampling. Also, the initial sampling had higher estimated carbon.

The recovery based on the height growth of *Axonopus compressus* for grazed, cut, and ungrazed in the opened area differed significantly. The recovery of the height of ungrazed was higher than grazed and cut, and the recovery height for cut *Axonopus compressus* in shaded was higher than the opened area.

Recovery height for grazed, cut, and ungrazed *Elaeis guineensis* differ significantly. The ungrazed *Elaeis guineensis* was higher in height than grazed, and there was a significant difference in height for ungrazed and cut. The height of grazed and cut also differ significantly. The cut *Elaeis guineensis* showed a higher increase in height in opened area than the shaded area. As for *Antrophyum reticulatum*, the recovery of grazed and the cut was differed in producing new shoots significantly.

The percentage of grazed *Axonopus compressus* exposed that the uncut was higher than cut, and this suggests that uncut was more preferred by livestock than cut.

The differences in elements contained in each species were small. In terms of amount, K was highest in all selected species, except for *Antrophyum reticulatum*, *Scleromitrium verticillatum*, *Elaeis guineensis*, and *Asystasia gangetica* *Axonopus compressus*. Element N content was the second-highest detected in all selected species except for *Axonopus compressus*. The other P, Mg, S, and Na elements were found only in small quantities in all chosen species. The four heavy metals contents Pb, Cd, Hg, and As

were not detected in all selected species, while only Al was detected in all species chosen with different amounts with the highest content found in *Melastoma malabathricum*.

CHAPTER 5

DISCUSSION

5.1 Integration of Livestock in Oil Palm Plantation

Oil palm plantations have not widely implemented the integration of livestock in oil palm plantations because of the lack of relevant technical expertise such as in animal husbandry and other outstanding problems that constraint the extensive and intensive practices like theft and property disturbance by livestock (Kamil et al., 2017). The plantation owners need to explore how to substitute the potential sources for plant nutrients due to the increasing cost of fertilizer. The government should provide a better understanding and strategy for the plantation owners to successfully make the integrated oil palm plantation and develop this practice in Malaysia. Concerted efforts are needed to enhance the sustainability of the integrated oil palm plantation that involves active participation and serious involvement and the commitment from all sectors to support this industry to complement the supply of meat in Malaysia. This practice also benefits both economically and environmentally in which it optimizes the land use of the plantation. Besides, the animals can consume agriculture by-products as feed and livestock can be reared for recreation and agrotourism.

In tropical and subtropical areas rearing livestock in the plantation of perennial crops is a well-known and fruitful practice. The obvious advantage is that grazing by livestock acts as a control of weeds in the plantation. Combining livestock and palm oil income brings more benefits than running the plantation alone (Ebenezer et al., 2012). In Malaysia, livestock such as cattle, buffaloes, and goats are being integrated with oil palm plantations that have reached mature age (more than five years) (Md. Said & Man, 2014). The

government encouraged this agricultural practice to meet the local demand for red meat and control weeds in oil palm plantations (Devendra, 2007). Livestock grazing can decrease the reliance on herbicides, where it indirectly helps maintain the farmland's bio-diversity (Rinella & Hileman, 2009; García et al., 2012; Jambari et al., 2012; Slade et al., 2014; Kamil et al., 2017).

The occurrence of the natural undergrowth varies with the oil palm age, soil type, climate, weed species, weed control programs and estate upkeep, and maintenance practices of the plantation (Kamil et al., 2014). The shade usually provided by tree crops influences light intensity, temperature, and humidity, thus limiting the weeds that can grow under them. As the crops get are closer due to growth, weed growth is suppressed, but the shade-tolerant weeds become familiar as the crop closes the canopy (Akobundu, 1987; Chee et al., 1991; Essandoh et al., 2011). The oil palm does not close up its canopy early enough and can accommodate weeds with or without preference shade in a more extended period. Hence, this is possibly caused for the presence of a wider diversity of weeds. As crop varies (Souza et al., 2003) and different cultivars of the same crop (Seavers & Wright, 1999) are capable of affecting the composition and growth of the weed (Essandoh et al., 2011).

5.1.1 Weeds Species in Oil Palm Plantation

The dominant weed species were determined using Summed Dominance Ratio (Anwar et al., 2013). The SDR values indicate the dominant species in an area express a ratio, and the importance value index (IVI) values show how dominant is a species in an area. The species dominance as expressed by SDR for both initial and second samplings showed the same species dominated the area. The top five dominant species include *Scleromitron verticillatum*, *Cyrtococcum patens* var. *latifolium*, *Centotheca lappacea*,

Axonopus compressus, and *Torenia crustacea*. However, the lesser species with low SDR values showed different species recorded during the initial sampling compared to the second sampling. For instance, initial sampling recorded 13 species with very low SDR values: *Antrophyum reticulatum*, *Dicranopteris linearis*, *Lygodium microphyllum*, *Oldenlandia corymbosa* and *Saurauia glabra*. In the second sampling, there were 12 species recorded with the lowest SDR value, which indicated the least dominant species within the area. *Callicarpa longifolia*, *Hyptis brevipes*, *Leea aculeata*, *Mallotus leucodermis*, and *Sida rhombifolia*. Meanwhile, for the highest observed RF value, which indicates the most common species, five species were recorded for both initial and second sampling: *Scleromitrium verticillatum*, *Centotheca lappacea*, *Axonopus compressus*, *Cyrtococcum patens* var. *latifolium*, and *Torenia crustacea*. The least common species with the lowest RF values includes four common species for both samplings were *Lasianthus* sp., *Cyrtophyllum fragrans*, *Saurauia glabra*, and *Struchium sparganophorum*.

Many recorded forage species can grow naturally in coconut, rubber, and oil palm plantations in Southeast Asia and the South Pacific countries. Some of the most common species can be found in all three plantations and several countries. *Axonopus compressus*, *Imperata cylindrica*, *Mimosa pudica*, and *Paspalum conjugatum*. This distribution includes Southeast Asia and the South Pacific, showing their ubiquitous nature and ability to grow in a wide range of environmental conditions. Other species like *Ottochloa nodosa*, *Mikania cordata*, and *Asystasia* spp. are also common in Southeast Asia rubber and oil palm (Stür & Shelton, 1991). A study reported that in the oil palm plantation in Ghana, *Chromolaena odorata*, *Aspillia africana*, and *Melanthera scandens* were dominated the mature plantation (Essandoh et al., 2011).

Axonopus compressus is well known for its ability to survive in heavy grazing pressure, and it has been mentioned to attack sown pastures that were not fertilized (Roberts, 1970) overgrazed (Watson & Whiteman, 1981) or in shaded areas (Chen et al., 1978). It is a valuable forage in high shady conditions with less than 30% of the light transmission because in highly shaded areas, sown grasses can't endure the regular grazing by livestock (Stür & Shelton, 1991). Another species, *Paspalum conjugatum* has a typical distribution to *Axonopus compressus*. Still, it is observed that it grows the best on more acidic soils, and it can survive in moderate grazing and disappears under continuous high grazing pressure. While in the South Pacific, it is said to be less productive than *Axonopus compressus* (Smith & Whiteman, 1983; Stür & Shelton, 1991). It is difficult to quantify the effect of weeds in oil palm because of their long economic life at 20-30 years, but it can affect the growth of crops or cause yield losses (Kuan et al., 1991). Thus, it is important to determine the weeds species present in an oil palm plantation, where weeds vegetation analysis is required to assess their density and growth dominance at certain locality (Rosli et al., 2010). Weeds populations in plantation areas are never constant, but they are in a dynamic state of flux due to the changes in climatic and environmental conditions and husbandry methods (Cobb, 1992).

5.2 Species Diversity

The initial weed vegetation analysis was conducted to determine the weed species present and evaluate their density and pattern of dominance in the experimental locality. It is essential to explore and determine the details about the weeds in the field and the density of each species present in the area and be one of the keys for a successful weed management strategy (Krueger et al., 2000). Understanding the mechanism of weed seed distribution also

acts as an effort that can contribute to weed management strategy (Sidik et al., 2018). Weed abundance and diversity must be well understood as it involved in critical aspects of both biodiversity conservation in agroecosystems (Marshall et al., 2003; Gibson et al., 2006; Power, 2010; Rassam et al., 2011) and also in integrated weed management (Maxwell and O'Donovan, 2007; Smith et al., 2010; Travlos, 2013; Travlos et al., 2018).

This study showed weed diversity by H' value was higher in second sampling than initial sampling, but for the value of $1-D$, the initial sampling was higher than the second sampling. Even though both indices refer to diversity but the interpretation is quite different. The H' value from two samplings indicated that the species composition structure is considered as a moderate community in terms of complexity. In contrast, $1-D$ value showed that both areas were supposed to have high species diversity. Similarly, a great variety of weeds species was recorded in a matured (5-15 years) oil palm plantation in Ghana with 0.98 and 3.8 Simpson's and Shannon indices, respectively (Essandoh et al., 2011).

Usually, the most used indices of diversity in ecology are Shannon (1948) and Simpson (1949), while richness and evenness as parts of diversity (Shah & Pandit, 2013). However, the comparison between both indices, the Simpson index, is used to evaluate the dominance but fails to provide an idea about species richness. In contrast, the Shannon-Wiener Index provides both diversity components, evenness and richness, but could not give any information on the rare species that are crucial in describing bio-diversity (Shah & Pandit, 2013). This demonstrates that diversity cannot be evaluated just by one index (Hayek & Buzas, 1997; Purvis & Hector, 2000). Therefore, different diversity indices have been used to overcome these restrictions in this study.

To make the results more compliable, Simpson's Index of Diversity (1-D) was used as the value of this index ranged between 0 to 1, but now it changed to the closest value to 1, the greater the diversity of the samples. But in this case, the index represents the possibility that two individuals randomly selected from a sample belonged to different species. The value of Simpson's Diversity Index is always higher as fewer species dominate the community, and the dominance is shared by a large number of species (Whittaker, 1965) that can also be used to describe both samples in this study which had the high values. Simpson's index is a measure of diversity that is too highly affected by the abundance of the two or three most abundant species in a community; thus, Simpson's index shows relatively less weight to the rare species and more to the common species (Yeom & Kim, 2011).

Samedani et al. (2014) mentioned that weeds, especially in crop areas, are never constant. Due to changes in climate and environmental conditions, cropping systems, growing season, cultural practices, weed seed bank composition, and periodicity of germination patterns of different weed species contribute to the dynamic state of flux (Juraimi et al., 2010). The result of this study proved that the weed floristic composition of a particular site might change due to time, and weed communities themselves are a complex ecological entity (Samedani et al., 2014). The high diversity of weeds species could also be due to the differences in seed production, dispersal, germination, and seedling establishment (Newman, 1994), which promotes the co-existence among the weed species at a high level (Essandoh et al., 2011).

At the immature stage, the palm fronds are small thus, the ground surrounding the oil palm is exposed to sunlight and assists prolific growth of the weeds. When the palm reaches its mature stage, the canopy closes and prevents sunlight from reaching the ground;

hence the weed growth is reduced (Ainie et al., 2017). The study by Tan & Abraham (1981) found the decline of percentage in undergrowth cover in grazing treatments for both rotation systems or free range to be double compared to the field where no sheep were kept. On the environmental side, this is the most efficient production system. The advantage is producing the animal products like meat, milk, and skins and many other benefits that can be highlighted by the integration of animals and perennial crops (Ebenezer et al., 2012).

5.2.1 Species Richness

Margalef's Richness index was used as a simple measure of species richness (Margalef, 1958). The results obtained were used for comparison of the two communities which responded to the different periods in the area of integrated oil palm plantation. Margalef's Index has no limit value, and the variation depends on the number of species. It is used to compare the sites where it takes only one component of diversity that is species richness in the consideration, reflecting sensitivity to the sample size (Shah & Pandit, 2013).

After six months of initial sampling, higher species richness was observed for the second sampling than the initial sampling, and it showed that the total of species of weeds was found more in the second sampling. The variation in richness may regulate diversity when seed availability and dispersal are the factors that influence diversity because richness is highly affected by the number of individuals (Wilsey & Stirling, 2007). The species of vegetation under oil palm also vary among the plantation as the factor of oil palm age is accounted. One of the potential efforts to produce better quality feed and increase production is introducing superior forage into the plantation (Nurhayati et al., 2015).

5.2.2 Species Evenness and Species Similarity

Evenness is highest when all species had the same number of individuals or equally abundant where the range was between 0 and 1. When the value was close to zero, it signified that most of the species were rare. Just a few were abundant, and when the value was the closest to 1, the potential evenness among the species ($H'_{\max}$) was equal to (H') (Essandoh et al., 2011) or simply saying that 0 signified that there was no evenness while 1 indicated full evenness. Evenness was higher for initial sampling than second sampling due to the same number of individuals or equally abundant. Since sampling was done in the same area, a less different number of species evenness was recorded. However, the variation in evenness may regulate diversity in sites with moderate disturbance like grazing, when grazing lowers the amount of dominance by common species but no new migrants are gained or lost (Wilsey & Stirling, 2007).

The index of similarity of Sorensen's Index was mainly used to identify the species composition in two sites, and the species shared between both sites (Nitesh Joshi et al., 2016). The purpose was to compare two populations instead of counting the same abundance of each species in a quadrat in which only the presence or absence of each species could be recorded at each quadrat sample. Sorensen's Index values indicated homogeneity of weed communities among the blocks. Bonham (1989) divided vegetation condition into 5 groups with excellent (91-100%), good (71-90%), fair (56-70), poor (45-55%), and unacceptable (less than 45%). The homogeneity value of more than 71% indicated a good to an excellent value to carry out weed control (Samedani et al., 2014). For the present study, the value of Sorensen's Index was 0.68 or 68%, thus categorized as fair in terms of species homogeneity.

5.3 Weeds Species Growth Form

In the oil palm production system, weed is a major component. The composition of weeds is a mixture of grass, sedges, and broadleaves plants influenced by the crop's growth stages, which provide specific climatic and environmental conditions suitable for particular weed growth (Rosli et al., 2010). The percentage of the plant growth form was the highest was from the herbaceous group for both initial and second samplings. A study reported that a wide range of broadleaved weeds is found in newly opened land, while a mixture of grassy and broadleaved weeds is found in young plantations and a predominance of grasses in well-established plantations (Chee et al., 1991). In the area for both samplings, when referring to SDR, most of the species ranked in the top five of the lists were from grasses growth form dominated by *Cyrtococcum patens var latifolium*, *Centotheca lappacea*, and *Axonopus compressus*. The statement supported that as the oil palm gets older, the shade provided by the palm canopy influences the nature of the composition of the weeds, and grass species tend to dominate (Wan Mohamed et al., 1987).

In terms of forages, the grasses and herbaceous legumes can be used in mixtures in grasslands and under plantation crops or as forage crops separately. The tree and shrub legumes can provide in protein banks, alley cropping, hedges, shade trees, or single trees (Mannetje & Jones, 1992). As a single predominant weed is hardly found in the field condition, it usually consists of few weed species (Aldrich, 1984). In this context, the composition of mixed weeds is suitable as a source of feed for livestock. Moreover, one of the major highlights to provide a successful post-emergent weed management strategy is the knowledge of weeds present in the field and the density of each species (Krueger et al., 2000).

Useful groundcover, including small ferns or leguminous nitrogen-fixing species, can be used to minimize erosion to hold the water at the oil palms plantation areas (Corley and Tinker, 2003; Koh, 2008). The common practice where the palm leaves that were trimmed kept under the oil palms gives a patchy environment of leaf litter in which the process of trimming leaves to harvest fruit bunches produces stubs that protrude 10 to 30 cm upwards from palm trunks. Epiphytes then grow on the stubs that are filled with the organic matter where epiphytes were well-distributed in oil palm plantation that supports epiphyte-associated species. The epiphytes in the plantation are mostly exotic species (Danielsen et al., 2009, Fayle et al., 2010).

5.4 Biomass and Carbon Stock of Undergrowth in Integrated Oil Palm Plantation

The estimated carbon stock per hectare in the integrated oil palm plantation was 0.43 tonne ha⁻¹ in the initial sampling and 0.41 tonne ha⁻¹ in the second sampling. Carbon stocks in oil palm plantations by age group in oil palm plantations in PT Daria Dharma Pratama (PT DDP) in Bengkulu Province, Indonesia, showed that the highest stored carbon in undergrowth plant biomass was recorded by the age group of 0 to 5 years at 5.22 tonne ha⁻¹. Whilst, the lowest stored carbon stock of biomass was recorded by the age group of more than 20 years with a total of 0.12 tonne ha⁻¹. The growth and development of undergrowth plants were hindered due to the competition of the sunlight for photosynthesis and the increased age of oil palms then produced greater and vast canopy cover (Yuliyanto et al., 2016).

The stored carbon stock in oil palm is influenced by plant age, soil fertility, and plant growth and development (Yuliyanto et al., 2016). Yuliyanto et al. (2016) stated that the highest carbon stock of biomass in oil palm plantations was in the age group of 11 to 15

years at 69.32 tonne ha⁻¹, and age group of 16 to 20 years at 54.13 tonne ha⁻¹. The quantification of carbon in plantations of *Elaeis guineensis* in Colombia indicated that the biomass conversion to carbon ranges from 45 to 50% (Castilla, 2004). The percentage of 50% is commonly used in many similar studies (Hamburg, 2000), and it can be considered unreasonably high for *Elaeis guineensis*. However, the value was changed to its default to 47% (Sanquetta et al., 2015). The carbon stock of each pool was estimated by multiplying the biomass by 0.47 for palm biomass and under-storey vegetation, 0.5 for necromass (deadwood), and 0.4 for the standing litter stock (conform the standards used by The European Commission, 2010) (Khasanah et al., 2015).

Estimating carbon stock is needed as the rising levels of greenhouse gases (GHGs) concentration, usually in CO₂ in the atmosphere, is a major concern responsible for climate change in the current global environment scenario. In tropical ecosystems, carbon storage has been disturbed through land-use and land-cover change releasing greenhouse gases (C emission) with a relative value of 10 to 13% annually (Houghton et al., 2012). The importance of proper plantation practices such as preventing land clearing by fire, avoiding drainage and erosion of topsoil, using cover crops, mulch, compost, etc., can prevent or reduce loss of some ecosystem functions through help in reducing climate change (Singh et al., 2018).

5.5 Forage Species Recovery

Several practices guidelines must be followed during the production, management, and utilization of the crops to optimize the benefits of crop growing. As for pasture, more attention is needed because of the integration and management of the forage production system, a livestock production system, and a forage utilization system operating

simultaneously and in the same space. There are three aspects of the difference between pasture (forage) and other livestock foods. First, pasture (forage) is any grazing place for an animal when it is not in a barn or feedlot, unlike other food such as corn, alfalfa or soybeans. The second aspect is that forage is utilized while it is alive and still growing or, in other terms, grazing as compared to any other livestock food that is being harvested and fed to livestock. Thus, the yield and quality are affected over time. The third aspect is how it is harvested directly by an animal rather than a machine. A machine does not account for plant looks, smells, feels, or tastes like animals (Emmick, 2012).

A pasture plant can be defined as a living system consisting of two connected and dependent parts. Forages grow at different rates at different times in the season and also in a single growth cycle. About three stages of growth include a slow growth phase, a mid-rapid growth phase, and a late mature phase. Every time a plant is grazed, the three phases of the growth rate must be passed at different times and depend on the time of year. In early slow growth, plants are leafy and immature, high in quality, low volume, and growing slowly due to less leaf area. In the mid-accelerate phase, plants are at the highest growth rate as plants are leafy, maturity increases and high quality with high volume. The late slow growth plants are stemmy and over-mature, slow growth, high yields, and lowest quality (Emmick, 2012). In a study, forage production results showed that rotational grazing with seven days grazing followed by 21 days resting period was not sufficient for the forage to substantially regrowth to meet the needs of Bali cows (Nurhayati et al., 2015). In this study, it was revealed that the recovery of forages for 1 to 3 days of grazing followed by 24 days of resting periods total up to 27 days in a rotation was sufficient.

Herbivory can limit the growth and survivorship of plants. Plants possessed complex responses to avoid being consumed, survive, and flourish after herbivory. It is acknowledged that plants can tolerate physical and biotic stresses and damage, and some experimental evidence is that herbivory may stimulate plant growth and increase plant fitness. However, compensation responses are not consistent across species or environments, and it has been shown that plant response to herbivory is species-specific. Compensation to herbivory is specific to herbivory type and intensities (Liu et al., 2012). Under the intense pressure of grazing, saliva minimises damage from herbivory. Plants are able to tolerate continuous herbivory and be adapted in the long term for grazing, which provides insight into the interpretation of mutualism and coevolution between plants and herbivores in grazing systems (Liu et al., 2012). Other studies demonstrated that the herbivore's saliva had no negative impacts on plants (Johnston & Bailey, 1972; Reardon et al., 1974; Capinera & Roltsch, 1980; Detling et al., 1981).

Cattle and sheep secrete large amounts of saliva, with appreciable amounts that may be deposited on a range of vegetation during grazing, and saliva contains inorganic salts and several nitrogenous compounds, particularly urea, that might influence the regrowth of grass after grazing (Johnston & Bailey, 1972). A study by Johnston and Bailey (1972) found no significant differences in the yield of tops or roots or final tiller numbers at any clipping height between *Festuca scabrella* Torr. and *Festuca idahoensis* Elmer either sprayed with water or with saliva and showed no evidence that bovine saliva affected the regrowth of clipped plants in the greenhouse where in this study, saliva was obtained from a rumen-fistulated Ayrshire cow. A study by Reardon et al. (1972), as mentioned in Johnston and Bailey (1972), reported that the foliage was increased and root yields of plants of *Bouteloua*

curtipendula after treatment with 0.2 ml bovine saliva per seedling. It is difficult to identify any benefit discussed on vegetation by grazing.

The grazing animal influences the growth of individual grass plants, and the effect may differ from mechanical clipping. It is not clearly understood why it is different in response due to clipping or grazing. Still, researchers have suggested several reasons why this happen, and one possibility is the effect of animals on the cycle of nutrients in the ecosystem (Reardon et al., 1974). About 75% to 96% of the nitrogen and phosphorus and 90% of potassium in forage consumed by grazing animals is returned to the pasture in faeces, but nearly all nitrogen, phosphorus, and potassium in the forage are removed by mowing (Peterson et al., 1956; Sears, 1951). The other reason that was first suggested by Vittoria and Rendina (1960) and later tested by Reardon et al. (1972) is that the grazing animal causes plant growth stimulation by secretion of saliva during grazing. Reardon et al. (1972) showed that animal saliva contained thiamine (Vitamin B₁) at concentrations previously reported to stimulate a growth response in grass plants. However, rumen saliva could contain detrimental contaminants such as bacterial enzymes and rumen microflora (Reardon et al., 1972; Johnson and Bailey, 1972; Reardon et al., 1974).

Plant growth stimulation may influence thiamine contained in saliva by secretion of saliva. Some grazing characteristics or saliva secreted on the plant during grazing may vary the result. Therefore, caution should be taken in interpreting data where in this study either it is needed to do cut treatment for the better forage recovery. Reardon et al. (1974) used side oats grama plants clipped at various heights and frequencies to compare plant growth response to animal saliva and thiamine additions. The comparisons were also made between plants that were either grazed or clipped. The results showed that plants responded to additions of thiamine when they were cut at a moderate intensity (6 inches) and a frequency

(6 weeks). Plants did not respond to thiamine or saliva when clipped to three inches regardless of the frequency, and it also found that plants grazed by cattle, sheep or goats had significantly higher growth rates than clipped plants.

Under the big canopy of tree crops, there is a possibility to provide a better microclimate environment as found in this study. The height of cut samples of *Axonopus compressus* showed a significant difference in opened and shaded areas. Thus, it indicated that the *Axonopus compressus* sprouted higher in shaded areas than in the opened area. It was also found that the height of cut *Elaeis guineensis* in opened and shaded areas was significantly different. The shade level in the plantation brings the most important factor in determining forages' growth. The lower irradiance results in less forage species growth and affects the output of competitive relations (Shelton et al., 1987). The tree crops provide live fences, windbreaks, shade trees, and soil and water conservation purposes, which benefit livestock production systems.

The light penetrability to the ground vegetation of oil palm and rubber trees depends on the age of the tree associated with canopy closure. About 92% photosynthetically active radiation (PAR) level of the light transmission under the rubber trees for 1 to 2 years old dropped only 9% when trees reached 6 to 10 years of growth (Chee & Ahmad Faiz, 1990). The level of the light penetration stays unchanged until trees are around 15 to 20 years old due to the slight opening of the trees canopy cover. As the trees mature, the light transmission also decreases and changes in the ground vegetation. These are important inputs to be well understood for sustainable utilization of the forages to ensure long-term livestock production. As this study took place in 20 years old oil palm plantation, thus the trees canopy cover also plays an important role as the forages need to compete for the light to grow.

However, in this study, the recovery of height for cut *Axonopus compressus* was higher in a shaded area than the opened area, which might be due to the competition for light and a smaller number of individuals growing in the shaded area. A previous study revealed that it created an almost linear increase in total leaf area (Durr & Rangel, 2000). *Axonopus compressus* was exposed to good shade tolerance under the plantation crop canopies (Wong, 1990; Chin, 2017). A study of shade responses of tropical grasses showed that *Panicum maximum* var. 'common guinea' (Wong et al., 1985) and *Panicum maximum* CV. Gatton (Sophanodora, 1989) have a great morphological adaptability in response to shade and feasibly the feature of the species (Durr & Rangel, 2000). The other study by Van Huylenbroeck & Van Bockstaele (2001) exposed that the various shade tolerance from observed turfgrass species resulted from the photosynthetic features of the species. The observed species such as *Festuca rubra* L. spp. *tricophylla*, *Festuca rubra* L. spp. *commutata*, *Koelana macrantha* (Ledeh.) Schultes and *Poa pratensis* L. showed the highest tolerance under reduced irradiance (observed based on grass cover) compared to *Lolium perenne* L. and *Festuca rubra* L. spp. *rubra* which were less tolerant.

Meanwhile, the recovery of height for cut *Elaeis guineensis* was found higher in the opened area due to the light preference for the species' growth. A study showed that the height of oil palm seedlings decreased as shade levels increased and the reduced light intensity. This could be due to the activity of apical buds or meristems that was suppressed when the light intensity was reduced. In addition, it was possibly caused by the reduced level of net photosynthesis as a low source of light intensity and limited the resources for the vegetative growth (Agyeidwarko, 2001).

The main limitation of the environment is the decrease in photosynthetically active radiation (photon irradiance) occurrence on the pasture under-storey. The restriction of

competition for water between the tree and pasture is unknown. In other words, compared to full sun-situation, the evaporation rate is reduced, and the soil water content is maintained at a higher level under the trees canopy. The result was less severe during the drought periods under the environment of trees. Moreover, the air and leaf temperature under the trees differs slightly from those in the open area, but the soil surface temperature can be much reduced. This may lead to a more conducive litter breakdown and nutrient turnover (Wilson & Ludlow, 1991).

The understanding of plant resources must be acknowledged as it is crucial to understand the growth that leads to better management to provide an optimum economic yield. For pasture (forage), the optimum yield is better than the maximum yield, not necessarily more. The quality of forages provides livestock with maximizing nutrient intake and performance. Lower total dry matter yields and higher yields of Total Digestible Nutrients (TDN) are included to make forages well-managed (Emmick, 2012). Integrated management must have enough acres to provide adequate forages to feed the livestock and ensure sufficient quality. The livestock will only intake sufficient quality and nutrition. As time passes, when forage is continually grazed, it reduces the amount of leaf tissue produced as well as causes the declined mass. Thus, the ability of the plants to extract moisture and nutrients from the soil will reduce and then lower the capacity for growth even though the availability of enough soil moisture and nutrients. It shows that rotational grazing will allow forages to recover before they are grazed again. Even though leaf tissues are removed and the root mass is reduced, the plant yields can be maintained at high levels (Emmick, 2012).

5.6 Forage Preferred by Livestock

Selective grazing encourages the evaluation of dietary phosphorus status, and it influences the intake of minerals as livestock consumes a mixture of pasture and browses material (Fordyce et al., 1996). This study discovered a significant difference in the percentage of forages grazed by livestock between cut and uncut forages. The rate of the grazed *Axonopus compressus* was at a different level for each day observed for both cut and uncut forages where the uncut forage was highly grazed by livestock compared to cut. The higher percentage was from uncut forages due to the maturity increase, preferable where the plants were leafier as the maturity increases with high quality and volume at the mid-accelerate phase (Emmick, 2012). Thus, it indicated that no cut treatment is needed to enhance the new sprout of *Axonopus compressus* to be consumed by livestock.

The palatability of the forage fodder decreases when the optimum cutting edge and then offer to the livestock exceeds. The higher crude fibre content in older fodder will limit the intake by livestock (Kamil, 2014). In this study, the sprout of older forage started to slow and had plateau height levels until the full day of observation (day 27). When the forage is too short, too tall or not suitable in the composition of species for the kind and class of livestock, animal nutrition requirements might not be sufficient. A consistent level of high-quality food in adequate quantity the pasture (forage) must be managed such that it the return are profit. The environment involved, such as soils, plants, and animals, must be well understood alongside their interactions (Emmick, 2012).

Furthermore, the height of cutting also plays a vital role in fodder crop integration with oil palm because of the ability of the fodder crops to regrow adequately after every cutting. The cutting height below the optimum level affects the regrowth of forage crops and

eventually the fodder yield, where it also affects the survival of forage stumps or clumps in the field as the clumps or stumps have a short productive life if cut under the optimum height (Kamil, 2014). In many areas where the growth of the tree crops such as coconut, oil palm, timber, firewood or rubber trees, forage crops, and pastures can be grown in the partial shade of these trees, especially during the first few years. Hence, it is required to grow forage grasses under low light conditions in the tropics. It has been found in many studies regardless of the decreased dry matter production under reduced light intensity with many species of grass and legume (Eriksen and Whitney, 1981), but the magnitude of the growth effect depends on the stage of growth and concurrent temperature, moisture, and nutrient (especially N) stresses. The shading of grasses usually causes elongated growth, reduced specific leaf weight, and increased leaf area ratio. Apart from that, the plants grown in the shaded area are also more succulent, which results in a lower dry matter percentage (Gordon et al., 1962), as well as plant height of most species, increased significantly with decreasing light intensity (Eriksen and Whitney, 1981).

The suitability of livestock for integrated production systems in oil palm plantations with ruminants like cattle, buffalo, deer, goat, and sheep has been studied in Malaysia. However, a serious effort must be made for agricultural development planning in Malaysia and other tropical countries that consider systematic and efficient management of land resources to increase agricultural productivity in the farm. In Malaysia, livestock production in the general system is using open pasture grazing is unsuitable to increase the supply of protein compared to the benefits of livestock integration in oil palm plantation that is better in terms of economic and the growing forages provided for grazing. Even though the total oil palm plantation showed a significant increase compared to the other plantation

commodities like rubber, it was contributed by conversion rather than opening up a new establishment (Kamil et al., 2014).

Forages are significant resources of feed for ruminants worldwide and may come feed as pastures, forage crops, and conserved hay, silage, or haylage. Wide varieties in quality of forages lead to analysis where the estimation of feeding value and the nutritive value is crucial for better production (Dynes et al., 2003). Forages as feed sources for livestock and consist of edible parts of plants, other than separated grain, usually with actual contents of cell walls which are suited to be consumed by herbivores that have the ability for microbial digestion of cell wall constituents (Wilkins, 2000; Dynes et al., 2003). Animal performance, including reproduction, meat, wool, and milk, can be linked to the functions of forage value. The optimised forage utilization and maximising the possibilities of the livestock to grow high economic yields are challenging for grazing livestock.

5.7 Elemental Analysis for Selected Consumed Species and Toxicity Analysis for Selected Unconsumed Species Presented in the Area of Integrated Oil Palm Plantation

The elemental analysis of N, P, K, Mg, S, Na for selected consumed species of *Axonopus compressus*, *Elaeis guineensis*, *Antrophyum reticulatum*, *Asystasia gangetica*, and *Scleromitron verticillatum* were conducted. Detection of hazardous heavy metals content of Pb, Cd, Hg, As and Al for selected unconsumed species were conducted on *Melastoma malabathricum*, *Miconia crenata*, *Diplazium esculentum*, *Taenitis blechnoides* and *Torenia crustacea*. Results showed Pb, Cd, Hg, and As were not detected for all species analysed due to the detection level being lower than 0.1 mg/kg for Hg and 1.5 mg/kg for the Pb, Cd and As (Table 4.10). The only heavy metal detected was Al.

5.7.1 Elemental Content of Selected Consumed Species

Several factors affecting both quantity and quality of the forages fed to ruminants come in wide variations, including areas, season, soil fertility, fertilizer application, and harvesting period (maturity) (Evitayani, 2004). It is suggested that differences in nutritive value between plant species are also due to their anatomy, biochemistry, and morphology (Norton & Poppi, 1995). Different species of forages are a unique mixture and differ in forage quality, thus making this combination challenging to analyse its nutritional value. The definition of forage quality itself also deals with the capacity of forage to provide livestock with the essential nutrients. Furthermore, the forage quality assessment of pastures is needed to explain the nutritive value and livestock grazing capacity (Fazel & Abdul Rashid, 2012). Each species was contained and constituted with different elements as found in this study.

Minerals are structural components of the body and essential in enzymes activities, hormones, a part of body fluids and tissues, being regulators of cell replication and differentiation and crucial in animals' physiological processes, including reproduction (Balamurugan et al., 2017). However, toxicity, insufficiencies, and imbalance of some mineral elements may lead to reproductive disorders due to the importance of minerals in the health and reproduction of livestock (Sharma et al., 2007). Such as in the reproductive process, minerals are involved in maintenance, metabolism, and growth (Hadiya et al., 2010) where the requirement for minerals are depended on a few factors such as age, stage of pregnancy, and stage of lactation. Some studies showed that tendency of the retention of placenta incidence caused by the element of minerals deficiency included calcium, phosphorus, iron, zinc, and copper (Balamurugan et al., 2017), repeat breeding in dairy cows

(Sheetal et al., 2014), abortion (Mee et al., 2004) and weak calf syndrome (Logan et al., 1990).

The body's structural components consist of minerals essential to run the enzymes hormones as elements of body fluids, tissues, and cell replication and differentiation regulators. Minerals are also necessary for animals' physiology, including reproduction (Elrod & Butler 1993). Nevertheless, the deficiencies, imbalances, and toxicity of certain mineral elements can cause reproductive disorders due to the importance of minerals in the health and reproduction of livestock (Sharma et al., 2007).

The amount of N in the five species varies slightly where *Asystasia gangetica* and *Scleromitron verticillatum* each content 1.5%, *Axonopus compressus* and *Antrophyum reticulatum* both had 1.4%, and *Elaeis guineensis* had 1.3% of N. The availability of N in the plant is helpful for growth and development of plant tissues, increasing appearance and elongation leaf rates (Lemaire & Chapman, 1996; Brambilla et al., 2012). N is an essential element among many different aspects in operating a sustainable dairy farm. Dietary protein that contains N provides amino acids for growth, maintenance, and milk production. On the other hand, the farming spectrum, N, is needed to maintain soil composition for sustainable and economical crop production. The excess N from the manure to the crop requirements may pollute the surface and well water resources. Nitrogen, such as nitrate, can be harmful to human health in the presence of drinking water. Besides, the loss of volatile N (as ammonia) into the atmosphere from the manure may reduce air quality due to the odour and nitrous oxide, a potent greenhouse gas, which contributes to global warming. Dairy farmers are taking steps to manage excess N in such a way as to reduce excess N that can get overlooked in nutritional management and act as proactive practices to reduce the possibility

of excess N excretion before it becomes pollution to the environment (Wright & Mutsvangwa, 2003).

A study done by Farrukh and Mufakhirah (2009) reported that Nitrogen contents were slightly higher in shrubs than grasses, with non-significant differences between grasses and shrubs at all phenological stages. Among shrubs, it was highest in *Artemisia maritima* (1.84%) and lowest in *Hertia intermedia* (1.31%), while among grasses, *Pennisetum orientale* had the highest (1.59%) and *Cymbopogon jwarancusa* the lowest (1.09%). The nitrogen contents were generally recorded high at the pre-reproductive stage than at other phenological stages (reproductive and post-reproductive stages) in all the tested species (Farrukh & Mufakhirah, 2009).

The P element is required for average milk production, growth, efficient feed use, cellulose digestion, and microbial protein synthesis. P is usually related to the decreased reproductive performance in dairy cows. Reduced fertility and reduced or delayed conceptions are the significant signs of P deficiency, while this can be treated with proper P supplementation (Balamurugan et al., 2017). This study analyzed the percentage of *Antrophyum reticulatum* and contained the highest P 0.4 %, followed by *Asystasia gangetica* 0.3%, *Scleromitrion verticillatum* 0.2% and 0.1% for each *Axonopus compressus* and *Elaeis guineensis*. The deficiency of P is mainly a chronic condition of grazing cattle followed by soil and climatic factors combination, limiting P in plants (Suttle, 2010). The level of mineral consumption affects the adequate intake of forages and minerals in base feedstuffs by livestock. Some factors such as soil type, plant species, the stage of maturity, dry matter yield, grazing management, and climate determined the level of minerals in plants (Khan et al., 2009).

The element K recorded the highest in *Antrophyum reticulatum* with 4.2%, followed by *Scleromitron verticillatum* 3.6%, *Elaeis guineensis* 1.8%, *Asystasia gangetica* 1.7%, and *Axonopus compressus* 1.1%. Other studies in the United Kingdom also showed K concentrations in forages among the highest ranged between 10 to 45 g/kg dry-weight (DM) with 24.3 g/kg DM mean recorded for fresh herbs. Similar results were found in Victoria and Queensland forages (McNeill et al., 2002) as well as in silage in the Netherlands (Schonewille et al., 1997) as referred to Suttle (2010). The suggested amount of K is 6 to 8 g/kg DM for growing beef cattle and 8 to 10 g/kg DM for lactating cows was similar with NRC recommendations (NRC, 2000, 2001) or when converted to the percentage as 0.6% to 0.8% DM for growing beef cattle and 0.8% to 10% DM for lactating cow. It was suggested that the level of K in forages for grazing animals was over 8 g/kg (Underwood, 1981). Later the recommended level of K is above 10 g/kg for high producing livestock under stress, especially heat stress (McDowell, 1985; Khan et al., 2006).

As for Mg, the values were low but still detected for each species except for *Axonopus compressus*. *Scleromitron verticillatum* detected the highest Mg with 0.7% and ranked next to *Antrophyum reticulatum* at 0.4% and 0.3% for *Elaeis guineensis* and *Asystasia gangetica*. The native and unimproved pasture forages contained lower levels of Mg as compared to most species of forages and grasses, but yet the differences of Mg constituent in this study within the literature could be influenced by forage species differences, level of Mg in the soil, locality and climate, growth stage, proportion of leaf, and stem fractions used for the analysis and season of the mineral when the samples were collected (Khan et al., 2009). About 60 to 70% of the body's Mg is found in the skeleton (Underwood & Suttle, 1999).

The strength and physical condition of plants are determined by the sufficient mineral nutrients from the soil. It proved that species with higher P and K in the leaves were more productive and more beneficial for livestock as the elements were known as the essentials for livestock (Ashraf et al., 1992; Irigoyen et al., 1992). Ca and Mg are known as beneficial for the normal growth of the livestock (Walker, 1980; Underwood, 1981; Aregheore & Hunter, 1999; Khan et al., 2004). The balance of minerals for mineral health is vital as the availability and assimilation are concerned where the body can tolerate longer in deficiency of vitamins rather than a deficiency of minerals (Grunes & Welch, 1989). The performance and health of grazing livestock can be affected by the sufficiency and availability of the mineral elements from forages among the nutritional elements provided by forages, and minerals are the most variable. In the pasture system, livestock depends on forages to fulfil their dietary requirements, but somehow, pastures often fail to provide all of the required minerals (Khan et al., 2007). As the health of livestock depends on the nutritional value of available forage thus, it is needed for the stockmen and range managers to better understand the dietary dynamics of forage to sustain the sufficient growth and reproduction of animals (Farrukh & Mufakhirah, 2009).

Meanwhile, the minerals deficiencies in forages and soils were reported in many incidences that caused the reproductive failure and low production rates (McDowell, 1985, 1997; Vargas & McDowell, 1997). The inadequacies of minerals tend to affect the production of grazing livestock on forages, including the major elements of Ca, P, Mg, Na, S, and the trace elements that are Co, Cu, I, Mn, Se, and Zn (Little, 1982; Judson et al., 1987; Judson & McFarlane, 1998; Khan et al., 2007). The high level of Mg in the forage also found in the study was above the requirement of the ruminants as suggested by the National Resource Council (1985), while no forage sample was below the critical level of 0.12 to

0.20% DM. The same adequate value of Mg in the sample forage in Florida was recorded by Salih et al., (1983). Forages in the grazing land had less forage Mg than most tropical grasses (Minson,1990).

Element Mg content in all sample species is considered as low with the range of 0% - 0.7% Mg content in the sample species (Table 4.9 and Figure 4.20). Other dietary components can affect Mg availability to stock, especially K (Dua & Care, 1995), and high nutritional levels of K and N will inhibit Mg absorption from the rumen. It was reported the adequacy of the forages K concentration in the study were in the range for the typical requirements of the animals (0.8% DM) (ARC, 1980) while tended to be higher in some forage samples during the study. Another study reported similar K concentrations by Prabowo et al. (1990) in Indonesia, Ogebe et al. (1995) in Nigeria, and Tiffany et al. (2000, 2001) in North Florida. The high concentration of K from different growing forages suggest that grazing livestock fed the forages would receive sufficient K (McDowell & Valle, 2000). In a certain country, there is still the possibility of K deficiency due to the decreasing amount of this mineral as the forage maturity increase (McDowell & Valle, 2000) as the deficiency was decided of being less than the critical value of 0.06% DM according to the National Resource Council (1985). In forages, the concentration of Mg varies widely on the plant species, season, and climate during plant growth and is little influenced by soil origin (Jumba et al., 1995).

The content of Sulphate that was detected in the five species samples was below 1.0% in which the nearer value was from *Anthrophyum reticulatum* highest content at 0.32% as compared to the other values as 0.06%, 0.05%, 0.05%, and 0.04% that were detected in *Asystasia gangetica*, *Scleromitron verticillatum*, *Axonopus compressus*, and *Elaeis*

guineensis, respectively. Similar to the other study, The S concentrations in forages and pastures between 0.5 to more than 5.0 g/kg DM that depends on plant species, availability of soil S, N and P and on-ward maturity (Suttle, 2010) or when converted to percentage it gave the value of 0.05% to more than 0.5%. Daily nutrition, energy, and mineral requirements of livestock ensured them to thrive and reproduce. It had adverse effects on livestock health, reproduction, and nutritional disorders due to mineral deficiency (Goswami et al., 2005; Khan et al., 2007).

The highest Na content was from *Scleromitron verticillatum* with 0.09% (886 mg/kg) followed by *Asystasia gangetica* with 0.03% (326 mg/kg), *Elaeis guineensis* 0.03% (316 mg/kg), *Antrophyum reticulatum* 0.03% (272 mg/kg) and the least from *Axonopus compressus* 0.02% (151 mg/kg). The Na concentrations in forages were less than the levels suggested for optimal livestock production (Khan et al., 2009). Normally, forages are lack Na due to some factors, including soil, plant, and farming. Low values of Na concentrations are usually found in tropical as compared to the temperate pasture where 50% of tropical legume samples constituted of less than 0.4 g/kg DM. In comparison, 50% of samples contain less than 1.5 g/kg DM as less value likely found in the tropical than the temperate pasture (Minson, 1990).

Deficiency of Na tends to occur in animal grazing tropical forages species. These plants usually accumulated lower Na than temperate species (Morris, 1980) as what had been reported in several tropical countries regarded the low content of Na in natural forages (McDowell, 1985). It was found that 0.6 to 0.8 g/kg DM is enough for growth under standard climatic conditions (Morris & Gartner, 1971; Morris & Murphy, 1972), while more Na is

needed for lactating cows (1.0 g/kg DM) (Morris, 1980; Edmeades and O' Connor, 2003; Suttle, 2010).

Previous studies of forage grasses grown in an area with different chemical characteristics showed the content of P differed significantly between years, locations, and species. The composition of P in samples ranged between 0.91% and 1.53%. Higher P composition was recorded in 2011 and 2012 as compared to 2013. Generally, temperature, light, ventilation, soil pH, and mutual interactions of ions are the main factors that affect the consumption of the nutritional elements by plants (Kacar & Katkat, 2015). Thus, it can take one or a few of the factors that may influence the result of the mineral contents in the plants. Regarding the locations, the highest amount of P contents was observed in control, with soil conditions highly saline and highly alkaline. The lowest value was obtained in a highly saline-alkaline location (Keskin et al., 2017).

It was found that the percentage of the elements were in the ranged of 1.3% to 1.5% for N, 0.1% to 0.4% for P, 1.1% to 4.2% for K, 0% to 0.7% for Mg, 0.04% to 0.32% for S and 0.02% to 0.09% for Na. Thus, it showed that the forages selected and preferred by the livestock contained the macro elements needed to grow with sufficient intake. From the result, Mg in *Axonopus compressus* was not detected at the detection level of 0.1%, but it did not mention whether the Mg was absent in the species. As stated by National Research Council (1985), recommended ratios of P, K^+ , Ca^{2+} , Mg^{2+} , Na^+ for all types of ruminants are 1.25% to 1.59%, 0.5% to 1.0%, 0.19% to 0.82%, 0.12% to 0.20%, and 0.06% to 0.18%. Previous studies showed average P, K, Ca, Mg, and Na contents of the plants ranged between 0.12% to 0.48%, 0.28% to 0.35%, 0.24% to 0.42%, 0.11% to 0.31%, and 0.47% to 1.13% (Keskin et al., 2017).

Generally, livestock gained their minerals from the intake of the feeds and foraged that they consumed. At the same time, some factors affect mineral intake by livestock, thus determining the mineral content of the forages. The mineral in plants usually depends on four factors: plant genotype, soil environment, climate, and the stage of maturity. However, the main factors differed minerals and depend on interactions with the listed factors and the aspects of crop or pasture husbandry such as fertilizer use, soil amendments, irrigation, crop rotation, intercropping, and high yield cultivars (Suttle, 2010).

Minerals in plants vary with soil properties, total and the available amounts of mineral in soil, cultivation and fertilization system, climate, and plant properties (Bengtsson et al., 2003; Warman & Termeer, 2005; Juknevičius & Sabienė, 2007). Different plant species tend to have different abilities to accumulate minerals even though grown under the same environments (Juknevičius & Sabienė, 2007). The balance between cations and anions among minerals uptake must be achieved, especially the macroelements cations such as Na^+ , P^+ , Ca^{2+} , and Mg^{2+} and anions such as Cl^- and SO_4^{2-} (Suttle, 2010).

5.7.2 Toxic Elements in Selected Unconsumed Species

Despite being potentially toxic to animals, the elements also play industrial uses. In contrast, the potentially harmful elements from the past industrial removal from the crust of the earth can cause harm to farm environments (Suttle, 2010). Contamination in the environment may cause subclinical exposure without overt, adverse effects in livestock but significant accumulations of the elements present in animal tissues and produce. It is of concern that the adverse effects of the potentially toxic elements in the animals and man (Chowdhury & Chandra, 1987; Fox, 1987; Scheuhammer, 1987) and continue to be a concern (World Health Organization, 2000, 2001; NRC, 2005; Suttle, 2010). Toxicity in

livestock is caused by potentially toxic elements influenced by factors that include; the uptake of the potentially harmful elements from the soil by plants the accidental ingestion of soil by animals from the diet as it absorbs the inherent and contaminant potential toxic elements. These dietary factors enhance or inhibit potential toxic elements uptake and retention, the existence of prediction sites for accumulation in the body and the duration and pattern of potentially toxic elements exposure. The soil is a significant source of potentially toxic elements (Suttle, 2010). However, plant uptake usually is slow, while soil ingestion by foraging livestock contributes to the main risk to both livestock and consumers.

The resources of feed for animals can be polluted with undesirable substances, which may originate from the environment as well as from the production process because when the production animals take the contaminated feed, the contaminants may transfer to the food of animal origins such as liver, meat, and milk (Adamse et al., 2017). The potential toxic elements were analyzed included Pb, Cd, Hg, As and Al. Results showed that Pb, Cd, and Hg were not detected except for Al. The result indicated that the unconsumed species by livestock were not due to the content of the potentially toxic elements and caused by other factors such as feed preference.

It comes with a concern of Cd through the contamination of forages with Cd obtained from fertilizers, and the following occurs in grazing livestock (Loganathan et al., 2008). Cd toxicity shows a similar symptom to Zinc (Zn) deprivation and is prevented by Zn supplementation. It is considered a high dietary Cd with more than 40 mg/kg DM (Powell et al., 1964). It included appetite loss, poor growth, retarded testicular development, and parakeratosis in sheep, liver, and kidney when Zn increased accordingly (Doyle & Pfander, 1975).

The livestock's Hg sources that threaten the livestock or are involved in the food chain are not influenced by the farm environment. Hg is found in soil in small amounts and much less in pastures and crops (less than 0.1 mg/kg). The use of Hg-based fungicides was normal for cereal seed dressing. This increases Hg concentrations to potential harm levels (approximately 20 mg/kg DM) and causes toxicity if consumed by the cattle (Boyd, 1985) or other species. Acute toxicity of organic Hg may lead to anorexia, inability to drink, blindness, ataxia, hypersensitivity reaction and death.

The toxicity of As to plants, animals, and humans requires encouragement to better understand the element's behaviour in the environment (Rosas et al., 1999). High concentrations of As in water and forage are the main ways through which the As enters the animal body, hence getting into the human food chain and leading to poisoning in humans and animals (Ashrafihelan et al., 2013).

The only detected toxic element in the study was Al which was detected the highest in *Melastoma malabathricum* with 0.96% (9600 mg/kg) followed by *Miconia crenata* with 0.58% (5760 mg/kg), *Torenia crustacea* with 0.18% (1790 mg/kg), *Taenitis blechnoides* with 0.02% (195 mg/kg), and the lowest from *Diplazium esculentum* with 0.01% (103 mg/kg). However, the result shows that Al content in selected species can be considered high, especially *Melastoma malabathricum* and *Miconia crenata*. The concentrations of Al was reportedly in the range of 2.5 to 10.0 mg/kg as found in human food (Greger, 1993), where trees, ferns, and tropical plants are accumulators and can contain 3.0 to 4.0 g/kg DM (Underwood & Suttle, 1999). The element Al is the most abundant mineral in most soils where the excess and not deficiency to the livestock under farming conditions is not surprising (Suttle, 2010).

Many plants can be consumed and safe for livestock, while a few species affect the bad health or even kill the livestock after feeding it. Therefore, the needs for identifying poisonous plants and proper livestock management are important to minimize the possibility of poisoning. The compound's total that can be considered toxic varies with the plant parts such as leaves, stems, roots, fruit or seeds. In addition, toxicity can vary over the growing season, thus making it hard to determine the poisoning level and consequences from repeated consumption over time (Gildersleeve et al., 2013). Metal toxicity of plants differs with plant species, specific metals, concentration, chemical form, soil composition, pH, and some of the metals are essential for plant growth. Metals are consumed and entered into the animal body via feeds, green fodder, drinking water, and pharmaceutical medicines. At the same time, other sources are unintentional access to the limed field, mineral supplements with high traced metal content and licking something that contains metallic pigments such as painted surface (Raikwar, 2008).

A study done by Azizol (2011) showed that the integration practices of livestock in crop plantation were cost-efficient as it saved the labour cost up to 50%. Sheep and goats were kept in a plantation where the herds of these animals produced many faecal pellets that seemed to accumulate in the grazing area. The dungs of the animals may provide microorganisms that are part of the process to decompose, which is vital to release nutrients from litter and soil organic matter. Sufficient protein and energy ensure young animals' optimum growth and reproductive performance. Adequate feed must be available in the form of undergrowth to ensure the sustainability of oil palm-livestock integration. The suitable growth conditions of 30 different species of native herbage are under the canopy shade of five-year-old oil palm trees (Chen & Shamsudin, 1991). It is usually dominated by *Asystasia intrusa*, *Ottochloa* sp., *Mikania* sp., and *Pueraria* (Ahmad Salihin et al., 1998).

High quality of nutrition and management results from the better performance and health of the animals. The productivity of livestock for high genetic merit is always linked to the nutrition (Ulyatt & Waghorn, 1993) that expresses milk production, multiple births, growth rate or disease resistance (Corson et al., 1999). Usually, poisonous plants come out in small densities where the impact on herbivores is still insignificant. However, it can be increased due to overgrazing as it can reduce the preferred species of forages, thus changing the relative plant biomass to the poisonous species. The apparent growth of poisonous species will create a condition of no choice but must be consumed by cattle as feed due to the inadequate occurrence of forages (Zhao et al., 2012).

5.8 Summary of Discussion

The chapter discusses the results obtained from this study. The population of weeds in crop areas are never constant, as they are in the dynamic state of flux due to the changes in climatic and environmental conditions and husbandry methods. In this study, the weed floristic composition of a particular site may change due to time and weed communities themselves and as a complex ecological entity. The competition of the sunlight for photosynthesis limits the growth and development of undergrowth plants, and as the age of oil palm increased it then produced greater and vast canopy cover as found in the other study that the undergrowth older oil palm plantation had lower carbon stock estimation compared to younger oil palm plantation. Estimating carbon stock is needed as the increase in concentration levels of greenhouse gases concentration commonly found as CO₂ in the atmosphere is a major concern responsible for global climate change.

This study revealed that the recovery of forages from the day of grazing started to the next rotation was sufficient to be grazed by livestock and strengthened by the plateau

height of recovery when it reached day 27, and the forage is grazed again in the next rotation by livestock. This study also revealed that grazed weeds could tolerate physical and biotic stresses as well as damage. Grazing did not result in the adverse effect of forage growth. The canopy provided by the mature oil palm trunk provides the low light transmission and promotes some changes to the ground vegetation. The uncut forage was more preferred by livestock as the maturity of *Axonopus compressus* increased, and the plants were leafier with high quality and density at the mid-stage of the growth phase. This suggests that no cut treatment is a better practice to enhance the new sprouting of *Axonopus compressus* for feeding the livestock.

The different amounts of elements in each selected species showed the differences in nutritional value in plant species due to the differences in species anatomy, biochemistry, and morphology. As suggested, different species of forages are a unique mixture and differ in forage quality, making the combination difficult to analyse the nutritional value and the forage quality definition, also dealing with forage capacity in providing essential nutrients to the livestock. Usually, the plant uptake is slow, while soil ingestion by foraging livestock contributes as the main risk to both livestock and consumer. The soil is a major source that holds potentially toxic elements. Some plants are consumed and safe for livestock, while a few adversely effects cause bad health or kill the livestock after being fed.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

It can be concluded that the two periods of sampling of the same study plot of integrated oil palm plantation differ in terms of the number of species, number of individuals and diversity indices. Initial sampling recorded a lower number of species but a higher number of individuals than the second sampling. In terms of diversity indices, the results showed that the second sampling recorded a higher H' value but lower 1-D value than the initial sampling. However, the value of H' showed moderate community complexity, and 1-D value stated that both areas were considered to have high species diversity.

Initial sampling showed the dominance of *Scleromitrion verticillatum* followed by *Cyrtococcum patens* var *latifolium*, *Centotheca lappacea*, *Axonopus compressus*, and *Torenia crustacea*. After six months of initial sampling in an integrated oil palm plantation, the expression of weed species showed the dominance of five species in the order of *Scleromitrion verticillatum*, *Cyrtococcum patens* var *latifolium*, *Axonopus compressus*, *Centotheca lappacea*, and *Torenia crustacea*. It was observed that the species dominance in the initial and second sampling was similar.

The estimated carbon stock was 0.43 tonnes ha⁻¹ in initial sampling and 0.41 tonnes ha⁻¹ in second sampling six months after the initial sampling. This showed that the initial sampling had a higher amount of biomass recorded contributed by 10961 individuals belonging to 53 species than six months after initial sampling with 62 species with 9959 individuals.

Forage recovery showed that *Axonopus compressus* recorded differently in the recovery height for grazed, cut, and ungrazed. The recovery of ungrazed was significantly higher than grazed. The grazed and cut *Axonopus compressus* found no significant difference in height recovery in the opened area. The cut *Axonopus compressus* in opened and shaded areas found higher recovery from the shaded area. For *Elaeis guineensis*, the height of samples that were significantly higher for ungrazed than grazed and recovery height of the grazed and cut *Elaeis guineensis* in the opened area differ significantly and for the cut and ungrazed *Elaeis guineensis*. For cut *Elaeis guineensis*, the recovery height was found higher in the opened area. The recovery of producing new shoots of the grazed *Antrophyum reticulatum* was significantly higher.

Livestock preferred *Axonopus compressus* that was uncut. It revealed that the trend of grazed was higher for uncut forages that were grazed by livestock. Thus, this illustrated that no cutting treatment is required to the forages in the integrated oil palm plantation due to the sufficient period of rotation system for forage to recover. This study showed that grazed weeds could tolerate physical and biotic stresses as well as damage, and livestock grazing did not affect forage growth.

Elements N, P, K, Mg, S, and Na detected in the selected consumed species showed almost similar. However, Mg was not in *Axonopus compressus*. Toxicity analysis of Pb, Cd, Hg, As and Al for selected unconsumed plants showed that the elements of Pb, Cd, Hg, and As were not detected in all species except for Al. A balanced diet must be emphasized in providing the livestock with forage feed in the integrated oil palm plantation. Continuous monitoring of well-being and health is needed by observing the symptoms of nutrient deficiencies and toxicity.

6.2 Recommendations

Further study can be conducted on the livestock dropping or faeces effect on growth and forage recovery. Faeces may affect the soil micro-flora and micro-fauna and their effects on the crop, soil, and environment either it brings benefit compounds or toxic compounds or no effect at all. Since different areas exhibit different species of forages, the quality of the forages must be determined before livestock are introduced in any oil palm plantation. This is because only healthy and good forage growth yields healthy livestock. A good and high nutritional value of feed source must be provided for the adequate quality and quantity of livestock.

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APPENDICES

Appendix A1: The Samarahan Plantations Sdn. Bhd. is certified with Malaysian Sustainable Palm Oil (MSPO) certification.

Certificate SGS-MSPO-MY20/1811030367

CERTIFICATE FOR MALAYSIAN SUSTAINABLE PALM OIL

SGS (Malaysia) Sdn. Bhd. hereby certifies that

Samarahan Plantations Sdn. Bhd.

Samarahan Estate, Jalan Ensegei, Off 32nd Mile
Kuching Serian Road, P.O. Box 66 94707, Serian, Malaysia

has complied with the requirements specified in the

MS 2530-3: 2013 PART 3: GENERAL PRINCIPLES FOR OIL PALM PLANTATIONS AND ORGANISED SMALLHOLDERS
under the MSPO Certification Scheme

SCOPE:
Production of Fresh Fruit Bunches (FFB) for Plantations in compliance to the
MSPO Certification Standard MS2530-3:2013 Part 3: General Principles For Oil
Palm Plantations And Organized Smallholders.

This certificate is valid from 27 April 2020 until 26 April 2025
Issue 1. Certified since 27 April 2020

Refer to Annex for details of certified Estate(s) and its GPS Coordinates.

Authorised by



SGS (Malaysia) Sdn Bhd
Lot 3 & Lot 4, Persiaran Jubli Perak, Seksyen 22
40300 Shah Alam, Selangor Darul Ehsan, MALAYSIA
t 603 - 7627 0080 www.sgs.com

This certificate remains the property of SGS and shall be returned upon request

Page 1 of 2





ACB MSPO 01














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Appendix A2: Livestock grazing in the integrated oil palm plantation.



Appendix A3: Livestock in the fencing area.



Appendix B1: The sampling area in the integrated oil palm plantation.



Appendix B2: Quadrature establishment (1m × 1m)



Appendix B3: Weeds were cut at ground level.



Appendix B4: Samples for identification



Appendix B5: Samples were separated to each species it belonged before further identification.



Appendix B6: Species identification.



Appendix C1: *Axonopus compressus*
P.Beauv.



Appendix C2: *Elaeis guineensis* Jacq.



Appendix C3: *Antrophyum reticulatum*
(Forst.) Kaulf.



Appendix C4: *Asystasia gangetica* (L.)
T.Anderson



Appendix C5: *Scleromitron verticillatum*

Appendix C6: *Melastoma malabathricum*

(L.) R.J.Wang



L.



Appendix C7: *Miconia crenata* (Vahl)
Michelang.



Appendix C8: *Diplazium esculentum*
(Retz.) Sw.



Appendix C9: *Taenitis blechnoides*
(Willd.) Sw.



Appendix C10: *Torenia crustacea* (L.)
Cham. & Schltdl.



Appendix D1: *Axonopus compressus* P.Beauv. samples for species recovery.



Appendix D2: Grazed sample of *Elaeis guineensis* Jacq. for species recovery.



Appendix D3: New shoot of *Antrophyum reticulatum* (Forst.) Kaulf.



Appendix E1: The measurement of the square that was used to estimate the percentage of forage grazed by livestock.



Appendix E2: Establishment of squares (5 m x 5 m)



Appendix E3: Forages were cut at the almost same height.



Appendix E4: Forage after the cut.



Appendix E5: The difference between cut and uncut forage.



Appendix E6: Grids used to count the percentage of forage grazed by livestock for forage preference.



Appendix E7: *Axonopus compressus* grazed by livestock.



Appendix E8: Another example of grazed *Axonopus compressus* grazed by livestock.



Appendix F1: Family dominance of weeds species in the initial sampling at the integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.

Family	Number of Species	D	F	RD	RF	IV	SDR
Poaceae	6	5186	2.8200	0.4731	0.3016	0.7747	0.3874
Rubiaceae	5	3810	1.0500	0.3476	0.1123	0.4599	0.2299
Melastomataceae	2	464	1.1900	0.0423	0.1273	0.1696	0.0848
Scrophulariaceae	1	421	0.6100	0.0384	0.0652	0.1036	0.0518
Euphorbiaceae	3	214	0.5200	0.0195	0.0556	0.0751	0.0376
Cyperaceae	7	136	0.5600	0.0124	0.0599	0.0723	0.0362
Moraceae	2	100	0.4200	0.0091	0.0449	0.0540	0.0270
Leguminosae	1	193	0.3300	0.0176	0.0353	0.0529	0.0265
Arecaceae	1	60	0.3800	0.0055	0.0406	0.0461	0.0231
Adiantaceae	1	87	0.3400	0.0079	0.0364	0.0443	0.0222
Asteraceae	4	109	0.2400	0.0099	0.0257	0.0356	0.0178
Woodsiaceae	1	65	0.2600	0.0059	0.0278	0.0337	0.0169
Acanthaceae	2	16	0.1200	0.0015	0.0128	0.0143	0.0071
Oleandraceae	1	34	0.0800	0.0031	0.0086	0.0117	0.0058
Schizaeaceae	3	10	0.0900	0.0009	0.0096	0.0105	0.0053
Commelinaceae	1	12	0.0700	0.0011	0.0075	0.0086	0.0043
Flagellariaceae	1	11	0.0700	0.0010	0.0075	0.0085	0.0042
Lamiaceae	2	13	0.0600	0.0012	0.0064	0.0076	0.0038
Mimosaceae	1	10	0.0400	0.0009	0.0043	0.0052	0.0026

Appendix F1: continued

Theaceae	1	3	0.0300	0.0003	0.0032	0.0035	0.0017
Actinidiaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Blechnaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Clusiaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Gleicheniaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Hypoxidaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Loganiaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Vittariaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Total	53	10961	9.3500	1.0000	1.0000	2.0000	1.0000

Appendix F2: Family dominance of weeds species in the second sampling of the integrated oil palm plantation represented by Summed Dominance Ratio (SDR) value.

Family	Number of Species	D	F	RD	RF	IV	SDR
Poaceae	8	4326	2.5100	0.4344	0.2737	0.7081	0.3540
Rubiaceae	6	3605	1.0600	0.3620	0.1156	0.4776	0.2388
Melastomataceae	2	433	1.2800	0.0435	0.1396	0.1831	0.0915
Scrophulariaceae	1	425	0.6900	0.0427	0.0752	0.1179	0.0590
Cyperaceae	8	162	0.5500	0.0163	0.0600	0.0762	0.0381
Euphorbiaceae	3	182	0.4700	0.0183	0.0513	0.0695	0.0348
Moraceae	2	106	0.4300	0.0106	0.0469	0.0575	0.0288
Leguminosae	2	223	0.3200	0.0224	0.0349	0.0573	0.0286

Appendix F2: continued

Adiantaceae	1	155	0.3700	0.0156	0.0403	0.0559	0.0280
Arecaceae	1	51	0.3300	0.0051	0.0360	0.0411	0.0206
Woodsiaceae	1	66	0.2800	0.0066	0.0305	0.0372	0.0186
Asteraceae	2	51	0.1600	0.0051	0.0174	0.0226	0.0113
Acanthaceae	2	31	0.1300	0.0031	0.0142	0.0173	0.0086
Commelinaceae	2	15	0.1300	0.0015	0.0142	0.0157	0.0078
Schizaeaceae	3	23	0.1200	0.0023	0.0131	0.0154	0.0077
Oleandraceae	1	14	0.0700	0.0014	0.0076	0.0090	0.0045
Lamiaceae	4	11	0.0600	0.0011	0.0065	0.0076	0.0038
Actinidiaceae	1	39	0.0100	0.0039	0.0011	0.0050	0.0025
Theaceae	1	4	0.0400	0.0004	0.0044	0.0048	0.0024
Gleicheniaceae	1	3	0.0300	0.0003	0.0033	0.0036	0.0018
Smilacaceae	1	4	0.0200	0.0004	0.0022	0.0026	0.0013
Blechnaceae	1	2	0.0200	0.0002	0.0022	0.0024	0.0012
Hypoxidaceae	1	2	0.0200	0.0002	0.0022	0.0024	0.0012
Mimosaceae	1	8	0.0100	0.0008	0.0011	0.0019	0.0009
Convolvulaceae	1	7	0.0100	0.0007	0.0011	0.0018	0.0009
Apiaceae	1	5	0.0100	0.0005	0.0011	0.0016	0.0008
Loganiaceae	1	3	0.0100	0.0003	0.0011	0.0014	0.0007
Leeaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Malvaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Piperaceae	1	1	0.0100	0.0001	0.0011	0.0012	0.0006
Total	62	9959	9.1700	1.0000	1.0000	2.0000	1.0000

Appendix G1: Dominant in the initial sampling at the integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.

Species	D	F	RD	RF	IV	SDR
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3780	0.9700	0.3449	0.1037	0.4486	0.2243
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2198	0.8300	0.2005	0.0888	0.2893	0.1446
<i>Centotheca lappacea</i> Desv.	1761	0.9500	0.1607	0.1016	0.2623	0.1311
<i>Axonopus compressus</i> P.Beauv.	1160	0.9100	0.1058	0.0973	0.2032	0.1016
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	421	0.6100	0.0384	0.0652	0.1036	0.0518
<i>Miconia crenata</i> (Vahl) Michelang.	242	0.6000	0.0221	0.0642	0.0862	0.0431
<i>Melastoma malabathricum</i> L.	222	0.5900	0.0203	0.0631	0.0834	0.0417
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	193	0.3300	0.0176	0.0353	0.0529	0.0265
<i>Ficus fulva</i> Reinw. ex Blume	99	0.4100	0.0090	0.0439	0.0529	0.0264
<i>Phyllanthus amarus</i> Schumach. & Thonn.	70	0.4200	0.0064	0.0449	0.0513	0.0257
<i>Elaeis guineensis</i> Jacq.	60	0.3800	0.0055	0.0406	0.0461	0.0231
<i>Taenitis blechnoides</i> (Willd.) Sw.	87	0.3400	0.0079	0.0364	0.0443	0.0222

Appendix G1: continued

<i>Diplazium esculentum</i> (Retz.) Sw.	65	0.2600	0.0059	0.0278	0.0337	0.0169
<i>Ageratum conyzoides</i> L.	103	0.1900	0.0094	0.0203	0.0297	0.0149
<i>Cyperus</i> sp.	54	0.2200	0.0049	0.0235	0.0285	0.0142
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	143	0.0900	0.0130	0.0096	0.0227	0.0113
<i>Cyperus compressus</i> L.	41	0.1600	0.0037	0.0171	0.0209	0.0104
<i>Asystasia gangetica</i> (L.) T.Anderson	14	0.1000	0.0013	0.0107	0.0120	0.0060
<i>Nephrolepis biserrata</i> (Sw.) Schott	34	0.0800	0.0031	0.0086	0.0117	0.0058
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	28	0.0800	0.0026	0.0086	0.0111	0.0056
<i>Paspalum conjugatum</i> P.J.Bergius	35	0.0700	0.0032	0.0075	0.0107	0.0053
<i>Murdannia nudiflora</i> (L.) Brenan	12	0.0700	0.0011	0.0075	0.0086	0.0043
<i>Flagellaria indica</i> L.	11	0.0700	0.0010	0.0075	0.0085	0.0042
<i>Lygodium circinatum</i> (Burm.f.) Sw.	7	0.0600	0.0006	0.0064	0.0071	0.0035
<i>Vitex pinnata</i> L.	6	0.0500	0.0005	0.0053	0.0059	0.0029
<i>Mimosa pudica</i> L.	10	0.0400	0.0009	0.0043	0.0052	0.0026

Appendix G1: continued

<i>Cyperus distans</i> L.f.	6	0.0400	0.0005	0.0043	0.0048	0.0024
<i>Sacciolepis indica</i> Chase	6	0.0400	0.0005	0.0043	0.0048	0.0024
<i>Exallage auricularia</i> (L.) Bremek.	4	0.0400	0.0004	0.0043	0.0046	0.0023
<i>Cyrtococcum oxyphyllum</i> Stapf	26	0.0200	0.0024	0.0021	0.0045	0.0023
<i>Timonius flavescens</i> Baker	22	0.0200	0.0020	0.0021	0.0041	0.0021
<i>Scleria sumatrensis</i> Retz.	4	0.0300	0.0004	0.0032	0.0036	0.0018
<i>Adinandra dumosa</i> Jack	3	0.0300	0.0003	0.0032	0.0035	0.0017
<i>Mikania micrantha</i> Kunth	3	0.0300	0.0003	0.0032	0.0035	0.0017
<i>Asystasia</i> sp.	2	0.0200	0.0002	0.0021	0.0023	0.0012
<i>Fimbristylis dichotoma</i> (L.) Vahl	2	0.0200	0.0002	0.0021	0.0023	0.0012
<i>Lygodium flexuosum</i> (L.) Sw.	2	0.0200	0.0002	0.0021	0.0023	0.0012
<i>Hyptis capitata</i> Jacq.	7	0.0100	0.0006	0.0011	0.0017	0.0009
<i>Lasianthus</i> sp.	3	0.0100	0.0003	0.0011	0.0013	0.0007
<i>Crassocephalum crepidioides</i> S.Moore	2	0.0100	0.0002	0.0011	0.0013	0.0006
<i>Antrophyum reticulatum</i> (Forst.) Kaulf.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Blechnum orientale</i> L.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	1	0.0100	0.0001	0.0011	0.0012	0.0006

Appendix G1: continued

<i>Cyrtophyllum fragrans</i> DC.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Ficus auriculata</i> Lour.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Fimbristylis quinquangularis</i> (Vahl) Kunth	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Lygodium microphyllum</i> (Cav.) R.Br.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Macaranga</i> sp.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Oldenlandia corymbosa</i> L.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Ploiarium elegans</i> Korth.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Saurauia glabra</i> Merr.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Struchium sparganophorum</i> (L.) Kuntze	1	0.0100	0.0001	0.0011	0.0012	0.0006
TOTAL	10961	9.3500	1.0000	1.0000	2.0000	1.0000

Appendix G2: Dominant species in the second sampling at the integrated oil palm plantation area represented by Summed Dominance Ratio (SDR) value.

Species	D	F	RD	RF	IV	SDR
<i>Scleromitrium verticillatum</i> (L.) R.J.Wang	3593	0.9600	0.3608	0.1047	0.4655	0.2327
<i>Cyrtococcum patens</i> var. latifolium (Honda) Ohwi	2256	0.7800	0.2265	0.0851	0.3116	0.1558
<i>Axonopus compressus</i> P.Beauv.	1052	0.7700	0.1056	0.0840	0.1896	0.0948
<i>Centotheca lappacea</i> Desv.	928	0.8400	0.0932	0.0916	0.1848	0.0924
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	425	0.6900	0.0427	0.0752	0.1179	0.0590
<i>Miconia crenata</i> (Vahl) Michelang.	251	0.6300	0.0252	0.0687	0.0939	0.0470
<i>Melastoma malabathricum</i> L.	182	0.6500	0.0183	0.0709	0.0892	0.0446
<i>Ficus fulva</i> Reinw. ex Blume	105	0.4200	0.0105	0.0458	0.0563	0.0282
<i>Taenitis blechnoides</i> (Willd.) Sw.	155	0.3700	0.0156	0.0403	0.0559	0.0280
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	218	0.3000	0.0219	0.0327	0.0546	0.0273

Appendix G2: continued

<i>Phyllanthus amarus</i> Schumach. & Thonn.	56	0.3500	0.0056	0.0382	0.0438	0.0219
<i>Elaeis guineensis</i> Jacq.	51	0.3300	0.0051	0.0360	0.0411	0.0206
<i>Diplazium esculentum</i> (Retz.) Sw.	66	0.2800	0.0066	0.0305	0.0372	0.0186
<i>Cyperus</i> sp.	43	0.2200	0.0043	0.0240	0.0283	0.0142
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	125	0.1100	0.0126	0.0120	0.0245	0.0123
<i>Ageratum conyzoides</i> L.	36	0.1500	0.0036	0.0164	0.0200	0.0100
<i>Cyperus rotundus</i> L.	38	0.1100	0.0038	0.0120	0.0158	0.0079
<i>Cyperus distans</i> L.f.	35	0.0900	0.0035	0.0098	0.0133	0.0067
<i>Murdannia nudiflora</i> (L.) Brenan	12	0.1000	0.0012	0.0109	0.0121	0.0061
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	39	0.0700	0.0039	0.0076	0.0115	0.0058
<i>Asystasia gangetica</i> (L.) T.Anderson	13	0.0800	0.0013	0.0087	0.0100	0.0050
<i>Nephrolepis biserrata</i> (Sw.) Schott	14	0.0700	0.0014	0.0076	0.0090	0.0045

Appendix G2: continued

<i>Cyrtococcum oxyphyllum</i> Stapf	38	0.0400	0.0038	0.0044	0.0082	0.0041
<i>Polytrias indica</i> (Houtt.) Veldkamp	46	0.0300	0.0046	0.0033	0.0079	0.0039
<i>Asystasia</i> sp.	18	0.0500	0.0018	0.0055	0.0073	0.0036
<i>Lygodium flexuosum</i> (L.) Sw.	7	0.0600	0.0007	0.0065	0.0072	0.0036
<i>Lygodium circinatum</i> (Burm.f.) Sw.	13	0.0400	0.0013	0.0044	0.0057	0.0028
<i>Saurauia glabra</i> Merr.	39	0.0100	0.0039	0.0011	0.0050	0.0025
<i>Hedyotis</i> sp.	5	0.0400	0.0005	0.0044	0.0049	0.0024
<i>Adinandra dumosa</i> Jack	4	0.0400	0.0004	0.0044	0.0048	0.0024
<i>Commelina diffusa</i> Burm.f.	3	0.0300	0.0003	0.0033	0.0036	0.0018
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	3	0.0300	0.0003	0.0033	0.0036	0.0018
<i>Paspalum conjugatum</i> P.J.Bergius	3	0.0300	0.0003	0.0033	0.0036	0.0018
<i>Hyptis capitata</i> Jacq.	7	0.0200	0.0007	0.0022	0.0029	0.0014

Appendix G2: continued

<i>Ramirezella strobilophora</i> var. <i>pubescens</i> (Rose) Maréchal Mascherpa & Stainier	5	0.0200	0.0005	0.0022	0.0027	0.0013
<i>Struchium sparganophorum</i> (L.) Kuntze	15	0.0100	0.0015	0.0011	0.0026	0.0013
<i>Smilax</i> sp.	4	0.0200	0.0004	0.0022	0.0026	0.0013
<i>Fimbristylis dichotoma</i> (L.) Vahl	3	0.0200	0.0003	0.0022	0.0025	0.0012
<i>Lygodium microphyllum</i> (Cav.) R.Br.	3	0.0200	0.0003	0.0022	0.0025	0.0012
<i>Uncaria elliptica</i> R.Br. ex G.Don	3	0.0200	0.0003	0.0022	0.0025	0.0012
<i>Clerodendrum chinense</i> (Osbeck) Mabb.	2	0.0200	0.0002	0.0022	0.0024	0.0012
<i>Cyperus compressus</i> L.	2	0.0200	0.0002	0.0022	0.0024	0.0012
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	2	0.0200	0.0002	0.0022	0.0024	0.0012
<i>Paederia foetida</i> L.	2	0.0200	0.0002	0.0022	0.0024	0.0012
<i>Stenochlaena palustris</i> (Burm.) Bedd.	2	0.0200	0.0002	0.0022	0.0024	0.0012

Appendix G2: continued

<i>Mimosa pudica</i> L.	8	0.0100	0.0008	0.0011	0.0019	0.0009
<i>Camonea umbellata</i> A.R.Simões & Staples	7	0.0100	0.0007	0.0011	0.0018	0.0009
<i>Oenanthe javanica</i> DC.	5	0.0100	0.0005	0.0011	0.0016	0.0008
<i>Cyrtophyllum fragrans</i> DC.	3	0.0100	0.0003	0.0011	0.0014	0.0007
<i>Axonopus</i> sp.	2	0.0100	0.0002	0.0011	0.0013	0.0006
<i>Callicarpa longifolia</i> Lam.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Ficus aurata</i> Miq.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Hyptis brevipes</i> Poit.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Cyperus brevifolius</i> (Rottb.) Endl. Ex Hassk.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Lasianthus</i> sp.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Leea aculeata</i> Blume	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Mallotus leucodermis</i> Hook.f.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Piper betle</i> L.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Rhynchospora corymbosa</i> (L.) Britton	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Sacciolepis indica</i> Chase	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Sida rhombifolia</i> L.	1	0.0100	0.0001	0.0011	0.0012	0.0006
<i>Urophyllum</i> sp.	1	0.0100	0.0001	0.0011	0.0012	0.0006
TOTAL	9959	9.1700	1.0000	1.0000	2.0000	1.0000

Appendix H1: Shannon-Wiener Diversity Index in the initial sampling at the integrated oil palm plantation area represented by H'.

Species	Number of Individual	P	- P Ln P
<i>Scleromitrium verticillatum</i> (L.) R.J.Wang	3780	0.3449	0.3671
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2198	0.2005	0.3222
<i>Centotheca lappacea</i> Desv.	1761	0.1607	0.2938
<i>Axonopus compressus</i> P.Beauv.	1160	0.1058	0.2377
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	421	0.0384	0.1252
<i>Miconia crenata</i> (Vahl) Michelang.	242	0.0221	0.0842
<i>Melastoma malabathricum</i> L.	222	0.0203	0.0790
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	193	0.0176	0.0711
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	143	0.0130	0.0566
<i>Ageratum conyzoides</i> L.	103	0.0094	0.0439
<i>Ficus fulva</i> Reinw. ex Blume	99	0.0090	0.0425
<i>Taenitis blechnoides</i> (Willd.) Sw.	87	0.0079	0.0384
<i>Phyllanthus amarus</i> Schumach. & Thonn.	70	0.0064	0.0323
<i>Diplazium esculentum</i> (Retz.) Sw.	65	0.0059	0.0304
<i>Elaeis guineensis</i> Jacq.	60	0.0055	0.0285
<i>Cyperus</i> sp.	54	0.0049	0.0262
<i>Cyperus compressus</i> L.	41	0.0037	0.0209
<i>Paspalum conjugatum</i> P.J.Bergius	35	0.0032	0.0184

Appendix H1: continued

<i>Nephrolepis biserrata</i> (Sw.) Schott	34	0.0031	0.0179
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	28	0.0026	0.0153
<i>Cyrtococcum oxyphyllum</i> Stapf	26	0.0024	0.0143
<i>Timonius flavescens</i> Baker	22	0.0020	0.0125
<i>Asystasia gangetica</i> (L.) T.Anderson	14	0.0013	0.0085
<i>Murdannia nudiflora</i> (L.) Brenan	12	0.0011	0.0075
<i>Flagellaria indica</i> L.	11	0.0010	0.0069
<i>Mimosa pudica</i> L.	10	0.0009	0.0064
<i>Hyptis capitata</i> Jacq.	7	0.0006	0.0047
<i>Lygodium circinatum</i> (Burm.f.) Sw.	7	0.0006	0.0047
<i>Cyperus distans</i> L.f.	6	0.0005	0.0041
<i>Sacciolepis indica</i> Chase	6	0.0005	0.0041
<i>Vitex pinnata</i> L.	6	0.0005	0.0041
<i>Exallage auricularia</i> (L.) Bremek.	4	0.0004	0.0029
<i>Scleria sumatrensis</i> Retz.	4	0.0004	0.0029
<i>Adinandra dumosa</i> Jack	3	0.0003	0.0022
<i>Lasianthus</i> sp.	3	0.0003	0.0022
<i>Mikania micrantha</i> Kunth	3	0.0003	0.0022
<i>Asystasia</i> sp.	2	0.0002	0.0016
<i>Crassocephalum crepidioides</i> S.Moore	2	0.0002	0.0016
<i>Fimbristylis dichotoma</i> (L.) Vahl	2	0.0002	0.0016

Appendix H1: continued

<i>Lygodium flexuosum</i> (L.) Sw.	2	0.0002	0.0016
<i>Antrophyum reticulatum</i> (Forst.) Kaulf.	1	0.0001	0.0008
<i>Blechnum orientale</i> L.	1	0.0001	0.0008
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	1	0.0001	0.0008
<i>Cyrtophyllum fragrans</i> DC.	1	0.0001	0.0008
<i>Ficus auriculata</i> Lour.	1	0.0001	0.0008
<i>Fimbristylis quinquangularis</i> (Vahl) Kunth	1	0.0001	0.0008
<i>Lygodium microphyllum</i> (Cav.) R.Br.	1	0.0001	0.0008
<i>Macaranga</i> sp.	1	0.0001	0.0008
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	1	0.0001	0.0008
<i>Oldenlandia corymbosa</i> L.	1	0.0001	0.0008
<i>Ploiarium elegans</i> Korth.	1	0.0001	0.0008
<i>Saurauia glabra</i> Merr.	1	0.0001	0.0008
<i>Struchium sparganophorum</i> (L.) Kuntze	1	0.0001	0.0008
TOTAL	10961	1.0000	2.0591

Appendix H2: Shannon-Wiener Diversity Index in the second sampling at the integrated oil palm plantation area represented by H'.

Species	Number of Individual	P	- P Ln P
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3593	0.3608	0.3678
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2256	0.2265	0.3364
<i>Axonopus compressus</i> P.Beauv.	1052	0.1056	0.2374
<i>Centotheca lappacea</i> Desv.	928	0.0932	0.2211
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	425	0.0427	0.1346
<i>Miconia crenata</i> (Vahl) Michelang.	251	0.0252	0.0928
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	218	0.0219	0.0837
<i>Melastoma malabathricum</i> L.	182	0.0183	0.0731
<i>Taenitis blechnoides</i> (Willd.) Sw.	155	0.0156	0.0648
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	125	0.0126	0.0549
<i>Ficus fulva</i> Reinw. ex Blume	105	0.0105	0.0480
<i>Diplazium esculentum</i> (Retz.) Sw.	66	0.0066	0.0332
<i>Phyllanthus amarus</i> Schumach. & Thonn.	56	0.0056	0.0291
<i>Elaeis guineensis</i> Jacq.	51	0.0051	0.0270
<i>Polytrias indica</i> (Houtt.) Veldkamp	46	0.0046	0.0248
<i>Cyperus</i> sp.	43	0.0043	0.0235
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	39	0.0039	0.0217

Appendix H2: continued

<i>Saurauia glabra</i> Merr.	39	0.0039	0.0217
<i>Cyperus rotundus</i> L.	38	0.0038	0.0212
<i>Cyrtococcum oxyphyllum</i> Stapf	38	0.0038	0.0212
<i>Ageratum conyzoides</i> L.	36	0.0036	0.0203
<i>Cyperus distans</i> L.f.	35	0.0035	0.0199
<i>Asystasia</i> sp.	18	0.0018	0.0114
<i>Struchium sparganophorum</i> (L.) Kuntze	15	0.0015	0.0098
<i>Nephrolepis biserrata</i> (Sw.) Schott	14	0.0014	0.0092
<i>Asystasia gangetica</i> (L.) T.Anderson	13	0.0013	0.0087
<i>Lygodium circinatum</i> (Burm.f.) Sw.	13	0.0013	0.0087
<i>Murdannia nudiflora</i> (L.) Brenan	12	0.0012	0.0081
<i>Mimosa pudica</i> L.	8	0.0008	0.0057
<i>Hyptis capitata</i> Jacq.	7	0.0007	0.0051
<i>Lygodium flexuosum</i> (L.) Sw.	7	0.0007	0.0051
<i>Camonea umbellata</i> A.R.Simões & Staples	7	0.0007	0.0051
<i>Hedyotis</i> sp.	5	0.0005	0.0038
<i>Oenanthe javanica</i> DC.	5	0.0005	0.0038
<i>Ramirezella strobilophora</i> var. <i>pubescens</i> (Rose) Maréchal Mascherpa & Stainier	5	0.0005	0.0038
<i>Adinandra dumosa</i> Jack	4	0.0004	0.0031
<i>Smilax</i> sp.	4	0.0004	0.0031
<i>Commelina diffusa</i> Burm.f.	3	0.0003	0.0024

Appendix H2: continued

<i>Dicranopteris linearis</i> (Burm.f.) Underw.	3	0.0003	0.0024
<i>Cyrtophyllum fragrans</i> DC.	3	0.0003	0.0024
<i>Fimbristylis dichotoma</i> (L.) Vahl	3	0.0003	0.0024
<i>Lygodium microphyllum</i> (Cav.) R.Br.	3	0.0003	0.0024
<i>Paspalum conjugatum</i> P.J.Bergius	3	0.0003	0.0024
<i>Uncaria elliptica</i> R.Br. ex G.Don	3	0.0003	0.0024
<i>Axonopus</i> sp.	2	0.0002	0.0017
<i>Clerodendrum chinense</i> (Osbeck) Mabb.	2	0.0002	0.0017
<i>Cyperus compressus</i> L.	2	0.0002	0.0017
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	2	0.0002	0.0017
<i>Paederia foetida</i> L.	2	0.0002	0.0017
<i>Stenochlaena palustris</i> (Burm.) Bedd.	2	0.0002	0.0017
<i>Callicarpa longifolia</i> Lam.	1	0.0001	0.0009
<i>Ficus aurata</i> Miq.	1	0.0001	0.0009
<i>Hyptis brevipes</i> Poit.	1	0.0001	0.0009
<i>Cyperus brevifolius</i> (Rottb.) Endl. Ex Hassk.	1	0.0001	0.0009
<i>Lasianthus</i> sp.	1	0.0001	0.0009
<i>Leea aculeata</i> Blume	1	0.0001	0.0009
<i>Mallotus leucodermis</i> Hook.f.	1	0.0001	0.0009
<i>Piper betle</i> L.	1	0.0001	0.0009
<i>Rhynchospora corymbosa</i> (L.) Britton	1	0.0001	0.0009

Appendix H2: continued

<i>Sacciolepis indica</i> Chase	1	0.0001	0.0009
<i>Sida rhombifolia</i> L.	1	0.0001	0.0009
<i>Urophyllum</i> sp.	1	0.0001	0.0009
TOTAL	9959	1.0000	2.1116

Appendix H3: Simpson's Index in the initial sampling at the integrated oil palm plantation area.

Species	Number (n)	n(n-1)	n(n-1)/(N(N-1))
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3780	14284620	0.11890715
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2198	4829006	0.04019731
<i>Centotheca lappacea</i> Desv.	1761	3099360	0.02579950
<i>Axonopus compressus</i> P.Beauv.	1160	1344440	0.01119130
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	421	176820	0.00147187
<i>Miconia crenata</i> (Vahl) Michelang.	242	58322	0.00048548
<i>Melastoma malabathricum</i> L.	222	49062	0.00040840
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	193	37056	0.00030846
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	143	20306	0.00016903

Appendix H3: continued

<i>Ageratum conyzoides</i> L.	103	10506	0.00008745
<i>Ficus fulva</i> Reinw. ex Blume	99	9702	0.00008076
<i>Taenitis blechnoides</i> (Willd.) Sw.	87	7482	0.00006228
<i>Phyllanthus amarus</i> Schumach. & Thonn.	70	4830	0.00004021
<i>Diplazium esculentum</i> (Retz.) Sw.	65	4160	0.00003463
<i>Elaeis guineensis</i> Jacq.	60	3540	0.00002947
<i>Cyperus</i> sp.	54	2862	0.00002382
<i>Cyperus compressus</i> L.	41	1640	0.00001365
<i>Paspalum conjugatum</i> P.J.Bergius	35	1190	0.00000991
<i>Nephrolepis biserrata</i> (Sw.) Schott	34	1122	0.00000934
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	28	756	0.00000629
<i>Cyrtococcum oxyphyllum</i> Stapf	26	650	0.00000541
<i>Timonius flavescens</i> Baker	22	462	0.00000385
<i>Asystasia gangetica</i> (L.) T.Anderson	14	182	0.00000151
<i>Murdannia nudiflora</i> (L.) Brenan	12	132	0.00000110
<i>Flagellaria indica</i> L.	11	110	0.00000092
<i>Mimosa pudica</i> L.	10	90	0.00000075
<i>Hyptis capitata</i> Jacq.	7	42	0.00000035

Appendix H3: continued

<i>Lygodium circinatum</i> (Burm.f.) Sw.	7	42	0.00000035
<i>Cyperus distans</i> L.f.	6	30	0.00000025
<i>Sacciolepis indica</i> Chase	6	30	0.00000025
<i>Vitex pinnata</i> L.	6	30	0.00000025
<i>Exallage auricularia</i> (L.) Bremek.	4	12	0.00000010
<i>Scleria sumatrensis</i> Retz.	4	12	0.00000010
<i>Adinandra dumosa</i> Jack	3	6	0.00000005
<i>Lasianthus</i> sp.	3	6	0.00000005
<i>Mikania micrantha</i> Kunth	3	6	0.00000005
<i>Asystasia</i> sp.	2	2	0.00000002
<i>Crassocephalum crepidioides</i> S.Moore	2	2	0.00000002
<i>Fimbristylis dichotoma</i> (L.) Vahl	2	2	0.00000002
<i>Lygodium flexuosum</i> (L.) Sw.	2	2	0.00000002
<i>Antrophyum reticulatum</i> (Forst.) Kaulf.	1	0	0.00000000
<i>Blechnum orientale</i> L.	1	0	0.00000000
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	1	0	0.00000000
<i>Cyrtophyllum fragrans</i> DC.	1	0	0.00000000
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	1	0	0.00000000

Appendix H3: continued

<i>Ficus auriculata</i> Lour.	1	0	0.00000000
<i>Fimbristylis quinquangularis</i> (Vahl) Kunth	1	0	0.00000000
<i>Lygodium microphyllum</i> (Cav.) R.Br.	1	0	0.00000000
<i>Macaranga</i> sp.	1	0	0.00000000
<i>Oldenlandia corymbosa</i> L.	1	0	0.00000000
<i>Ploiarium elegans</i> Korth.	1	0	0.00000000
<i>Saurauia glabra</i> Merr.	1	0	0.00000000
<i>Struchium sparganophorum</i> (L.) Kuntze	1	0	0.00000000
Total	10961	23948632	0.19935172

Appendix H4: Simpson's Index in the second sampling at the integrated oil palm plantation area.

Species	Number (n)	n(n-1)	n(n-1)/(N(N-1))
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3593	12906056	0.13013847
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	2256	5087280	0.05129769
<i>Axonopus compressus</i> P.Beauv.	1052	1105652	0.01114886

Appendix H4: continued

<i>Centotheca lappacea</i> Desv.	928	860256	0.00867441
<i>Torenia crustacea</i> (L.) Cham. & Schltl.	425	180200	0.00181705
<i>Miconia crenata</i> (Vahl) Michelang.	251	62750	0.00063274
<i>Grona triflora</i> (L.) H. Ohashi & K. Ohashi	218	47306	0.00047701
<i>Melastoma malabathricum</i> L.	182	32942	0.00033217
<i>Taenitis blechnoides</i> (Willd.) Sw.	155	23870	0.00024069
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	125	15500	0.00015629
<i>Ficus fulva</i> Reinw. ex Blume	105	10920	0.00011011
<i>Diplazium esculentum</i> (Retz.) Sw.	66	4290	0.00004326
<i>Phyllanthus amarus</i> Schumach. & Thonn.	56	3080	0.00003106
<i>Elaeis guineensis</i> Jacq.	51	2550	0.00002571
<i>Polytrias indica</i> (Houtt.) Veldkamp	46	2070	0.00002087
<i>Cyperus</i> sp.	43	1806	0.00001821
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	39	1482	0.00001494
<i>Saurauia glabra</i> Merr.	39	1482	0.00001494
<i>Cyperus rotundus</i> L.	38	1406	0.00001418

Appendix H4: continued

<i>Cyrtococcum oxyphyllum</i> Stapf	38	1406	0.00001418
<i>Ageratum conyzoides</i> L.	36	1260	0.00001271
<i>Cyperus distans</i> L.f.	35	1190	0.00001200
<i>Asystasia</i> sp.	18	306	0.00000309
<i>Struchium sparganophorum</i> (L.) Kuntze	15	210	0.00000212
<i>Nephrolepis biserrata</i> (Sw.) Schott	14	182	0.00000184
<i>Asystasia gangetica</i> (L.) T.Anderson	13	156	0.00000157
<i>Lygodium circinatum</i> (Burm.f.) Sw.	13	156	0.00000157
<i>Murdannia nudiflora</i> (L.) Brenan	12	132	0.00000133
<i>Mimosa pudica</i> L.	8	56	0.00000056
<i>Hyptis capitata</i> Jacq.	7	42	0.00000042
<i>Lygodium flexuosum</i> (L.) Sw.	7	42	0.00000042
<i>Camonea umbellata</i> A.R.Simões & Staples	7	42	0.00000042
<i>Hedyotis</i> sp.	5	20	0.00000020
<i>Oenanthe javanica</i> DC.	5	20	0.00000020
<i>Ramirezella strobilophora</i> var. <i>pubescens</i> (Rose) Maréchal Mascherpa & Stainier	5	20	0.00000020
<i>Adinandra dumosa</i> Jack	4	12	0.00000012
<i>Smilax</i> sp.	4	12	0.00000012

Appendix H4: continued

<i>Commelina diffusa</i> Burm.f.	3	6	0.00000006
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	3	6	0.00000006
<i>Cyrtophyllum fragrans</i> DC.	3	6	0.00000006
<i>Fimbristylis dichotoma</i> (L.) Vahl	3	6	0.00000006
<i>Lygodium microphyllum</i> (Cav.) R.Br.	3	6	0.00000006
<i>Paspalum conjugatum</i> P.J.Bergius	3	6	0.00000006
<i>Uncaria elliptica</i> R.Br. ex G.Don	3	6	0.00000006
<i>Axonopus</i> sp.	2	2	0.00000002
<i>Clerodendrum chinense</i> (Osbeck) Mabb.	2	2	0.00000002
<i>Cyperus compressus</i> L.	2	2	0.00000002
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	2	2	0.00000002
<i>Paederia foetida</i> L.	2	2	0.00000002
<i>Stenochlaena palustris</i> (Burm.) Bedd.	2	2	0.00000002
<i>Callicarpa longifolia</i> Lam.	1	0	0.00000000
<i>Ficus aurata</i> Miq.	1	0	0.00000000
<i>Hyptis brevipes</i> Poit.	1	0	0.00000000
<i>Cyperus brevifolius</i> (Rottb.) Endl. Ex Hassk.	1	0	0.00000000

Appendix H4: continued

<i>Lasianthus</i> sp.	1	0	0.00000000
<i>Leea aculeata</i> Blume	1	0	0.00000000
<i>Mallotus leucodermis</i> Hook.f.	1	0	0.00000000
<i>Piper betle</i> L.	1	0	0.00000000
<i>Rhynchospora corymbosa</i> (L.) Britton	1	0	0.00000000
<i>Sacciolepis indica</i> Chase	1	0	0.00000000
<i>Sida rhombifolia</i> L.	1	0	0.00000000
<i>Urophyllum</i> sp.	1	0	0.00000000
Total	9959	20356216	0.20526230

Appendix I1: Biomass and carbon stock estimation of weeds species in the initial sampling at the integrated oil palm plantation area.

Species	Total Biomass Sampled in 100 Quadrates (kg)	Carbon Stock in 100 Quadrates (kg) (Biomass × 0.47)	Estimated of Carbon per Hectare (kg)
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3.7023	1.7401	174.0062
<i>Miconia crenata</i> (Vahl) Michelang.	0.8116	0.3815	38.1471
<i>Centotheca lappacea</i> Desv.	0.7723	0.3630	36.2995
<i>Axonopus compressus</i> P.Beauv.	0.7029	0.3304	33.0372
<i>Taenitis blechnoides</i> (Willd.) Sw.	0.6770	0.3182	31.8181
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	0.6287	0.2955	29.5508
<i>Diplazium esculentum</i> (Retz.) Sw.	0.3596	0.1690	16.9007
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	0.2845	0.1337	13.3724
<i>Ficus fulva</i> Reinw. ex Blume	0.2511	0.1180	11.8008

Appendix I1: continued

<i>Elaeis guineensis</i> Jacq.	0.1317	0.0619	6.1876
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	0.1140	0.0536	5.3599
<i>Melastoma malabathricum</i> L.	0.1140	0.0536	5.3599
<i>Nephrolepis biserrata</i> (Sw.) Schott	0.0889	0.0418	4.1802
<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	0.0651	0.0306	3.0574
<i>Cyrtococcum oxyphyllum</i> Stapf	0.0639	0.0300	3.0038
<i>Mimosa pudica</i> L.	0.0501	0.0236	2.3566
<i>Adinandra dumosa</i> Jack	0.0378	0.0178	1.7771
<i>Cyperus compressus</i> L.	0.0308	0.0145	1.4490
<i>Hyptis capitata</i> Jacq.	0.0306	0.0144	1.4382
<i>Ageratum conyzoides</i> L.	0.0297	0.0140	1.3964
<i>Lasianthus</i> sp.	0.0242	0.0114	1.1351
<i>Flagellaria indica</i> L.	0.0225	0.0106	1.0589
<i>Cyperus</i> sp.	0.0145	0.0068	0.6806
<i>Timonius flavescens</i> Baker	0.0140	0.0066	0.6599

Appendix I1: continued

<i>Paspalum conjugatum</i> P.J.Bergius	0.0130	0.0061	0.6129
<i>Phyllanthus amarus</i> Schumach. & Thonn.	0.0100	0.0047	0.4695
<i>Lygodium circinatum</i> (Burm.f.) Sw.	0.0084	0.0039	0.3939
<i>Scleria sumatrensis</i> Retz.	0.0063	0.0030	0.2966
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	0.0054	0.0025	0.2529
<i>Cyperus distans</i> L.f.	0.0053	0.0025	0.2510
<i>Asystasia gangetica</i> (L.) T.Anderson	0.0041	0.0019	0.1913
<i>Mikania micrantha</i> Kunth	0.0034	0.0016	0.1589
<i>Saurauia glabra</i> Merr.	0.0032	0.0015	0.1481
<i>Cyrtophyllum fragrans</i> DC.	0.0027	0.0013	0.1260
<i>Lygodium flexuosum</i> (L.) Sw.	0.0027	0.0013	0.1255
<i>Ficus auriculata</i> Lour.	0.0025	0.0012	0.1194
<i>Blechnum orientale</i> L.	0.0021	0.0010	0.0964

Appendix I1: continued

<i>Asystasia</i> sp.	0.0020	0.0009	0.0949
<i>Antrophyum reticulatum</i> (Forst.) Kaulf.	0.0011	0.0005	0.0498
<i>Lygodium microphyllum</i> (Cav.) R.Br.	0.0009	0.0004	0.0442
<i>Vitex pinnata</i> L.	0.0009	0.0004	0.0418
<i>Sacciolepis indica</i> Chase	0.0006	0.0003	0.0287
<i>Ploiarium elegans</i> Korth.	0.0006	0.0003	0.0259
<i>Murdannia nudiflora</i> (L.) Brenan	0.0005	0.0002	0.0230
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.0005	0.0002	0.0221
<i>Macaranga</i> sp.	0.0004	0.0002	0.0193
<i>Crassocephalum</i> <i>crepidioides</i> S.Moore	0.0003	0.0001	0.0122
<i>Exallage auricularia</i> (L.) Bremek.	0.0003	0.0001	0.0118
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	0.0002	0.0001	0.0108

Appendix I1: continued

<i>Fimbristylis</i> <i>quinguangularis</i> (Vahl) Kunth	0.0002	0.0001	0.0103
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	0.0002	0.0001	0.0071
<i>Oldenlandia corymbosa</i> L.	0.0001	0.0001	0.0052
<i>Struchium</i> <i>sparganophorum</i> (L.) Kuntze	0.0000	0.0000	0.0019
Total	9.0997	4.2768	427.6840
			0.4277 tonne/ha

Appendix I2: Biomass and carbon stock estimation of weeds species in the second sampling at the integrated oil palm plantation area.

Species	Total Biomass Sampled in 100 Quadrates (kg)	Carbon Stock in 100 Quadrates (kg) (Biomass × 0.47)	Estimated of Carbon (kg/ha)
<i>Scleromitron verticillatum</i> (L.) R.J.Wang	3.6754	1.7274	172.7433
<i>Taenitis blechnoides</i> (Willd.) Sw.	0.7789	0.3661	36.6102

Appendix I2: continued

<i>Miconia crenata</i> (Vahl) Michelang.	0.6202	0.2915	29.1494
<i>Cyrtococcum patens</i> var. <i>latifolium</i> (Honda) Ohwi	0.6012	0.2826	28.2583
<i>Melastoma malabathricum</i> L.	0.5522	0.2595	25.9543
<i>Axonopus compressus</i> P.Beauv.	0.5258	0.2471	24.7140
<i>Cleistanthus collinus</i> (Roxb.) Hook.f.	0.4258	0.2001	20.0126
<i>Centotheca lappacea</i> Desv.	0.3249	0.1527	15.2684
<i>Diplazium esculentum</i> (Retz.) Sw.	0.2969	0.1395	13.9543
<i>Elaeis guineensis</i> Jacq.	0.1726	0.0811	8.1103
<i>Cyperus rotundus</i> L.	0.1566	0.0736	7.3607
<i>Ficus fulva</i> Reinw. ex Blume	0.1343	0.0631	6.3116
<i>Torenia crustacea</i> (L.) Cham. & Schltdl.	0.0729	0.0343	3.4263

Appendix I2: continued

<i>Grona triflora</i> (L.) H.Ohashi & K.Ohashi	0.0703	0.0330	3.3018
<i>Uncaria elliptica</i> R.Br. ex G.Don	0.0496	0.0233	2.3303
<i>Hyptis capitata</i> Jacq.	0.0461	0.0216	2.1644
<i>Adinandra dumosa</i> Jack	0.0304	0.0143	1.4279
<i>Cyperus distans</i> L.f.	0.0299	0.0140	1.4030
<i>Ageratum conyzoides</i> L.	0.0146	0.0069	0.6876
<i>Lygodium flexuosum</i> (L.) Sw.	0.0144	0.0068	0.6782
<i>Phyllanthus amarus</i> Schumach. & Thonn.	0.0140	0.0066	0.6566
<i>Lygodium circinatum</i> (Burm.f.) Sw.	0.0139	0.0066	0.6552
<i>Nephrolepis biserrata</i> (Sw.) Schott	0.0137	0.0064	0.6425
<i>Smilax</i> sp.	0.0120	0.0056	0.5626
<i>Dicranopteris linearis</i> (Burm.f.) Underw.	0.0111	0.0052	0.5203
<i>Struchium</i> <i>sparganophorum</i> (L.) Kuntze	0.0105	0.0049	0.4921

Appendix I2: continued

<i>Mimosa pudica</i> L.	0.0095	0.0045	0.4456
<i>Eleocharis parvula</i> (Roem. & Schult.) Link ex Bluff, Nees & Schauer	0.0091	0.0043	0.4291
<i>Asystasia gangetica</i> (L.) T.Anderson	0.0088	0.0041	0.4136
<i>Leea aculeata</i> Blume	0.0078	0.0036	0.3643
<i>Camonea umbellata</i> A.R.Simões & Staples	0.0069	0.0032	0.3234
<i>Asystasia</i> sp.	0.0063	0.0030	0.2970
<i>Cyrtococcum oxyphyllum</i> Stapf	0.0058	0.0027	0.2735
<i>Ramirezella strobilophora</i> var. <i>pubescens</i> (Rose) Maréchal Mascherpa & Stainier	0.0056	0.0026	0.2613
<i>Cyperus</i> sp.	0.0047	0.0022	0.2223
<i>Stenochlaena palustris</i> (Burm.) Bedd.	0.0045	0.0021	0.2124
<i>Polytrias indica</i> (Houtt.) Veldkamp	0.0045	0.0021	0.2115

Appendix I2: continued

<i>Lasianthus</i> sp.	0.0044	0.0021	0.2073
<i>Murdannia nudiflora</i> (L.) Brenan	0.0043	0.0020	0.2040
<i>Clerodendrum chinense</i> (Osbeck) Mabb.	0.0042	0.0020	0.1993
<i>Piper betle</i> L.	0.0039	0.0019	0.1852
<i>Lygodium microphyllum</i> (Cav.) R.Br.	0.0035	0.0016	0.1640
<i>Mallotus leucodermis</i> Hook.f.	0.0031	0.0015	0.1452
<i>Oenanthe javanica</i> DC.	0.0030	0.0014	0.1419
<i>Paspalum conjugatum</i> P.J.Bergius	0.0026	0.0012	0.1203
<i>Paederia foetida</i> L.	0.0022	0.0010	0.1011
<i>Sida rhombifolia</i> L.	0.0017	0.0008	0.0776
<i>Curculigo latifolia</i> Dryand. ex W.T.Aiton	0.0015	0.0007	0.0705
<i>Hedyotis</i> sp.	0.0013	0.0006	0.0616
<i>Cyperus compressus</i> L.	0.0012	0.0006	0.0559
<i>Commelina diffusa</i> Burm.f.	0.0011	0.0005	0.0536
<i>Urophyllum</i> sp.	0.0009	0.0004	0.0442

Appendix I2: continued

<i>Ficus aurata</i> Miq.	0.0009	0.0004	0.0400
<i>Cyperus brevifolius</i> (Rottb.) Endl. Ex Hassk.	0.0007	0.0003	0.0343
<i>Callicarpa longifolia</i> Lam.	0.0007	0.0003	0.0338
<i>Cyrtophyllum fragrans</i> DC.	0.0007	0.0003	0.0334
<i>Hyptis brevipes</i> Poit.	0.0005	0.0002	0.0244
<i>Sacciolepis indica</i> Chase	0.0003	0.0001	0.0127
<i>Saurauia glabra</i> Merr.	0.0002	0.0001	0.0113
<i>Rhynchospora corymbosa</i> (L.) Britton	0.0002	0.0001	0.0108
<i>Fimbristylis dichotoma</i> (L.) Vahl	0.0002	0.0001	0.0080
<i>Axonopus</i> sp.	0.0001	0.0000	0.0042
Total	8.7850	4.1289	412.8945
			0.4129 tonne/ha

Appendix J1: Height (cm) of species recovery recorded along with the day of the sample observed in the opened area for the grazed sample of *Axonopus compressus*.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	4.5	5.2	5.3	8.0	8.5	8.5	8.7	8.7	8.7	8.7
2	5.1	6.0	6.1	6.5	6.7	6.7	6.7	6.7	6.7	6.7
3	4.6	5.0	5.3	5.3	6.0	6.0	6.0	6.0	6.0	6.0
4	4.0	4.6	4.8	5.1	5.6	5.6	5.7	6.0	6.4	6.4
5	11.5	12.3	12.5	12.7	12.7	12.7	12.7	12.7	12.7	12.7
6	9.0	9.6	9.8	10.1	10.1	10.1	10.1			
7	6.8	8.4	8.7	10.8	10.8	10.8	10.8			
8	4.0	5.0	5.8	6.0	6.5	6.5	6.5			
9	5.7	7.5	8.0	8.0	9.2	9.4				
10	3.0	5.0	5.5	7.6	7.6	7.6				
11	5.2	6.0	6.3	6.5	6.5	6.5				
12	5.7	6.2	6.6	8.0	8.4	8.4				
13	9.0	10.0	11.0	12.0	13.0	13.0				
14	5.8	6.4	6.5	6.6	7.2	7.2				
Mean	6.0	6.9	7.3	8.1	8.5	8.5	8.4	8.0	8.1	8.1

Appendix J2: Height (cm) of species recovery recorded along with the day of the sample observed in the opened area for ungrazed sample of *Axonopus compressus*.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	13.0	13.5	18.0	20.0	23.5	24.0	24.5	24.5	24.5	24.5
2	15.0	16.0	18.5	21.7	23.0	23.8	24.5	24.5	24.5	24.5
4	23.1	24.1	25.5	29.0	31.0	33.6	34.0	37.5	40.8	
5	25.5	28.0	29.5	29.5	31.7	32.2	33.2	33.5	34.3	
6	15.6	21.0	22.5	22.5	23.0	23.0	24.5	24.7	24.9	
7	14.0	17.7	21.5	25.1	27.8	27.8	27.8	27.8		
8	15.8	20.1	24.5	25.5	31.5	36.2	38.5	40.0		
9	17.1	23.1	27.0	28.2	29.2	35.0	35.2	35.6		
3	12.0	15.5	16.1	17.2	20.0	20.0	22.0			
10	21.2	23.1	25.1	25.6	27.5	30.2				
11	26.2	27.1	27.5	30.2	32.0	32.2				
12	14.6	19.0	19.5	21.2	24.5	29.8				
13	20.0	23.0	25.3	32.0	34.5	36.5				
Mean	17.9	20.9	23.1	25.2	27.6	29.6	29.4	31.0	29.8	24.5

Appendix J3: Height (cm) of species recovery recorded along with the day of the sample observed in the opened area for cut treatment sample of *Axonopus compressus*.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	5.9	6.9	6.9	7.0	7.0	7.0	7.0	7.0	7.0	7.5
2	3.5	4.4	5.0	6.1	6.4	6.5	6.5	6.5	6.5	7.5
3	4.0	4.3	5.5	6.0	7.4	7.6	7.6	7.6	7.6	7.6
4	4.2	5.0	5.7	6.0	6.8	6.8	6.8	6.8	6.8	6.8
5	4.8	5.5	8.7	9.0	9.5	9.6	10.0	10.0	10.2	10.2
6	4.4	5.6	8.1	10.0	12.0	13.5	14.5	15.0	15.0	15.3
7	2.5	3.9	7.5	8.3	9.0	9.0	9.0	9.0	9.0	9.0
8	2.7	4.2	5.6	7.2	8.2	9.0	9.2	9.8	10.2	10.2
9	3.0	6.2	8.2	10.4	10.6	12.0	12.0	12.0	12.0	12.0
10	0.6	3.3	5.5	6.2	6.5	6.5	6.5	7.4	7.4	7.7
11	3.0	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
12	4.8	6.0	8.0	9.2	9.5	9.5	9.5	9.5	9.7	9.7
13	3.3	4.1	5.2	6.0	6.0	6.5	6.5	6.5	6.7	6.7
14	2.6	3.9	6.9	7.7	7.7	7.8	7.8	8.0	8.0	8.0
15	3.0	4.0	4.5	4.8	4.8	5.1	6.0	7.6	8.1	8.9
16	3.0	3.6	5.0	5.4	5.5	5.7	5.7	5.7	5.7	5.7
18	3.3	5.1	5.6	8.6	9.5	10.0	10.1	10.1	10.1	
17	2.6	3.4	7.5	8.5	9.0	9.4	9.4	10.0		
19	3.0	4.7	6.7	8.5	10.0	12.0	12.0	12.1		
Mean	3.4	4.7	6.4	7.4	7.9	8.4	8.5	8.7	8.6	8.6

Appendix J4: Height (cm) of species recovery recorded along with the day of the sample observed in the shaded area for cut treatment sample of *Axonopus compressus*.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	2.0	3.0	3.5	4.3	5.5	5.8	5.8	5.8	6.0	6.0
2	2.0	5.0	7.5	10.0	11.6	12.4	13.3	13.9	13.9	13.9
3	2.3	6.0	8.2	10.0	10.5	11.5	12.5	13.1	13.4	13.4
4	3.0	5.0	6.0	6.8	7.0	7.0	7.3	7.3	7.3	7.3
5	4.5	7.0	8.7	11.0	12.7	15.0	16.7	17.6	18.0	18.6
6	2.3	3.5	5.5	7.0	9.0	9.7	10.7	12.9	13.3	13.3
7	3.4	5.1	8.0	9.0	9.5	10.1	10.3	10.3	10.5	10.5
8	3.8	7.0	9.9	12.5	15.0	16.5	18.7	19.5	19.6	19.7
9	2.5	5.0	6.5	7.2	7.6	7.7	8.0	8.0	8.0	8.0
10	3.3	5.7	7.0	8.2	9.0	9.6	10.5	11.5	11.7	11.7
11	2.2	3.6	6.0	6.7	6.7	6.7	7.0	7.2	7.3	7.3
12	2.0	3.0	4.5	5.5	5.5	6.0	6.0	6.0	6.0	6.0
13	2.2	3.8	4.1	4.5	5.9	6.0	7.2	8.0	8.0	8.0
14	3.0	4.2	5.7	6.0	6.9	6.9	6.9	7.2	7.4	7.4
15	3.5	5.6	6.7	8.0	8.7	9.1	9.7	9.7	9.7	9.7
16	3.0	4.5	7.5	8.0	9.5	10.1	11.6	11.6	12.0	12.0
17	4.2	6.5	8.1	8.8	9.2	9.4	9.4	9.5	9.8	10.4
18	2.6	5.0	7.2	7.5	7.5	7.5	7.8	7.8	7.8	7.8
19	4.7	8.3	10.3	11.9	13.3	14.6	15.5	16.5	16.9	16.9
Mean	3.0	5.1	6.9	8.0	9.0	9.6	10.3	10.7	10.9	10.9

Appendix J5: Height (cm) of species recovery recorded along with the day of the sample observed in the opened area for a grazed sample of *Elaeis guineensis*.

Seedling	Day									
	0	3	6	9	12	15	18	21	24	27
1	4.0	6.0	7.2	11.5	11.5	11.5	11.5	11.5	11.5	11.8
2	14.5	16.0	17.3	17.5	18.0	18.0	18.0	18.0	18.0	18.0
3	6.0	7.4	7.7	9.5	10.3	10.3	11.2	11.6	12.5	12.8
4	6.2	7.5	7.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0
5	5.8	6.5	7.2	8.5	9.5	9.5	9.5	9.5	9.6	9.6
6	12.0	12.5	13.1	13.5	13.5	13.5	13.5	13.5	13.5	13.5
7	7.0	8.5	9.6	11.5	12.0	12.0	13.4	13.8	14.1	15.0
8	5.4	6.8	8.0	9.0	9.7	9.7	10.5	10.5	10.5	10.5
9	7.6	8.8	10.0	10.4	10.9	11.0	11.0	11.0	11.0	
10	4.0	4.4	5.8	6.4	6.4	7.0	8.4	8.4	9.0	
11	7.4	8.9	10.4	12.0	12.6	12.6	12.6	12.6	12.6	
12	7.0	7.5	8.0	8.0	8.0	8.0	8.0			
13	6.0	8.0	10.0	11.7	12.5	13.5				
14	4.5	6.0	7.2	9.6	10.0	11.0				
15	6.1	7.4	9.0	10.0	11.5	13.0				
16	8.5	9.0	9.5	9.5	9.5	9.5				
Mean	7.0	8.2	9.2	10.4	10.9	11.1	11.3	11.7	11.8	12.4

Appendix J6: Height (cm) of species recovery recorded along with the day of the sample in the opened area for ungrazed sample of *Elaeis guineensis*.

Seedling	Day									
	0	3	6	9	12	15	18	21	24	27
1	6.0	8.0	8.6	9.5	9.5	10.0	11.0	11.5	12.5	12.9
2	10.0	11.0	11.4	12.0	12.3	12.5	12.6	12.6	12.6	12.9
3	12.0	14.2	14.5	14.5	14.5	14.5	14.5	14.7	14.7	14.7
4	17.5	19.3	20.0	20.7	20.7	21.4	22.0	22.1	22.1	22.2
5	8.5	10.0	11.2	12.9	14.4	15.7	17.6	18.0	19.0	20.2
6	9.8	11.2	11.3	11.8	12.1	12.7	13.9	13.9	14.0	14.4
7	11.3	12.5	13.9	14.2	14.2	14.7	15.2	15.2	15.2	15.3
9	12.5	14.1	15.1	16.2	16.3	16.3	16.3	16.3	16.5	16.5
10	13.9	17.5	18.6	19.0	20.1	20.5	20.8	21.0	21.6	21.9
12	10.2	12.4	13.0	14.1	16.0	17.2	18.8	19.5	21.2	21.7
13	10.8	12.6	13.8	15.1	16.2	16.7	18.7	18.7	18.7	18.7
14	11.0	12.0	13.2	13.6	14.5	15.0	15.2	15.6	15.8	16.1
15	9.5	11.5	12.6	13.6	14.2	15.2	16.0	16.7	17.3	17.8
16	16.0	16.5	17.9	19.2	20.5	21.6				
Mean	11.4	13.1	13.9	14.7	15.4	16.0	16.4	16.6	17.0	17.3

Appendix J7: Height (cm) of species recovery recorded along with the day of the sample observed in the opened area for cut treatment of *Elaeis guineensis*.

Seedling	Height of sample (cm)									
	0	3	6	9	12	15	18	21	24	27
1	7.2	7.9	8.5	8.5	9.3	9.6	9.6	9.8	9.8	9.8
2	9.3	10.6	12.7	13.0	14.3	15.4	16.5	17.3	17.9	18.6
3	10.5	12.2	13.8	14.5	15.5	17.0	17.5	18.0	18.5	19.0
4	11.0	12.0	12.0	12.0	12.0	13.5	13.5	13.5	13.9	13.9
5	13.0	14.5	16.2	16.5	16.9	17.3	17.6	18.0	18.3	18.6
6	7.9	10.2	13.2	14.5	15.5	16.7	17.8	18.6	19.2	19.6
7	10.4	11.2	12.0	12.0	13.0	13.6	13.6	14.2	14.2	14.2
8	9.0	10.9	12.5	14.0	15.5	16.7	17.7	18.8	19.6	19.6
9	8.6	11.2	13.0	14.5	17.2	19.8	22.1	23.8	25.5	27.5
10	6.6	8.2	10.1	11.5	12.7	14.6	16.4	17.7	19.4	20.4
11	11.0	13.0	14.0	16.0	18.2	20.5	23.4	24.9	26.7	28.3
12	6.8	8.0	10.0	11.3	13.0	14.9	17.0	17.8	18.8	20.4
13	9.0	10.5	11.3	13.1	14.1	15.2	16.4	17.2	18.0	18.8
14	8.0	9.0	11.5	13.0	15.1	16.0	17.5	18.8	20.1	21.1
15	9.5	10.3	11.4	11.6	12.0	12.0	13.0	13.0	13.5	13.9
16	12.9	14.0	15.4	16.2	16.6	17.6	18.8	19.3	20.5	20.9
17	8.0	9.5	11.0	12.0	13.3	14.2	14.8	16.0	16.6	17.5
18	7.5	9.0	10.0	10.5	11.7	12.0	12.8	13.1	13.6	13.8
19	10.9	11.5	12.3	12.4	12.4	12.4	12.4	12.4	12.4	12.4

Appendix J7: continued

20	5.4	6.0	7.4	7.5	7.5	7.5				
Mean	9.1	10.5	11.9	12.7	13.8	14.8	16.2	17.0	17.7	18.3

Appendix J8: Height (cm) of species recovery recorded along with the day of the sample observed in the shaded area for cut treatment sample of *Elaeis guineensis*.

Seedling	Day									
	0	3	6	9	12	15	18	21	24	27
1	6.0	6.4	7.0	8.0	8.3	9.0	9.2	9.8	10.2	10.6
2	11.5	12.6	14.0	14.7	16.5	17.0	18.4	19.3	20.3	21.3
3	8.4	8.6	9.2	9.5	10.0	10.3	10.3	10.5	10.5	10.5
4	10.0	11.1	12.0	12.5	13.5	13.5	13.5	13.8	14.0	14.3
5	8.4	9.1	9.8	10.4	10.7	10.7	12.0	12.7	13.3	13.3
6	5.4	6.4	7.7	8.0	8.8	9.0	9.2	9.8	10.3	10.5
7	5.8	6.5	7.7	8.0	8.5	8.5	9.0	9.4	9.9	10.3
8	11.0	12.0	13.0	14.2	15.2	16.0	16.4	16.5	16.9	17.2
9	8.0	9.0	10.1	11.0	11.8	12.3	12.8	13.5	13.5	15.2
10	6.0	7.0	7.5	8.0	8.2	8.2	8.5	9.0	10.4	11.1
11	10.2	11.0	12.5	12.6	13.0	13.0	13.0	13.3	14.0	14.0
12	10.2	11.2	12.6	13.1	15.0	15.0	16.2	16.2	17.5	17.9
13	7.5	8.0	9.2	9.5	11.0	11.9	12.1	13.3	14.3	14.9
14	10.6	11.3	12.5	12.5	13.4	13.6	14.0	14.2	14.6	14.6
15	9.0	10.0	11.5	11.5	12.7	12.7	12.7	12.7	13.0	13.2

Appendix J8: continued

16	8.0	8.8	9.2	9.8	10.0	10.8	11.5	11.8	12.2	12.9
17	8.5	9.5	10.3	10.8	11.2	11.6	12.0	12.3	12.7	12.7
18	7.8	8.7	9.3	9.3	10.0	10.4	10.7	11.4	11.9	12.4
19	9.5	10.2	10.5	11.5	11.7	12.0	12.2	12.5	13.4	14.0
Mean	8.5	9.3	10.3	10.8	11.6	11.9	12.3	12.7	13.3	13.7

Appendix J9: Total number of new shoots of species recovery recorded along with the day of the sample observed for the grazed sample of *Antrophyum reticulatum* on oil palm trunk at the integrated oil palm plantation.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	0	0	1	1	1	1	1	1	1	1
2	0	0	0	0	0	0	0	0	0	1
3	1	1	1	1	1	1	1	1	1	1
4	0	0	0	0	0	0	0	1	1	1
5	1	1	1	1	1	2	2	2	2	2
6	0	0	0	0	0	1	1	1	1	1
7	0	0	0	0	0	1	2	3	4	4
8	0	0	0	0	0	0	1	1	1	1
9	1	1	1	1	1	1	1	2	2	2
10	0	0	0	1	1	2	2	2	2	2
11	0	1	1	2	2	2	2	3	3	3

Appendix J9: continued

12	0	0	0	0	0	0	0	0	2	2
13	0	0	0	0	0	0	0	0	0	0
14	1	1	1	1	2	2	2	2	2	3
15	0	0	0	0	4	4	4			
16	1	1	1	1	1	1				
17	0	0	1	1	2	2				
18	3	3	3	4						
Mean	0	1	1	1	1	1	1	1	2	2

Appendix J10: Total number of new shoots of species recovery recorded along with the day of the sample observed for the cut treatment sample of *Antrophyum reticulatum* on oil palm trunk at the integrated oil palm plantation.

Clump	Day									
	0	3	6	9	12	15	18	21	24	27
1	0	0	1	1	1	1	1	1	1	1
2	0	0	0	0	0	1	1	1	1	1
3	0	0	0	0	1	2	2	2	2	2
4	0	0	1	2	2	2	2	2	2	3
5	0	0	0	0	0	1	1	2	2	2
6	0	0	0	0	0	0	0	0	0	0
7	0	1	1	1	1	1	1	1	1	1
8	0	0	1	1	1	1	1	1	1	1

Appendix J10: continued

9	0	0	1	1	2	2	2	2	2	2
10	0	0	1	1	1	1	1	1	1	1
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	1	1	1	1	1	1	1
13	0	0	1	1	1	1	1	1	1	1
14	0	0	1	1	1	1	1	1	1	1
15	0	0	0	0	0	0	1	1	1	1
16	0	0	1	1	2	2	3	3	3	3
17	0	0	1	1	1	1	1	1	1	1
18	0	0	0	0	0	0	0	0	1	
Mean	0	0	1	1	1	1	1	1	1	1

Appendix K1: Percentage (%) of forage grazed by cattle with 2 different factors of the day of the sample observed and treatment for the samples that were cut and uncut of *Axonopus compressus*.

Day	0 to 1	4 to 5	8 to 10	9 to 12	13 to 15	15 to 19	18 to 20	23 to 26	24 to 27	28 to 30	30 to 32
Cut	0.08	0.08	1.20	0.65	9.06	1.36	0.28	4.85	0.00	1.49	6.42
	0.00	0.00	0.05	1.01	9.63	0.68	1.19	2.52	2.71	8.29	8.63
	0.00	0.02	1.86	0.00	1.68	2.54	0.00	0.49	5.10	3.12	11.86
	0.02	0.00	0.00	1.46	0.21	0.46	0.00	3.01	8.47	9.05	2.06
	1.10	0.11	0.00	0.04	4.81	1.89	2.43	0.06	3.18	1.29	4.69
Mean	0.24	0.04	0.62	0.63	5.08	1.39	0.78	2.19	3.89	4.65	6.73
Uncut	2.87	4.25	3.21	17.13	10.66	1.67	0.09	7.64	0.00	1.21	6.03
	2.09	1.05	6.83	6.24	20.35	2.62	4.26	1.15	5.65	14.00	10.37
	0.60	1.40	4.52	0.90	7.29	5.93	1.05	0.65	5.20	0.40	14.28
	1.98	0.74	0.59	4.93	1.24	2.23	0.28	2.32	3.64	19.23	4.64
	1.47	0.62	4.17	3.85	6.25	2.07	4.75	2.25	1.24	1.79	2.12
Mean	1.80	1.61	3.86	6.61	9.16	2.90	2.09	2.80	3.15	7.33	7.49