Effect of land-use change on the diversity of useful plants in Sumatra (Indonesia)

Submitted by
Kamal Raj Aryal
MSc Sustainable Forest and Nature Management
(SUFONAMA)

Supervisor
Prof. Dr. Holger Kreft

Co-supervisor
Dr. Katja Rembold

Master‟s thesis at the
Faculty of Forest Science and Forest Ecology
Georg-August-Universität Göttingen
September, 2017

Der Effekt von Landnutzungsänderungen auf die Nutzpflanzen-Vielfalt in Sumatra (Indonesien)

Kamal Raj Aryal
MSc Sustainable Forest and Nature Management
(SUFONAMA)

Betreuer
Prof. Dr. Holger Kreft

Zweitbetreuer
Dr. Katja Rembold

Masterarbeit
Zur Erlangung des M.Sc. an der
Fakultät fur Forstwissenschaften und Waldökologie
Georg-August-Universität Göttingen
September, 2017

Acknowledgements

I would like to express my kind gratitude to Prof. Dr. Holger Kreft and Dr. Katja Rembold for providing me the opportunity to conduct my thesis on this topic. Their support and the encouraging supervision were really remarkable not only to conduct my thesis, but also to broaden my horizon of knowledge in the field of forest and biodiversity. It would not have been possible to complete this thesis without their regular guidance, encouragement, and supervision. Furthermore, I am fully impressed for their friendly behavior and genuine support during the period of my thesis. Their contributions for my career will always remain in the novel page of my life.

I also want to thank Erasmus Mundus programme for providing me with a scholarship for pursuing master degree in sustainable forest and nature management (SUFONAMA) course. Besides this, I would like to thank all my professors who provided me in-depth knowledge during the period of my study in Goettingen University (Germany), Bangor University (United Kingdom) and Copenhagen University (Denmark).

Additionally, I am grateful to the EFForTS project for providing me opportunity to use already collected primary data for my thesis. My thanks go to all authors and editors of PROSEA books through which I got lots of information for my thesis.

Furthermore, I would also like to thank my friend Arun Parajuli, Thakur Prasad Magrati, Lalit Dongol and Chandra Sekhar Badu for their company during the period of my thesis. Their direct and indirect involvement, suggestions and moral supports during my thesis period was always motivating me for the betterment of my work.

At last but not least, I am very much thankful to my father and mother for providing me a favorable environment in my every step of my life. Their noble love, care and support will be always in my heart and does not matter wherever I am, ranging from the top of Mount Everest to the bottom of sea level.

Summary

Tropical rainforest has continually been threatened by land-use change due to which a lot of species have been already extinct and some are in danger of extinction. This has also caused serious threat to the livelihood of large numbers of indigenous people as their dependence on forest is high to fulfil their daily needs. This study analyzes how useful plant species diversity varies while the tropical rainforest converted into agricultural land. A plot-level based inventory of vascular plant was carried out in 32 plots with four different land-use systems (forest, jungle rubber, rubber plantation and oil palm plantation) in Sumatra, Indonesia. A total of 1382 species in four land-use systems was found, and a literature review was conducted to identify the useful value of each species. Altogether, 769 species were found to be useful. Species richness, species abundance, Simpson index, Shannon diversity and Pielou‟s evenness (evenness) were compared between land-use systems. Further, we categorized, useful plant species into 14 categories based on their potential uses and species richness was calculated for each plot under different land-use sysems. Kruskal-Walis tests were performed to identify the significant difference between land-use systems. Linear regression analyses were performed to test the relationship between total plant species richness and useful plant species richness.

We found that the forest had higher useful plant diversity (Simpson diversity, species richness, Shannon diversity, and evenness) than agricultural systems. However, statistically forest is different from only rubber plantation in terms of Simpson diversity, and both rubber plantation and oil palm plantation in terms of species richness. Similarly, forest had significantly higher Shannon diversity and evenness than rubber plantation and oil palm plantation. For all measures of diversity index, forest was not significantly different from jungle rubber. The number of individuals was higher in agricultural land than forest. However, the significant difference was found between forest and oil palm plantation only.

While looking over different use categories, mixed result had been found. Species richness under color, fuelwood, medicine, timber, and poison were significantly higher in the forest than rubber and oil palm plantation. Similarly, species richness under fibre and magic category were also significantly higher in the forest than in rubber. Ornamental species, although found more rarely in jungle rubber, did not differ significantly in terms of species richness between land-use systems. However, nutrient enrichment, erosion control, and fodder species were in highest amount in agricultural system (oil palm plantation and rubber

plantation). Agricultural lands are more liable to erosion so are necessary to maintain the fertility of land. Therefore, farmer might prefer species that provide erosion control and nutrient enrichment due to which agricultural land having more erosion and nutrient enriching species.

We found a linear relationship between useful plant species richness and total plant richness The relationship was also linear in all land uses, however the extent of predictability was higher in agricultural land than in forest.

In conclusion, though forest had a higher useful plant diversity than agricultural systems, species richness of some use categories were lowest in forest. A significant linear relationship between total plant diversity and useful plant diversity indicates that to get diverse useful products, it is necessary to maintain total plant diversity. Furthermore, our result shows that total plant diversity can serve as an estimator for useful plant diversity what might be very useful for the estimation of consequeneces of land-use change in other areas.

Zusammenfassung

Der Tropische Regenwald ist seit Langem durch Landnutzungsänderungen bedroht. Dadurch sind schon viele Arten ausgestorben bzw. vom Aussterben bedroht. Dies hat auch zu ernsthaften Problemen für den Lebensunterhalt einer großen Zahl von indigenen Völkern geführt, denn deren Abhängigkeit von den Ressourcen des Regenwaldes ist hoch. Die vorliegende Untersuchung analysiert, wie sich die Artenvielfalt von Pflanzen bei der Umwandlung des tropischen Regenwaldes in landwirtschaftliche Nutzflächen ändert. Auf Sumatra (Indonesien) wurde in 32 Plots mit verschiedenen Landnutzungstypen (Regenwald, Dschungel Kautschuk, Kautschuk-Plantage und Ölpalmen-Plantage) das Gefäßpflanzen-Inventar erfasst. Insgesamt haben wir 1.382 Arten in den vier Landnutzungstypen gefunden. Mit Hilfe einer Literaturstudie haben wir den Nutzwert jeder Art identifiziert: Insgesamt werden 769 Arten genutzt. Die Landnutzungstypen wurden hinsichtlich ihrer Artenzahl, der Abundanz, des Simpson-Index, der Shannon-Diversität verglichen und Pielou"s Äquität (Äquität). Die Nutzpflanzen wurden in 14 Nutzungs-Kategorien eingeteilt. Für alle Plots wurde der Artenreichtum unter Berücksichtigung der verschiedenen Nutzungstypen berechnet. Signifikante Unterschiede wurden mit dem Kruskal-Walis-Test ermittelt. Um die Beziehung zwischen der Gesamt-Artenzahl und der Zahl der Nutzpflanzen darzustellen, haben wir eine lineare Regressionsanlayse durchgeführt.

Wir fanden heraus, dass der Regenwald eine höhere Pflanzenvielfalt besitzt als die landwirtschaftlich genutzten Flächen (Simpson-Index, Artenreichtum, Shannon-Diversität und Äquität). Statistisch gesehen unterscheidet sich der Regenwald allerdings nur von den Kautschuk-Plantagen in Bezug auf die Simpson-Diversität und die Kautschuk-Plantagen und die Palmöl-Plantagen in Bezug auf den Artenreichtum. Der Regenwald hat ebenso eine signifikant höhere Shannon-Diversität und Äquität als die Kautschuk- und die Palmöl-Plantagen. Für keinen der Messwerte des Diversitäts-Index fanden wir signifikante Unterschiede zwischen dem Regenwald und den Dschungel Kautschuk.

Bei der Betrachtung verschiedener Kategorien wurde ein gemischtes Ergebnis gefunden. Arten, die reich an Farbe, Brennholz, Medizin, Holz und Gift waren, waren im Wald deutlich höher als die Kautschukplantage und Ölpalmenplantage. Ebenso war die Vielfalt der Arten in der Faser- und magische Kategorie im Wald deutlich höher als in Kautschukplantage .Obwohl Zierarten in den Dschungel Kautschuk seltener gefunden haben, gab es beim Artenreichtum keine signifikanten Unterschiede zwischen den Landnutzungssystemen.

Erosion Nährstoffanreicherung, und die Zahl von Futterpflanzen waren in den Kautschuk- und Palmöl-Plantagen am höchsten. Die landwirtschaftliche Nutzung ist für die Erosion verantwortlich, so dass man dort viel für die Erhaltung der Bodenfruchtbarkeit tun muss. Offenbar bevorzugen die Bauern Pflanzenarten, die für eine Erosionskontrolle und Nähstoffanreicherung des Bodens sorgen, weshalb in den landwirtschaftlichen Flächen eine größere Zahl solcher Arten gefunden werden.

Wir fanden einen linearen Zusammenhang zwischen der Anzahl von Nutzpflanzenarten und der Gesamtzahl der Pflanzenarten. Das trifft auch für die landwirtschaftlich genutzten Flächen zu. Die Vorhersagbarkeit dieses Zusammenhangs war allerdings bei diesen Flächen höher als im Regenwald.

Obwohl der Regenwald eine höhere Anzahl von Nutzpflanzenarten beherbergt als die landwirtschaftlich genutzten Flächen, war die Artenzahl in bestimmten Nutzpflanzen-Kategorien im Regenwald geringer. Der signifikante lineare Zusammenhang zwischen der Gesamtartenzahl und der Nutzpflanzenzahl zeigt, dass es wichtig ist, die Pflanzen-Diversität insgesamt zu erhalten, um eine vielseitige Nutzung pflanzlicher Produkte zu ermöglichen. Unsere Ergebnisse zeigen weiterhin, dass die Pflanzen-Diversität als Maß für die Zahl nutzbarer Pflanzen dienen kann. Diese Erkenntnisse können auch für die Abschätzung der Auswirkungen von Landnutzungsänderungen in anderen Gebieten genutzt werden.

Table of contents

Acknowledgement……………………………………………………………………………iii

Summary…………………………………………………………..……………….…….iv

Zusammenfassung………...….....………………………………………...…..………………....vi

List of figures……………………………………………………………………..…...…....ix

List of Appendices………………………………………..………………………….……….x

1. Introduction……………………...………………………………………..…..……………1

1.1 The EFForTS Project……………..…...………………………………...…… …………1

1.2 Tropical rainforest in Indonesia and Sumatra...………….….…………………….……..…2

1.3 Agricultural land-use systems in Indonesia..…...3

1.3.1 Jungle rubber agroforest……….……..………………………………………4

1.3.2 Rubber monocultures………..………….………………………...…………..5

1.3.3 Oil palm monoculture ……………………….……………..……….…………5

1.4 Useful plants……………..……………………………………………..…….……..…6

1.5 Objectives ....…....8

2. Materials and methods………...………………...………………………..………..………..8

2.1 The study area……………………………………………..…………………..……8

2.2 Sampling design………………………………………………………….……………..9

2.3 Data collection……………………………..…………………………..…………..….…10

2.3.1 Vegetation survey……………………..…………………………………..…..10

2.3.2 Literature survey………………..………….…………………………...…...10

2.4 Data analysis…………………………………………………………….…….…...……12

3. Result…….……………...……………………………………………………………...…...14

3.1 Useful plant species diversity and abundance across different land-use systems….…...18

3.2 Variation of useful plant species categories across different land-use systems...…...….23

3.3 Relationship between total plant species richness and useful plant species richness.….25

4. Discussion……………………..………….………………………………………..……27

4.1 Useful plant species diversity and abundance across different land-use systems……...28

4.2 Variation of useful plant species categories across different land-use systems…….......31

4.3 Relationship between total plant species richness and useful plant species richness…..33

5. Conclusion……………………..…………………………………….…………………...35

6. Bibliography...……………………..……………………………...………...……….…37

7. Appendix………………………………………………………………..………..….46

8. Statement of declaration 53

List of figures

Figure 1: Location of study sites in Sumatra (Jambi Province) where core plots were located in two landscapes near to Bukit Duabelas National Park and Harapan Rainforest (framed in red). Core plots locations are indicated through grey square…….……………..…………9

Figure 2: Allocation of plots across four land-use systems and two landscapes…………….10

Figure 3: Species richness (a), and abundance (b) of useful plant species across four land-use systems (F- forest, J- jungle rubber, R-rubber plantation and O- oil palm plantation)……………………………………………………………………….………15

Figure 5: Species-accumulation curves for useful plant species in four land-use systems…..16

Figure 6: Useful plant species richness (a), number of individual (b), Simpson index (c), Shannon diversity (d), Evenness (e) in the four different land-use systems (n= 8 plots per system)……………………………………………………………………….…………18

Figure 7: Diagrammatical representation of link between 14 use categories of plant species (useful plant categories) in four land-use systems. Useful plants species were categorized based on their useful value to human. The 14 use categories are Color (Col), Erosion control (Ero), Fibre (Fib), Fodder (Fod), Food (Foo), Fuelwood (Fue), Handicraft (Han), Magic (Mag), Medicine (Med), Nutrient enrichment (Nut), Ornamental (Orn), Poison (Poi), Rubber (Rub) and Timber (Tim)……………………………….…………………………………19

Figure 8: Total number of multipurpose and single purpose species across four different land-use systems (F- forest, J- jungle rubber, R-rubber plantation, and O- oil palm plantation) (a), total number of multipurpose species (b), total number of single purpose species (c), total number of species under different categories of useful plant (d) and total individuals under different categories of species(e) across four land-use system………………………………21

Figure 9: Mean number of 14 categories of useful plant species in four land-use systems. Useful plants were categorized based on their useful value to human. The 14 category of useful plant are color (a), erosion (b), fibre (c), fodder (d), food (e) , fuelwood (f), handicraft (g), magic (h), medicine (i), nutrient enrichment (j), ornamental (k), poison (l), rubber (m) and timber (n)………………………………………………………………………………...24

Figure 10: Simple linear regression models: useful plant species richness plotted against total species richness (a) and useful plant species individual number plotted against total individual number (b). Overall useful species richness plotted against total species richness (c) and useful plant individual number against total individual number (d)…………………………26

List of appendices

Appendix 1: Results of simple linear regression models between useful plant species richness and total species richness in different land uses……………………………………………..46

Appendix 2: Results of simple linear regression models between useful plant individual number and total individual number in different land uses…………………………………..46

Appendix 3: Results of simple linear regression model between useful plant species richness and total plant species richness……………………………………………………………46

Appendix 4: Results of simple linear regression models between useful plant individual number and total plants individual number …………………………………………………47

Appendix 5: Number of plant species in each category and their intersection (species overlapped) to other categories. These useful categories are color (Col), erosion control (Ero), fibre (Fib), fodder (fod), food (Foo), fuelwood (Fue), handicraft (Han), magic (Mag), medicine (Med), nutrient enrichment (Nut), ornamental (Orn), poison (Poi), rubber (Rub) and timber (Tim)………………………………………………………………………………….47

Appendix 6: References lists used for identification of useful value of each plant species…47

1. Introduction

1.1 The EFForTS-Project

This thesis was conducted in collaboration with the interdisciplinary research project "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems in Sumatra, Indonesia" (EFForTS). EFForTS focuses on issues on both ecological and socioeconomic aspects of rainforest conversion to three different agricultural land-use system (rubber plantation, oil palm plantation, jungle rubber agroforests) in Jambi province, Indonesia. The project has set its major objective as to facilitate in-depth understanding of the causes and consequences of rainforest transformation into agricultural systems for biodiversity, ecosystem functions as well as human well-being. EFForTS is based on three major lines of research: (i) environmental processes, (ii) biota and ecosystem services, and (iii) human dimensions.

The project area covers two landscapes with in the province of Jambi in central Sumatra, Indonesia. These landscapes are characterized by two different systems namely Bukit Deuabelas National Park and Harapan Rainforest. A core plot design is used to collect data regarding to ecological dimension while socioeconomic survey design is used to collect data regarding human dimensions. In each landscape, four core plots measuring 50m x 50m in each of the four land-use systems have been established in 2012, resulting in a total of 16 plots per landscape and altogether 32 core plots in the project area. Similarly, socioeconomic surveys were carried out all over Jambi Province through the survey design following complementary approach ranging from micro to macro level using a joint sampling framework.

The EFForTS project is a collaborative research project involving four different institutes of two countries; Germany and Indonesia. These institutes are University of Gottingen (UGOE), University of Jambi (UNJA), and Bogor Agricultural University (IPB) and Tadulako University (UNTAD). The financial support for the EFForTS is managed by the German Research Foundation (DFG) in the framework of the Collaborative Research Centre 990. (For further information about the EFForTS project see Drescher *et al*., 2016).

1.2 Tropical rainforest and deforestation in Indonesia

Tropical rainforest, one of the foremost vegetation types of the earth (Whitmore, 1998), has been considered as the most important forest type in terms of biodiversity, carbon storage, as well as sustaining the livelihood of the large number of forests dwelling communities (Seymour *et al.*, 2014). Occupying only 6 % of the earth"s land surface, tropical rainforest contains a larger diversity of plants and animals than anywhere else on earth i.e. more than half of the 1.4 million identified species of the world (Seymour *et al.*, 2014). It has been estimated that a single hectare of rainforest harbours more than 100 tree species having greater than 10cm dbh (diameter at breast height) while in some cases more than 200 tree species (Turner, 2001). In terms of overall plant species richness, 942 plant species has been recorded in a single hectare of tropical rainforest (Balslev *et al*., 1998). Similarly, the timber volume in tropical rainforest varies from place to place and has been estimated as 5-35 m^3/ha in Africa to 50-120 m^3/ha in Asia (Goldsmith, 2012). Furthermore, tropical rainforest is composed of very ancient ecosystem with rich in highly specialized organisms. Therefore, it is highly fragile and highly sensitive to human disturbances (Goldsmith, 2012).

Deforestation is the major factor threatening the tropical rainforest and accounts for a loss of 13 million hectares per year globally (FAO, 2005). More importantly, Southeast Asia is losing forest at a faster pace than other part of the world and has been forecasted as only one fourth of the forest could be remained by 2100 if the existing speed of deforestation continues (Sodhi *et al*., 2004). Out of three block of tropical rainforest distribution (the American rainforest, the African rainforest and the Indo-Malayan rainforest), Indonesia lies in the Indo-Malayan rainforest block (Whitmore, 1998) and is the third largest tropical rain forest rich country in the world. It has total forest coverage of about 91 million hectare of which around 51% are primary forests and remaining 44% are naturally regenerated forests and just around 5% plantation forests (FAO, 2015). Primary forests were lost at a rate of 0.5% per annum between the period 2010 and 2015 while the overall deforestation rate between the periods 1990 to 2015 was 1.1% per year. This means that Indonesia already lost about 27.5 million hectare of forest between the periods 1990 to 2015 (FAO, 2015). Moreover, it has been estimated that Sumatra alone already lost forest at a rate of 550 thousand hectares per year in the period between 1990 and 2007 (Laumonier *et al.*, 2010).

The vast loss of the rainforest has had an effect on biodiversity, ecosystem functioning, sustainable land use, and local economies (Chapin *et al.*, 2000; Hoekstra *et al*., 2005). It has been estimated that biodiversity loss of up to 42% in Southeast Asia could be occurred by 2100 (Sodhi *et al.*, 2004). More importantly, the situation is further worst in Indonesia as Indonesian tropical rainforests are supporting a high percentage of endemic plant species (nearly 60% of total vascular plants in Indonesia) and are therefore of high importance for biodiversity conservation (Sodhi *et al.*, 2004). Besides this, some communities such as customary land users are directly suffering from rainforest conversion because they either have to change their professions due to depleted forest resources or they need to travel further to collect forest resources which were previously available nearby their settlements (Obidzinski *et al.*, 2012).

1.3 Agricultural land-use systems in Indonesia

Globally, agricultural expansion is the major cause of deforestation in the tropics (FAO, 2005). More than 55% and another 28% of fresh agricultural land in tropical areas came through deforestating intact forest and disturbed forest respectively during the period of 1980 to 2000 (Gibbs *et al.*, 2010). The pressure on tropical forest will be further increased, as the demand for agricultural land is increasing. FAO (2009) has already predicted that 70% increment in the food production is necessary to feed the increasing trend of population (9.1 billion) by 2050. Along with the demand for food, the rising demand for feed, timber, fuel and biofuel has also accelerated the conversion of forest to agricultural land (Gibbs *et al.*, 2010; Lambin and Meyfroidt, 2011; Tilman *et al.*, 2001). Furthermore, agricultural plantations , mainly rubber, oil palm and coconut are also responsible for the losses of rainforest and has occupied about 20-30% of all cultivated land in Southeast Asia (Rademaekers *et al.*, 2010).

In Sumatra, along with pulp and timber operations, the increasing trend of oil palm expansion and rubber plantation has major role in deforestation (Margono *et al.*, 2012; Villamor *et al.*, 2014). These agricultural plantations are expanding due to their associated incomes to smallholders (Rist *et al.*, 2010). Moreover, the increasing farmer‟s technical knowledge, experiences and easy access for processing due to development of infrastructure have further motivated farmer for the expansion of agricultural plantations mainly oil palm plantation (Euler *et al.,* 2016).

1.3.1 Jungle rubber agroforest system

The conversion of tropical forest into traditional agroforest systems has been started in Sumatra at the beginning of the 20th century, where exotic rubber tree were planted intermixed with natural vegetation (Penot, 2004). Such form of agroforest system is called jungle rubber and is characterized by resembling secondary or disturbed forest in structure because of growing wild plant species in between the rubber trees (Beukema *et al*., 2007). In this system, a minimum of two-thirds of total trees will be occupied by non-rubber species and other products like fruits, medicines, resin, and timber (Pye-Smith, 2011).

Jungle rubber agroforests are established either in the previously logged forest or in degraded forest (Gouyon *et al*., 1993, Wibawa *et al*., 2005). In this system, clearance of forest is done using slash and burn techniques followed by plantation of rubber into the gaps. Annual food crops are usually cultivated in between the rubber rows and repeat cultivation for the period of 2-3 years (Joshi *et al*., 2000) until weed growth, shade of rubber tree and soil depletion create unfavourable environment for further cultivation of crops (Gouyon *et al*., 1993). However, we did not observe such types of intercropping practices in our study area (jungle rubber).

For the management of jungle rubber, weeding is carried out for the first 2-3 years after slash and burns (Beukema *et al*., 2007). After a few years, a complex forest-like vegetation develops since most wild species colonizing the area are allowed to grow with the rubber trees (Beukema *et al*., 2007). In this system, re-planted is usually done after about 40 years while some jungle rubber plots are maintained up to an age of 70 -80 years whenever profitability continues to exist (Beukema *et al*., 2007).

The major direct benefit of this system is low input (cost and labor) required to achieve diversified income from the diversified useful plants such as food, fruits, rattans, fodder, fuelwood, timber and other non-timber forest products growing in with rubber (Gouyon *et al*., 1993; Penot, 2004; Michon, 2005). So, jungle rubber is becoming the major sources of income for the millions of households in Indonesia (Joshi *et al*., 2006) while about 7 million people are living from this system only in Sumatra and Kalimantan (De Foresta and Michon, 1996). Besides this, this system is associated with other benefits such as high environmental and soil conservation values compared to monoculture plantations (Penot, 2004). Therefore, this system is considered as the most viable option for the conservation of biodiversity in the case of disappeared condition of forest (De Foresta and Michon, 1996; Bohnert *et al*., 2016).

Further, the continuous and natural regeneration of various species in this system provides the mimic of forest structure composed of plants of every age group (Feintrenie and Levang, 2009) which in fact has vital role for the conservation of forest flora (Ekadinata *et al*., 2004).

1.3.2 Monoculture rubber plantation:

Increasing global demand with striking price of the natural rubber is continually creating the pressure for the conversion of jungle rubber into more productive monoculture rubber plantations (Feintrenie and Levang, 2009). Though, the conversion to the monoculture system has been continuously occurred since 1950 (Feintrenie and Levang, 2009), the most rapid change has been occurred in 1990s in Sumatra, where international agencies (mainly World Bank) were encouraging monoculture rubber plantations and were replacing traditional jungle rubber gardens in a greater extent (Pye-Smith, 2011). This has led to the decreasing trend in the jungle rubber area, but the total rubber area has been increasing day by day. Unless, the rewarding provisions are made for retaining jungle rubber, farmers will continue to replace high diverse jungle rubber with low diverse monoculture system (Pye-Smith, 2011). In Indonesia (mostly in Sumatra and Kalimanthan), the monoculture along with jungle rubber which was 1.8 million hectares in 1990 rapidly expanded and reached 3.5 million hectares in 2013 (FAOSTAT, 2016).

The monoculture rubber plantation is an intensively managed system characterized by less than 1% non- rubber trees growing unintentional in most of the cases (Pye-Smith, 2011). The productivity under this system is three times higher than the jungle rubber system (Penot, 2004). However, this systems needs high level of capital investment for establishment (Pye-Smith, 2011). Along with threatening diverse jungle rubber, this system has also posed a threat to the forest. So, the expansion of this system is also associated with negative effect on biodiversity, environment and soil conservation (Penot, 2004; Pye-Smith, 2011).

1.3.3 Oil palm plantation

In Indonesia, oil palm cultivation has been started commercially from the east coast of Sumatra in 1911 under Dutch administration (Corley and Tinker, 2003). Although the large scale cultivation in the region was successful, the native people planted it only for decorative purpose without replacing their coconut palms. However, later, the rising demand and more profitability of oil palm plantation as well as government policy for technical and financial incentive to the farmer lured people to focus more on oil palm plantation (Budidarsono and

Susanti, 2013). The oil palm plantation demonstrates much higher financial returns comparing to other form of agricultural products such as rubber or rattan (Belcher *et al*., 2004) so in Indonesia, this plantation is replacing not only forests but also rubber plantations (Feintrenie *et al*., 2010). The dramatic increment in the cultivation appeared between the period 1990 and 2013. The total plantation was only 700 thousand hectare in 1990 and reached seven million hectares in 2013 (FAOSTAT, 2016). Therefore, since 2008, Indonesia is in the topmost position in the list of palm oil producing and exporting countries in the world (Feintrenie *et al*., 2010).

Expansion of oil palm plantation is one of the major factors causing forest loss in Indonesia. Simultaneously with the increasing cultivation of the oil palm, the forest loss was also increasing. Between 1990 and 2005, 1.7-3 million hectares of Indonesian forests were lost due to oil palm expansions, what amounts to 50% of the total forest loss during that period (Fitzherbert *et al*., 2008). From 2000 till 2010, another 11% of the deforestation were due to oil palm expansion in Indonesia (Abood *et al*., 2015). The situation will get further worst since the government of Indonesia has set its goal to double the oil palm production within the next ten years (Carlson *et al*., 2013). So, the monoculture plantations of oil palm will further dominate the landscape of Indonesia, particularly in Sumatra (Carlson *et al*., 2013) and will create even more stress on the tropical biodiversity and ecosystem functioning (Laurance *et al.,* 2014). This situations will ultimately threat to the human well-being in long run as degradation in the ecosystem services is associated with the insufficient provision of goods and services needed for human well-being (Daily *et al*., 1997).

1.4 Useful plant species

Useful plants are the plants that have been documented as importance for human, animal or the wider environment for the fulfilment of particular needs (Kew, 2016). People use plant species for several functions such as for medicine, poisons, dyes, shelter, fiber, religious and cultural ceremony (Heywood, 1999). A total of 31,128 plant species in the world are considered as useful and have documented use (Kew, 2016). Besides ornamental species, it has been estimated that only about 7,000 species are cultivated worldwide (FAO, 2014). This indicates that a large number of useful plant species are non-cultivable and are found outside cultivated land or grow naturally on cultivated land.

Although agriculture is the major sources for nutrition and supporting for the survival of 60% of world population (FAO, 2009), forest also plays an important role in the fulfillment of various needs. Globally, around 300 million people are dependent on useful plants from the tropical forest (Richardson, 2010) out of which 60 million indigenous people are fully dependent on the rainforest for the purpose of materials, as well as cultural and spiritual wellbeing (Seymour *et al*., 2014). Furthermore, forest foods such as wild fruits, nuts, vegetables etc. play an important role in contributing for food security, to fulfil household nutrition during the time of leans seasons or in the period of little agricultural productions (Kehlenbeck *et al*., 2013). Moreover, wild products from the tropical forests have been an important sources of income for large number of people living around tropical forests. In and around tropical forest, households have made 21% of their total income through harvesting wild products (Seymour *et al*., 2014).

Tropical rainforest is the original habitat for some useful plant species. Many foods that we consumed worldwide such as Brazil nuts, avocados, various chilies, papayas, sweet potatoes, etc. are from tropical rainforest (Seymour *et al*., 2014). Furthermore, the world most important food that we are eating today (rice, sugarcane, banana, coconut, mango) are originated from the tropical rainforest of Southeast Asia (Whitemore and Burhnam, 1984) Beyond that, tropical rainforest are rich in commercially valuable plants species used in raw materials for the manufacture of several products such as resins, oils, fibres, and fruits for the production of valuable raw materials (Myers, 1988). Moreover, tropical rainforest are the potential store house of the medicinal plants, as the product that we collected and tested for the biologically active compounds for the development of new drugs are only the small fraction of rainforest plants (Balick and Mendelsohn, 1992).

Most plant species in the tropical rainforest are rare and needs large areas to maintain viable populations (Alvarez-Buylla *et al*., 1996), so the increasing human disturbances have driven numerous plant species to the edge of extinction (Barraclough and Ghimire, 1990). IUCN has already estimated that about 21% of the total plant species are at risk of extinction (Kew, 2016).The extinction of plant species is associated to the livelihood of a large number of people on one hand and their contribution for sustaining ecosystem on otherhand. This situations highlights the need to explore more about useful plant diversity to decide proper land-use practices for the fulfilment of human needs and ecosystem functioning.

1.5 Objectives

Some previous researches (Böhnert *et al*., 2016; Rembold *et al*., 2017) in the same area through EFForTS project were confined to study on another aspect of plant diversity but did not analyze about the diversity of useful plant species . This study aims at analysing how the useful plant species diversity changes with the changes in land-use system. For this, we made comparison about the useful plant diversity in four different land-use systems. Besides this, species richness under different use categories of plant species across four land-use systems were also compared. Furthermore, we tried to explore relationship between total plant diversity and useful plant diversity.

To achieve our objectives, we had set three main hypotheses for this study. (H1) Useful plant species diversity is higher in forest than in agricultural systems; (H2) Species richness under different use categories are higher in forest than in agricultural systems and (H3) Useful plant species richness and total plant species richness are linearly related.

2. Materials and Methods

2.1 Study area

The study area was located in the EFForTS (Ecological and Socio-economic Functions of Tropical Lowland Rainforest Transformation Systems) project region in the lowlands of Jambi Province, central Sumatra, Indonesia (Fig.1). Jambi, one of the 34 provinces of Indonesia, is positioned on the eastern coast of central Sumatra. It covers 50160km^2 expanding from the southern Malacca Strait in the east to the Barisian Mountain range in the west (Statistik, 2014). Jambi province is suffered from deforestation mainly due to increasing population and agricultural intensification. It has only 30% forest area whereas 10% is degraded land, and remaining 55% is agricultural land (Drescher *et al*., 2016)

The study was conducted in the area of naturally regenerated lowland rainforest and three different agricultural systems, i.e. jungle rubber, rubber plantation, and oil palm plantations. The core plot established in rainforest represents primary degraded forest with signs of human disturbance like logging and extraction of forest products (Drescher *et al*., 2016). Jungle rubber represents a agroforestry system established through rubber tree plantation in previously logged or degraded rainforest (Gouyon *et al*., 1993; Wibawa *et al*., 2005). Both rubber core plots and oil palm core plots have been established in monoculture plantations managed by smallholders (up to 50-ha landholdings). During the time of plot selection in 2012, the age of rubber plantations was between 7 and 16 years and that of oil plam plantations was between 8 and 15 years (Drescher *et al*., 2016; Kotowska *et al*., 2016).

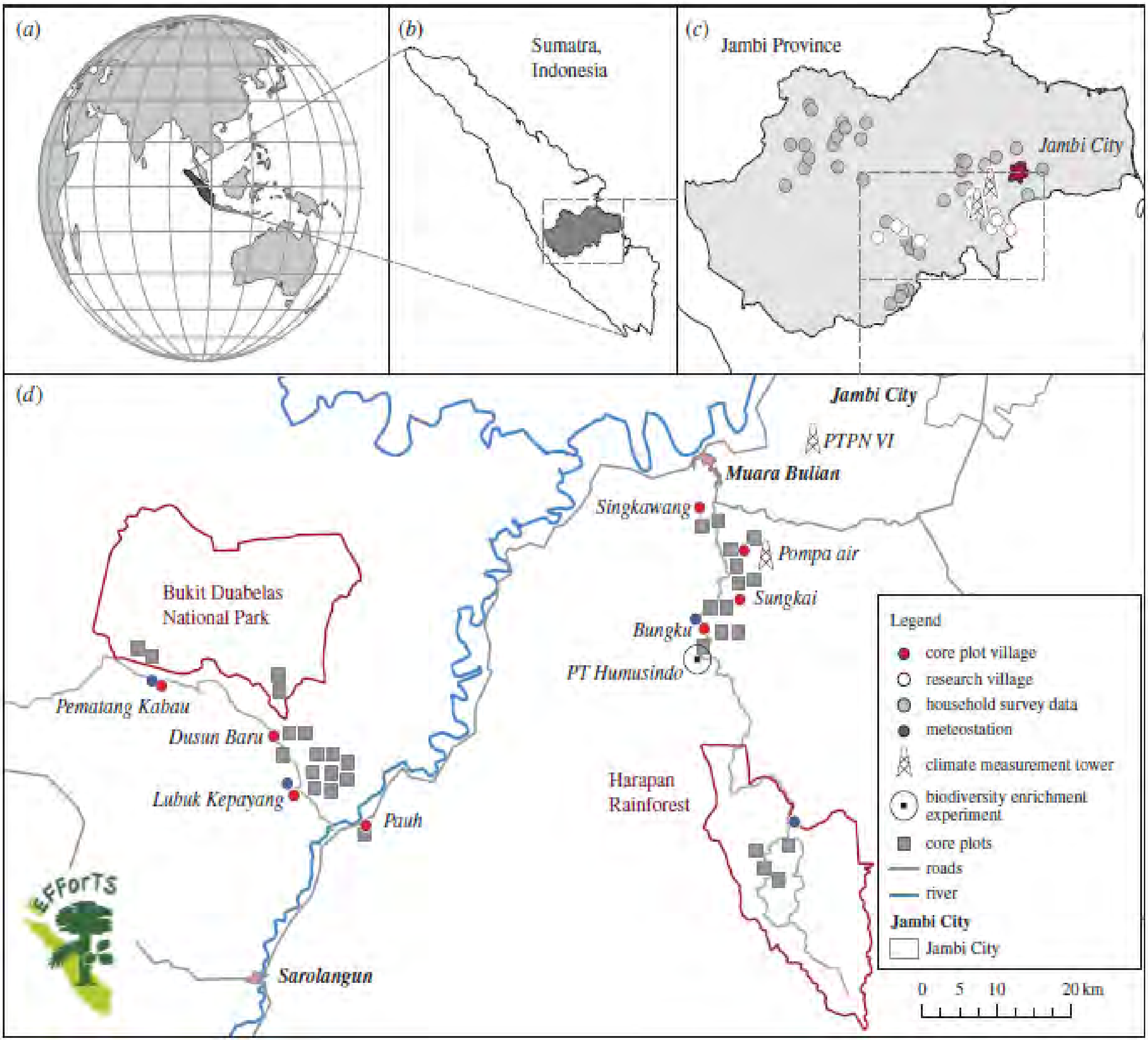


Figure 1: Location of study sites in Sumatra (Jambi Province) where core plots were located in two landscapes near to Bukit Duabelas National Park and Harapan Rainforest (framed in red). Core plots locations are indicated through grey square. (Sources: Drescher *et al*., 2016)

The study area has two landscapes .i.e Harapan landscape and the Bukit Duabelas landscape. Soils in Harapan landscape are characterized by more even proportions of sand, silt and clay so called loam Arisols whereas clay Arisols with more factions of clays in Bukit Duabelas landscape (Allen *et al*., 2015). The study area has tropical humid climate with mean monthly rainfall of more than 100mm throughout the year and the annual weather is characterized by a rainy season (October to April) and a dry season (July-August) (Drescher *et al*., 2016).

2.2 Sampling Design

Eight plots measuring 50 m x 50 m in each of the four land-use systems were already established in 2012, resulting in a total of 32 study plots (Fig. 2). These plots were used for the inventory of trees with a minimum dbh of 10 cm. All plants smaller than that were assessed in five subplots measuring 5m x 5m nested within in each plot (160 subplots in total).

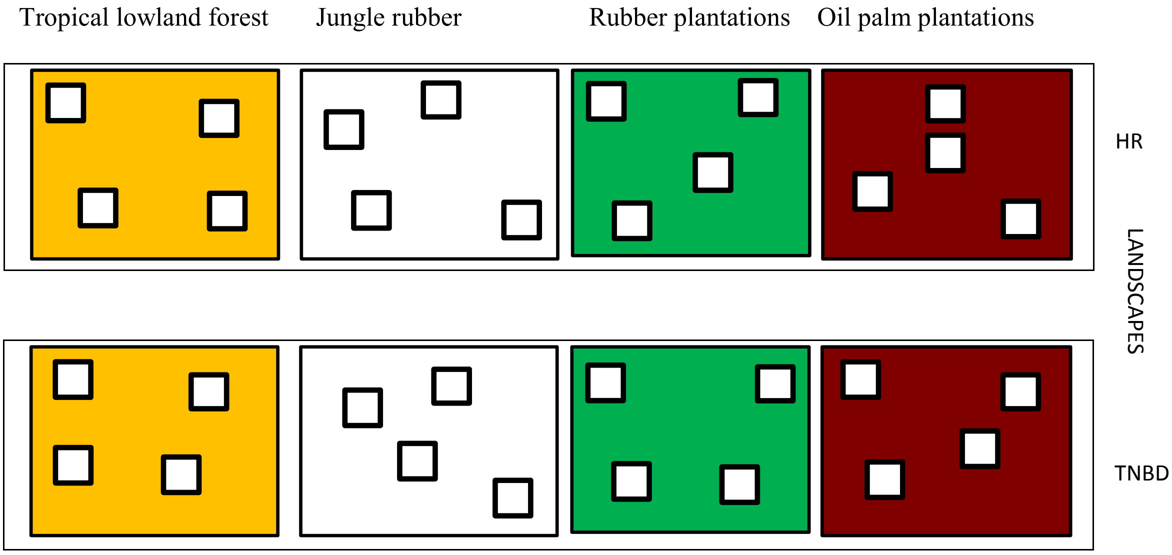


Figure 2: Allocation of plots across four land-use systems and two landscapes

2.3 Data Collection

2.3.1 Vegetation survey

A vegetation survey was the major method to collect primary data about the plant species found in the study area. For this study, we took an opportunity of already collected data from a vegetation survey carried out by Rembold *et al*. (2017). 1382 species were found in that study, out of which 312 species were not yet identified to species level. So in our study to identify the useful species, we only focused on 1070 identified plant species.

2.3.2 Literature survey

Literature survey was another important aspect of this study since our study was fully based on the literature survey to find out the potential uses of each plant species. For this, our work began with the collection of information from all published volumes of PROSEA (Plant Resources of South-East Asia) books. After that, we searched information from the online portal named „Useful Tropical Plant" database (http://tropical.theferns.info/). For additional information, we used Google Scholar and Web of Science to find published articles.

Different authors (Kew,2016; Sheil *et al.*, 2006) have categorized useful plant species into different categories, but with the nature of our data we categoried useful plant species in our own way in 14 categories on the basis of their potential useful functions to human (Table 1). The full list of literatures used for classifying useful plant species into different categories are provided in the appendix 6 and details about collected data with citations is available at: https://drive.google.com/drive/folders/0B4OtJT8YsDqvRkpQbVBDTHZLSjQ?usp=sharing.

Table 1: Categorization of plant species into 14 main use categories.

Use category	Description
Color (Color species)	Plants that can be used as paint, varnishes, tanning and dyes
Erosion control (Erosion control species)	Plants that have the potential to minimize erosion
Fibre (Fibre species)	Plants that are used for making clothes, ropes or that are used as rope or for tying purposes.
Fodder (Fodder species)	Plants that are edible for domestic animals
Food (Food species)	Plants or plants parts that are edible for humans as food or spices or oil
Fuelwood (Fuelwood species)	Plants or plants part (including oil) that are potential for cooking purposes.
Handicraft (Handicraft species)	Plants that can be used for making different items through weaving and carving.
Magic (Magic species)	Plants that are used as magical purposes, religious belief
Medicine (Medicinal species)	Plants potential to be used as treatment for human disease
Nutrient enrichment (Nutrient species)	Plants potential for enriching soil or making soil fertile such as green manure, some leguminous crops.
Ornamental (Ornamental species)	Plants that can be planted for decorative purposes. For instance, planted for road side area or garden just to give beautiful looks.
Poison (Poison species)	Plants that are potential to be used as poison. It also includes insecticides, fish poisons etc.
Rubber (Rubber species)	Plants that are used for producing rubber/gum/wax etc
Timber (Timber species)	Plants that are potential for making building materials, furniture, tools, plywood and veneer etc.

2.4 Data Analysis

Since most methods for measuring diversity are actually composed of two factors namely species richness and species evenness (Magurran, 2004). So, we also followed the same path and we calculated the species richness, species abundance (number of individuals), Simpson index, Shannon diversity and evenness for each land-use system to measure the useful plant species diversity in different land uses.

Species richness was calculated on the basis of total number of useful plant species in each land-use system. Species richness is the most widely used diversity measure because of its simplicity and effectiveness to use (Stirling and Wilsey, 2001). It is also considered as a rational option for monitoring and evaluation purposes to judge outcomes in conservations (Cardinale *et al.*, 2011). The plot-wise species richness was also calculated for making later comparisons on using test statistical tools.

Simpson"s index of diversity is actually based on the chance of getting same species in the case of randomly selected two individuals from an infinity large community (Simpson, 1949).This index is less sensitive to species richness and emphasize on the most abundant species in a sample (Magurran 2004). It is expressed as

$$\mathrm{D} = \sum \mathrm{pi}^2$$

Where, pi denotes the proportion of the abundance of i^{th} species. But in the case of finite community, the related index (D) is calculated as:

$$\mathrm{D} = \sum \frac{\mathrm{ni}[\mathrm{ni} - 1]}{\mathrm{N}[\mathrm{N} - 1]}$$

Where ni and N represent the abundance of individuals in the i^{th} species and total abundance respectively. The index in this form has inverse relationship with diversity so is counterintuitive. Therefore, to get a flawless figure for the clear presentation of the value, we used 1-D as a measure of Simpson index of diversity in this study. In this study, the value of Simpson index of diversity (1-D) would be between 0 and 1. The higher value of an index represents the greater diversity and vice versa.

Evenness(E) was calculated based on the Shannon diversity (H'). This diversity index is commonly used diversity index as it takes both species richness and abundance into account and is highly sensitive to the variation in the rarest class (Heuserr, 1998). This diversity index is calculated as

$$E = \frac{H'}{\ln s}$$

$H' = \sum pi \ln pi$ and $pi = \frac{ni}{N}$

Where, pi indicates individual"s proportion in the i^{th} species.

In this measurement, both more even distribution and higher species richness increase species diversity. The value of H' determines the respective species diversity in the different land use. Higher the diversity, greater will be the value of H' and vice versa. Land use with single species would have H' value of 0 because pi would be 1 and its multiplication (product) with log pi equals to 0. This indicates that the value of H' allow us to know both number of species and their distribution in the community (Magurran, 1988).

Species richness, species abundance, Simpson index, Shannon diversity and evenness were calculated per plot. The per plot findings were tested for normality using skewness and kurtosis, and judging through plotted histogram. We used Shapiro-Wilk-test (Shapiro and Wilk, 1965) to conclude the normality of data. We found abnormality in the distribution of plot-wise data, so, we used non parametric test called Kruskal-Wallis one-way analysis of variance (Kruskal and Wallis, 1952) to make comparison of data from different land-use systems. Further, we analysed data using post hoc multiple comparison to determine the pairwise differences within these data between land-use systems.

Species accumulation curves were also drawn to estimate total species richness per system. For this, sample-based species–accumulation curves were plotted from samples taken randomly within a given area as mentioned by Gotelli & Colwell (2001). These curves denote the aggregate number of recorded species as a function of sample plots (Colwell and Coddington, 1994). The rise and stable nature of curve depends on the availability of new species in the additional sample plot. The curve will rise when new species are found and will remain in the stable condition in absence of new species in additional sample plot. This stable condition represents no more sampling effort required for the estimation of the total species richness of the particular area.

To identify the variation of 14 use categories of useful plant species in four land-use systems, we calculated number of species (species richness) per plot in each land uses. These plot datas were tested for normality (following the procedure as mentioned earlier). However, we found abnormalities in the distribution of data, so we used Kruskal and Wallis tests to determine how different use categories of useful plant species varies when land shift from one land-use system to another.

To examine the relationship between total plant species richness and useful plant species richness, we used the regression analysis and plot the diagram with the equation. Simple linear model was used to examine the relationship between dependent and independent variable. Total plant species richness was modelled as an explanatory variable against useful plant richness (dependent variable). Similarly, the relation between total plant abundance and useful plant abundance were also identified using the same method.

The useful plant species diversity and abundance were analyzed using the free software statistical package for social science (IBM SPSS statistics 22) and Microsoft excel. Most of the figures were created in SPSS however; species accumulation curve was calculated using vegan package in the free software for statistical computing and graphics R, Version 3.2.1.

3. Results

3.1 Useful plant species diversity and abundance across different land-use systems

Out of 156,006 individuals of 1,382 species found in the study area, about 78% (121,107) of total individuals and about 56% (769) of the total species were found to be useful to fulfil the different needs of humans. Useful plant species richness was highest in the forest (548) followed by jungle rubber (421) and rubber plantation (168). The lowest useful plant species richness was observed in oil palm plantation (157) (Fig.3a). The abundance of species was found just reverse of the useful plant species richness in different land-use systems. Despite the highest number of useful plant species in the forest, the abundance was lowest in the forest (11,002 individuals) and jungle rubber had approximately 15,170 individuals. Although oil palm plantation had the lowest number of species, the abundance was highest (61,942 individuals) followed by rubber plantation (32,993 individuals) (Fig.3b).

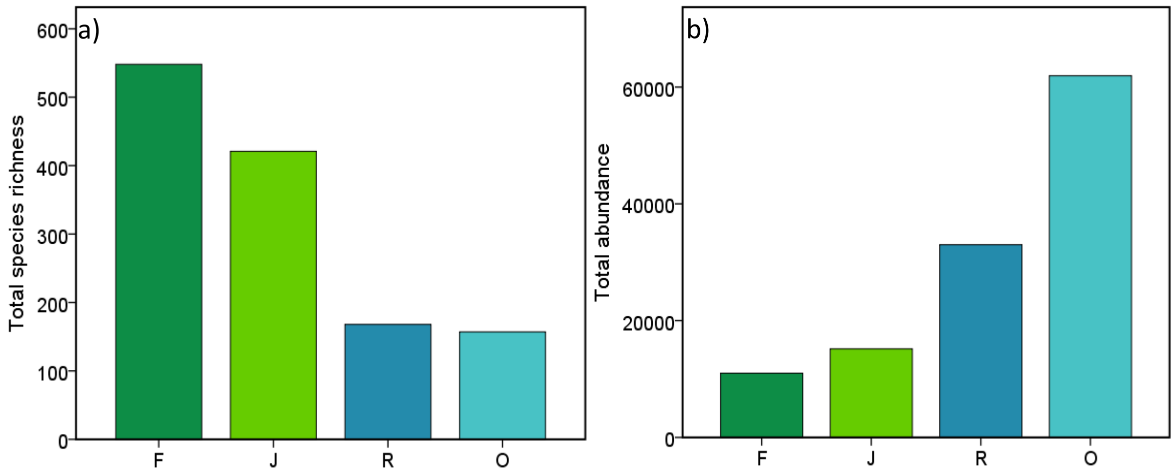


Figure 3: Species richness (a), and abundance (b) of useful plant species across four land-use systems (F- forest, J- jungle rubber, R-rubber plantation and O- oil palm plantation).

Out of 769 useful plant species identified in the study area, most species (267 species) were exclusively found in the forest followed by jungle rubber (102) and 173 species were only confined to both forest and jungle. Rubber plantation had lowest number of unique species (10) however oil palm had 29 unique species. The majority of species were confined to forest and jungle rubber while only 40 species are found in all types of land-use. Only three species *Mikania micrantha*, *Selaginella intermedia* and *Calophyllum pulcherrimum* were found in all types of land-use systems besides jungle rubber. Five species (*Syzygium racemosum, Hypserpa nitida, Friesodielsia biglandulosa, Baccaurea parviflora*, *Xylopia elliptica*) were restricted to only forest and oil palm. Oil palm plantation and jungle rubber had four species (*Archidendron jiringa, Millettia sericea, Symplocos fasciculate, Merremia umbellata*) in common which were not found in other land uses. Similarly, 33 species were found in all agricultural land-use systems, however these species are completely absent in forest (Fig. 4).

If we categorize useful plant species into two types: generalist (found in at least two land uses) and specialist (found in only one land-use system), forest comprised of nearly more or less equal amount of both generalist (51%) and specialist plant species (49%). But in the case of agricultural land-use systems, the situation was quite different as there was domination of generalist species over specialist species. It is interesting to mention that 94 % of the useful plant species in the rubber plantation were occupied by generalist species and 83% and 75% percentage respectively in oil palm plantation and jungle rubber.

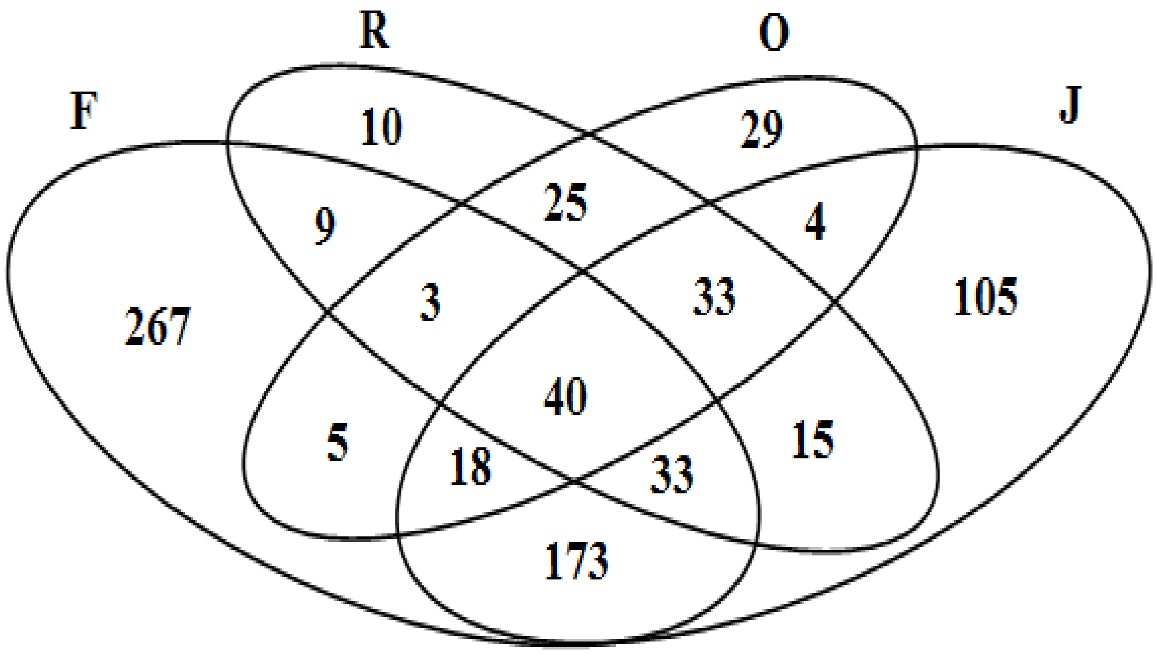


Figure 4: Venn diagram showing numbers of useful plant species across four land-use systems (F- forest, J- jungle rubber, R-rubber plantation and O- oil palm plantation).

The species accumulation curves drawn for all four systems clearly showed the differences in the number of plant species in all systems (Fig. 5). Forest and jungle rubber had far more species than the two plantations, regardless of the number of plots. While all curves are still increasing, the plantations are rather closed to saturations, while more plots would lead to increasing number of useful plants in forest and jungle rubber. These accumulation-curves specify that the sampling effort of 32 plots (8 plots per land-use system) was sufficient to make comparison of land-uses in terms of species richness. However, it seems that sampling effort is not sufficient to depict the maximum number of species in all these four land-use.

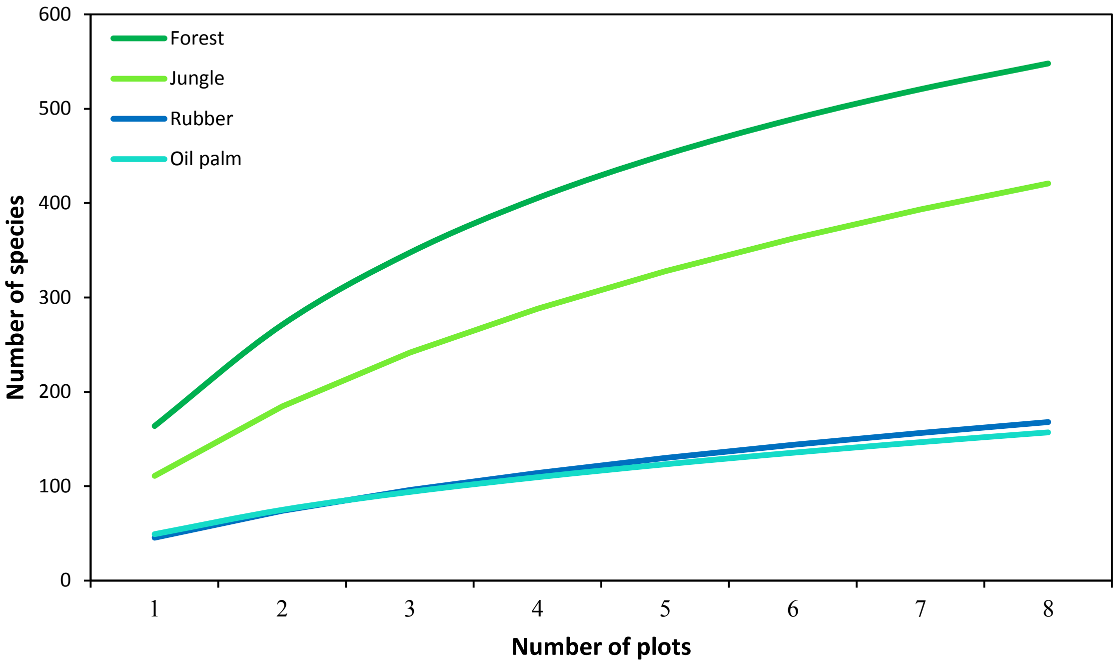
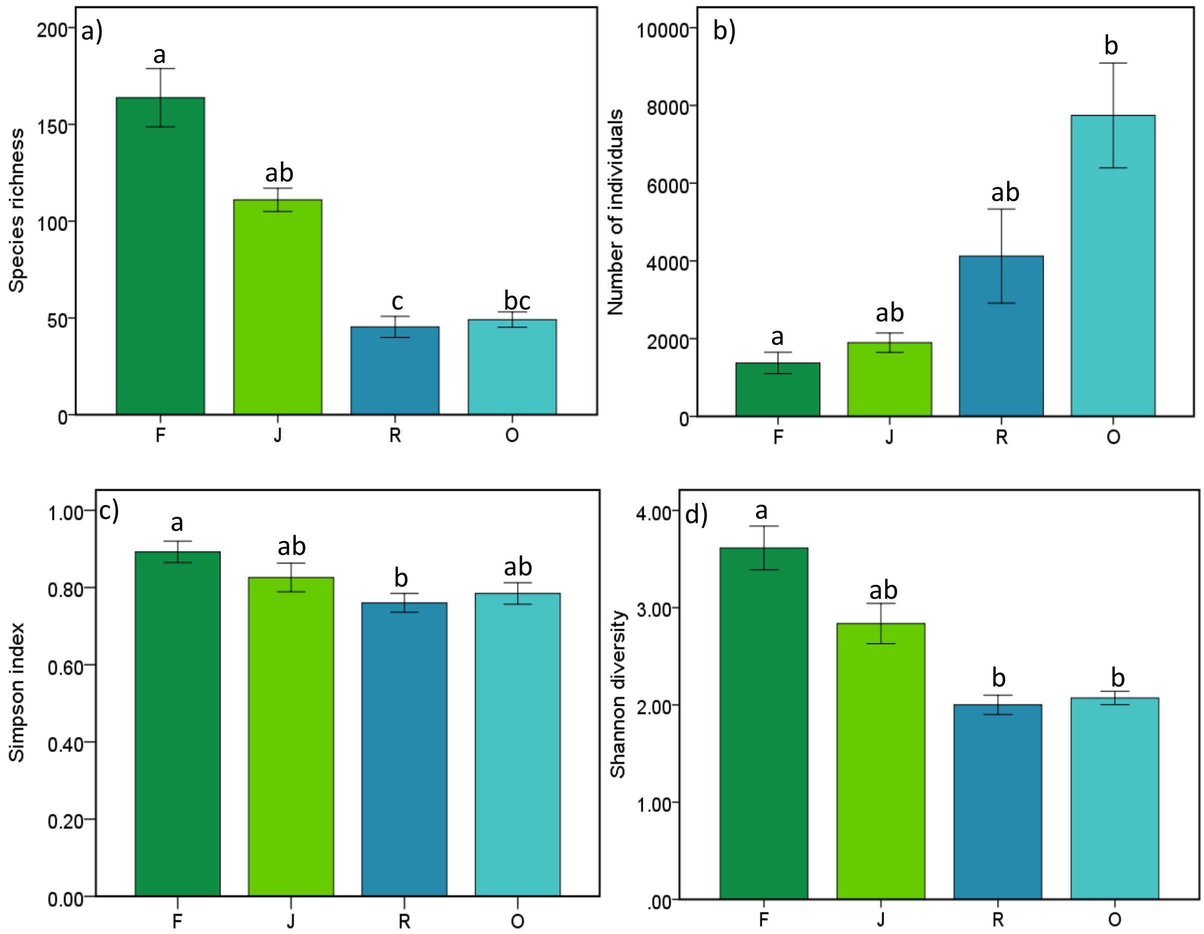


Figure 5: Species-accumulation curves for useful plant species in four land-use systems.

Species richness, number of individuals, Simpson‟s index, Shannon diversity, and evenness differed between the four land-use systems(Fig.6). Forest had the highest Species richness, Simpson‟s index, Shannon diversity and evenness and was followed by jungle and oil palm respectively. The value for all these measures of diversity indices were lowest in rubber plantation. But in the case of a number of individuals, different pattern was observed as the forest had lowest mean number of individuals while oil palm plantation had highest mean number of individuals. Kruskal-Wallis test also showed the significant differences of land-use system in terms of Species richness, number of individuals, Simpson index, Shannon diversity and evenness ($P<0.05$).

With respect to species richness, post hoc comparison showed significant differences between forest and rubber ($P<0.001$), rubber and jungle ($P=0.019$), and forest and oil palm ($p=0.001$) (Fig. 6a). In terms of number of individuals, only the mean difference between forest and oil palm was significant ($p=0.001$)(Fig. 6b).

Post hoc multiple comparisons showed that forest had significantly higher Simpson index than rubber plantation only ($P=0.017$) (Fig. 6c). Forest had significantly higher Shannon diversity and evenness than rubber plantation ($p=0.012$ and $p<0.001$ respectively) and oil palm plantation ($p=0.012$ and $p<0.001$ respectively) (Fig. 6d and 6e). In all measures of diversity indices, forest was not significantly different with jungle rubber.



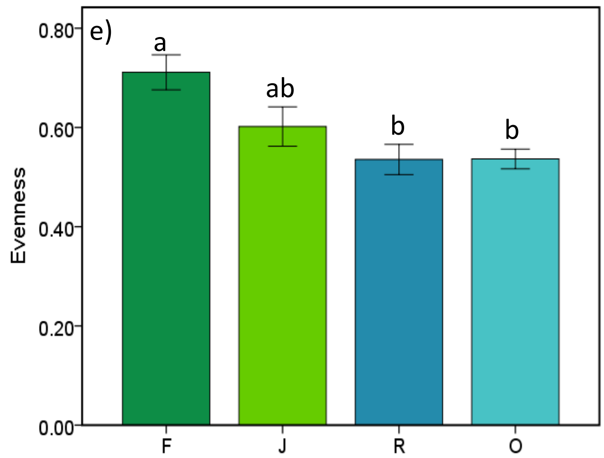


Figure 6: Useful plant species richness (a), number of individual (b), Simpson index (c), Shannon diversity (d) and Evenness (e) in the four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences; p=0.024 (a), p<0.001 (b), p=0.007 (c), p<0.001(d) and p=0.002 (e). Bar indicates mean value while error bars indicate standard error. Means with different letters within one system, are significant different from each other (post hoc multiple comparisons after Kruskal-Wallis). X-axis represent four different land-use systems (F- forest, J- jungle rubber, R- rubber plantation and O- oil palm plantation).

3.2 Variation of useful plant species categories across different land-use systems

While looking over the all 14 use categories of useful plant, we found strong links between timber, food and medicine categories. This means that from 151 to 200 timber species had also potential to be used as food and medicine. Similarly, 101 to 150 species had potential to be used for both timber and fuelwood while 51 to 100 medicinal plant species have the potential to be used for fuelwood, color, poison and ornamental. The interesting thing is that not a single species was potential to be used for both fodder and rubber. A similar pattern was also seen between the connection between magic and nutrient species as not a single species has a dual function of both magic and nutrients. Besides these, the rest of the categories had linkage between them (Fig.7).

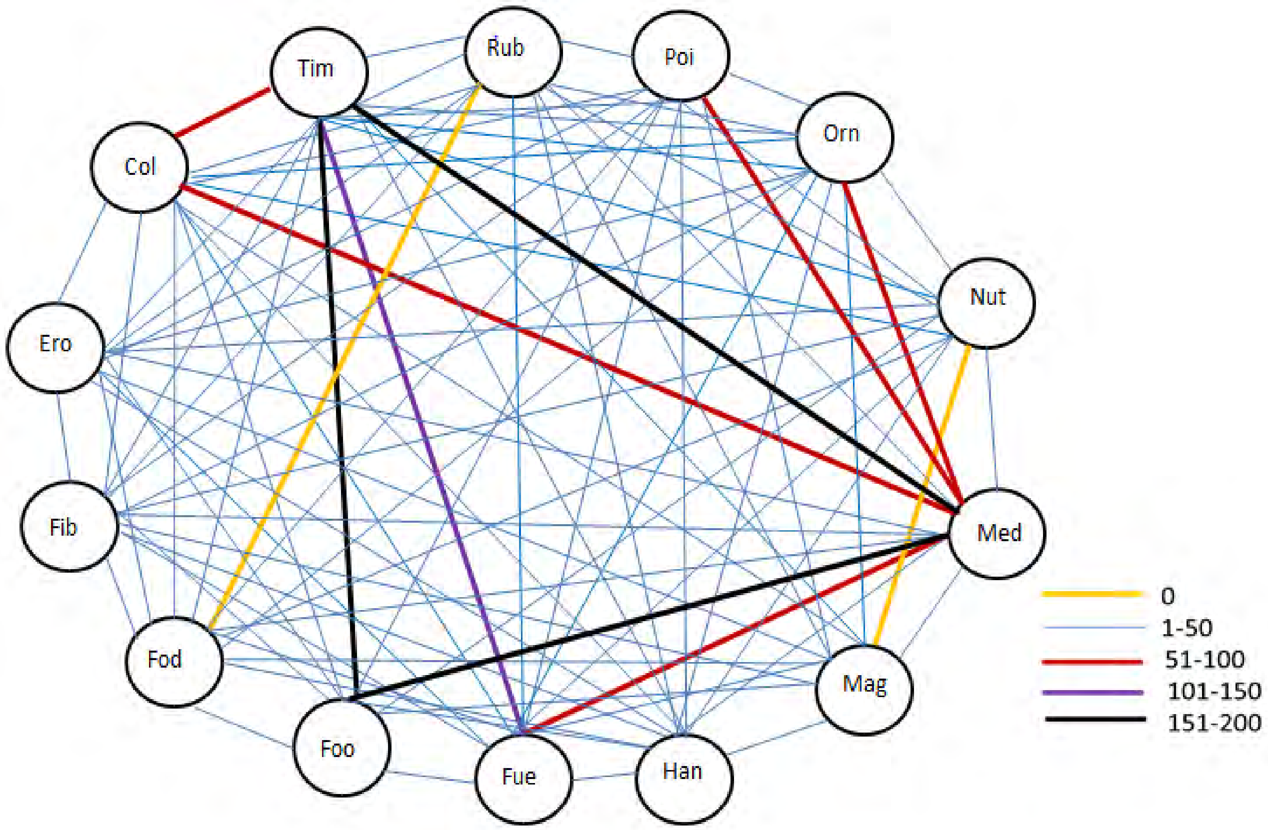


Figure 7: Diagrammatical representation of link between 14 use categories of plant species (useful plant categories) in four land-use systems. Useful plants were categorized based on their useful value to human. The 14 use categories are Color (Col), Erosion control (Ero), Fibre (Fib), Fodder(Fod), Food (Foo), Fuelwood (Fue), Handicraft (Han), Magic (Mag), Medicine (Med), Nutrient enrichment (Nut), Ornamental (Orn), Poison (Poi), Rubber (Rub) and Timber (Tim). The different color of line connecting each use category indicates the number of useful plant species (as shown in index) overlap between these two categories. Details about these links have been presented in Appendix 5.

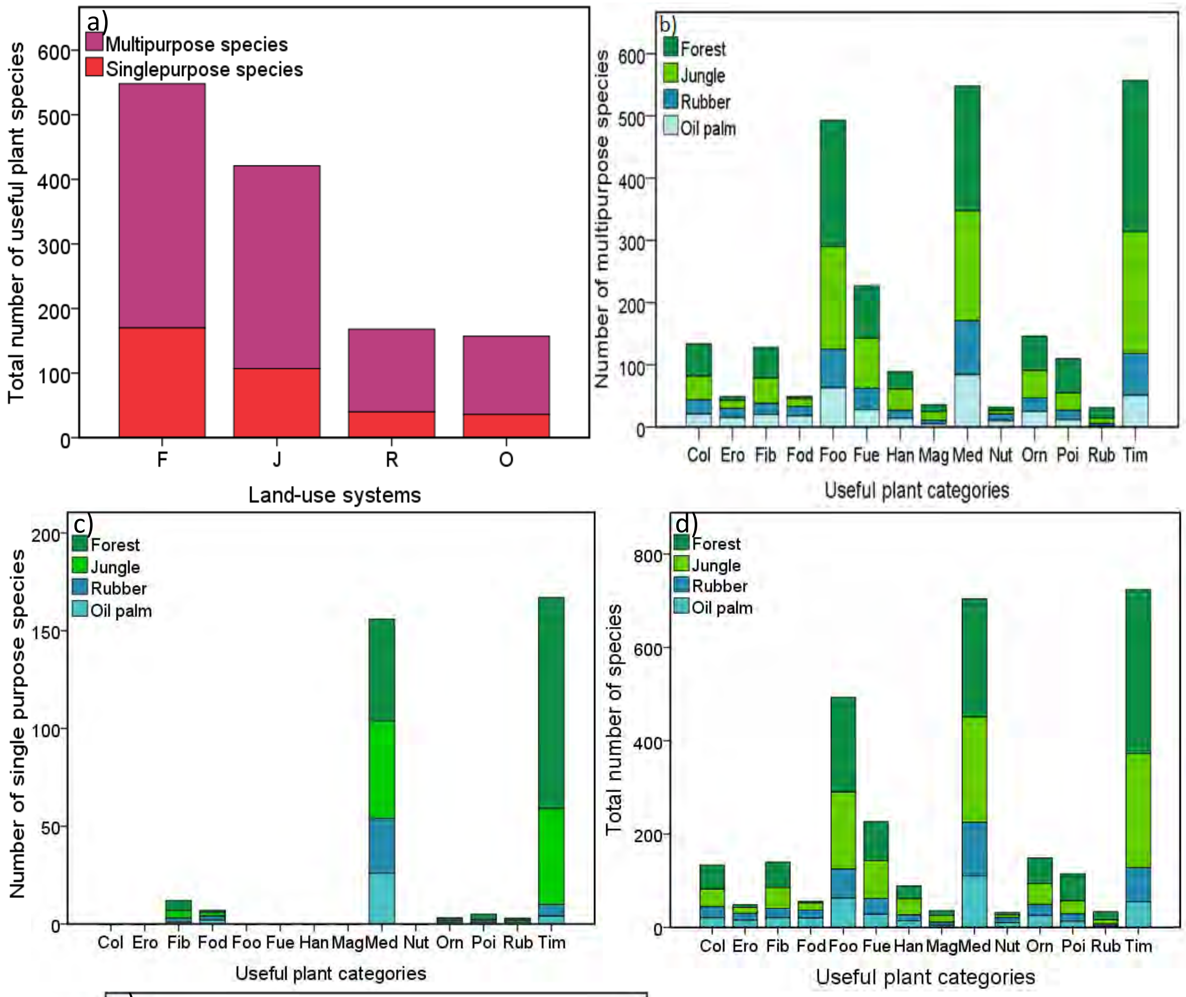
If we consider the species having more than one useful value as multi-purpose species and species having a single value as single purpose species, we found that multi-purpose species occupied more than 68% of the useful plant species in each land-use system. Forest was characterized by highest number (378 species) of multi-purpose species followed by jungle rubber (314) and rubber plantation (128 species). The lowest number of multipurpose species was found in oil palm plantation (121 species)(Fig.8a). However, whenever we looked over the percentage on the basis of total useful plant species in each land-use system, the trend was reversed. Only 69% percentages of useful plant species in forest were multipurpose while

75%, 76% and 77% of species in jungle rubber, rubber plantation and oil palm plantation respectively were multipurpose species. A similar pattern was also followed in the case of number of single purpose species as forest (170 species) had the highest number of single purpose species followed by jungle (107 species) and rubber (40 species) and lowest in Oil palm (36 species) (Fig. 8a). But in terms of percentage of total useful species found in each land-use system, forest was characterized with 32% of single purposes species, while jungle rubber, rubber plantation and oil palm plantation were characteriszed with 25%, 24% and 23% single purposes respectively.

Out of fourteen categories of the useful plant species, most of the multipurpose species were timber species followed by medicinal and food species and were mostly found in forest and jungle. Very few numbers of multipurpose fodder species and multi-purpose erosion control species were found in forest comparing to other land-use systems (Fig. 8b). Interestingly, seven out of fourteen categories were characterized by some single purpose species, while remaining seven categorized had no any single purposes species. Plant categories under timber, medicinal and fiber were the dominant single purposes species and these were also mostly found in the forest followed by jungle rubber, rubber plantation and oil palm plantation respectively. The interesting thing is that not as single single purposes ornamental species was found in forest, while jungle rubber and oil palm had equal number of single purpose ornamental species (Fig. 8c).

In overall (combining both multipurpose and single purpose species), timber species were the dominant species followed by medicinal and food species respectively in both forest and jungle rubber. Similarly, medicinal plant species were the dominant species in both rubber plantation and oil palm plantation. The number of species having potential to control erosion, fodder and nutrient enrichment was higher in agricultural land-use systems than in the forest (Fig. 8d).

In terms of total individuals, highest number of individuals under most of the categories were found in oil palm plantation however, individuals under timber categories were in a higher amount in forest than agricultural land-use systems. Lowest number of individuals were noticed under nutrient category in all land-use systems apart from oil palm plantation. Medicinal plant species were in greater amount in all land-use systems, however species such as magic, handicraft and nutrients enrichment were in lesser amount in all land-use systems compared to other categories of useful value (Fig. 8e).



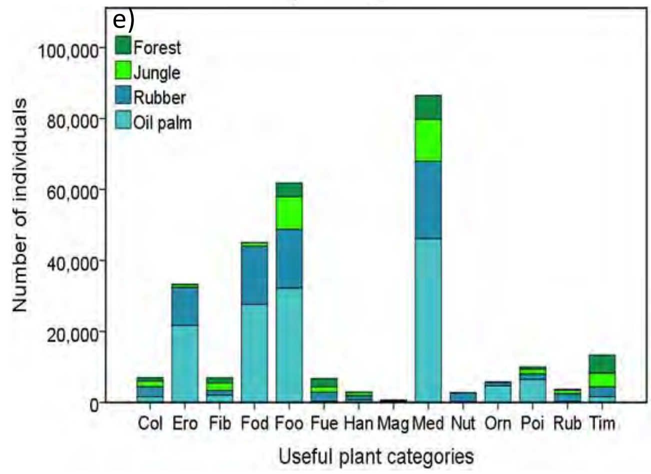
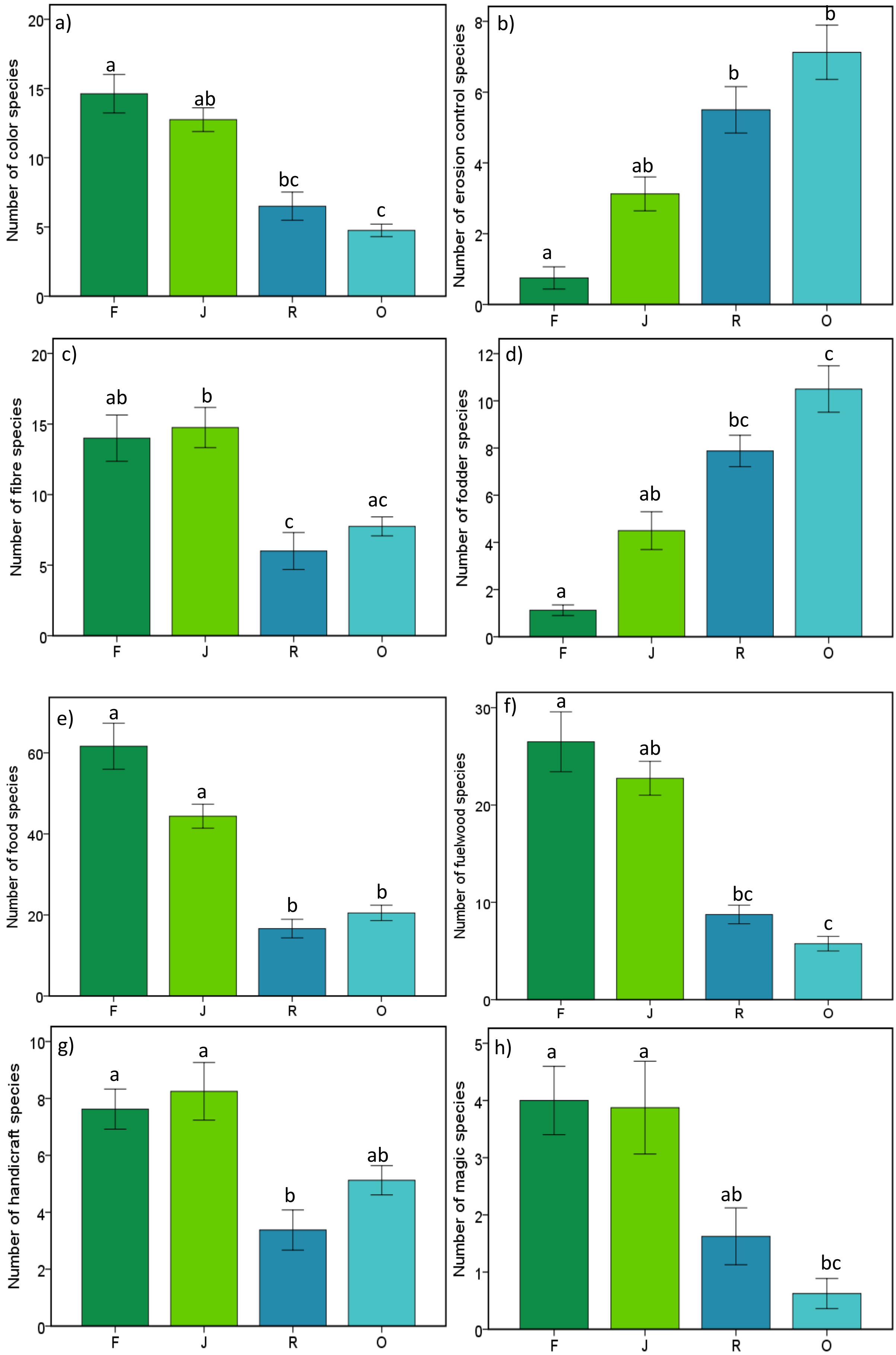


Figure 8: Total number of multipurpose and single purpose species across four different land-use systems (F- forest, J- jungle rubber, R-rubber plantation, and O- oil palm plantation) (a), total number of multipurpose species (b), total number of single purpose species (c), total number of species under different categories of useful plant(d) and total individuals under different categories of species (e) across four land-use system. Useful plants were categorized into 14 categories based on their useful value to human. The 14 category of useful plant are Color (Col), Erosion(Ero), Fibre (Fib), Fodder (Fod), Food (Foo), Fuelwood (Fue), Handicraft (Han), Magic (Mag), Medicine (Med), Nutrient enrichment (Nut), Ornamental (Orn), Poison (Poi), Rubber (Rub) and Timber (Tim).

On the plot level analysis, the four systems showed significant differences within number of all 14 categories of useful plant species (Kruskal-Walis one way analysis of variance, P<0.05). The mean number of species potential for color production was highest in forest followed by jungle rubber and rubber plantation respectively while lowest number was in oil palm plantation. With respect to the number of color species per plot, Kruskal-Wallis post-hoc comparisons showed significant difference between the pair oil palm plantation and jungle rubber (p=0.004), oil palm plantation and forest (p<0.001) and forest and rubber plantation (p=0.012) (Fig. 9a). The mean number of fuelwood species, timber species, rubber species and poison species also followed the same trend as color species (highest in forest and lowest in oil palm plantation). However, significant difference was noticed only in certain pairs in each category. Such as in terms fuelwood species, rubber species and timber species richness, the mean difference between forest and rubber plantation, forest and oil palm plantation, and jungle rubber and oil palm plantation were significant (P<0.05) (Fig. 9f, 9m, 9n) but in poison species, only the mean difference between forest and rubber plantation, and forest and oil palm were significant (p<0.001) (Fig. 9l)

The mean number of erosion control species was highest in oil palm plantation followed by rubber plantation and jungle rubber respectively while forest had lowest number of such species. However, the post hoc comparisons showed the significant difference between only the pair forest and rubber plantation (p=0.002) and forest and oil palm plantation (p<0.001) (Fig.9b). Mean number of fodder species also followed the same path as erosion control species followed (highest in oil palm plantation and lowest in forest) but only the mean difference between the pair forest and rubber plantation, forest and oil palm plantation, and jungle and oil palm plantation were significant (p=0.003, <0.001 and 0.029 respectively) (Fig. 9d).

Jungle rubber had highest mean number of fibre species followed by forest and oil palm plantation respectively. The post hoc comparisons showed the mean difference between forest and rubber plantation, jungle rubber and rubber plantation, and jungle rubber and oil palm plantation were significant (P=0.007, 0.003 and 0.037 respectively) (Fig. 9c). The mean number of food species and medicinal species were highest in forest followed by jungle rubber and oil palm plantation respectively however lowest in rubber plantation. The post hoc comparisons showed the mean difference between forest and rubber plantation, forest and oil palm plantation, jungle rubber and rubber plantation, and jungle rubber and oil palm plantation were significant in terms of both food and medicinal species richness (p<0.05) (Fig. 9e).



a)
Number of color species
b)
Number of erosion control species
c)
Number of fibre species
d)
Number of fodder species
e)
Number of food species
f)
Number of fuelwood species
g)
Number of handicraft species
h)
Number of magic species
F
J
R
O

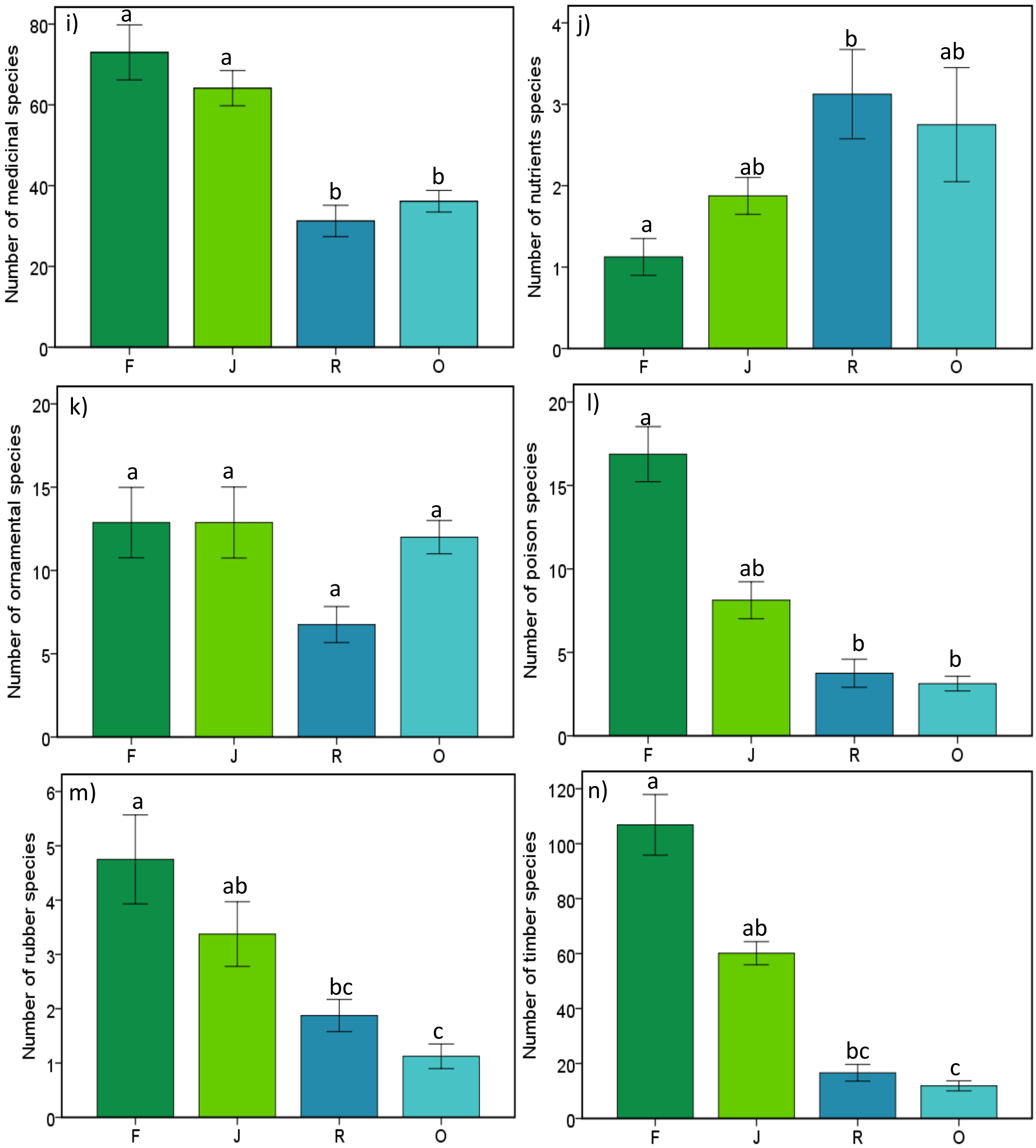


Figure 9: Mean number of 14 categories of useful plant species in four land-use systems. Useful plants were categorized based on their useful value to human. The 14 category of useful plant are color (a), erosion (b), fibre (c), fodder (d), food (e) , fuelwood (f), handicraft (g), magic (h), medicine (i), nutrient enrichment (j), ornamental (k), poison (l), rubber (m) and timber (n). Kruskal-Wallis one-way analysis of variance showed significance level of differences; $p<0.000$ (a), $p<0.000$ (b), $p<0.001$ (c), $p<0.001$(d), $p<0.001$ (e), $p<0.001$ (f), $p<0.002$ (g), $p=0.001$ (h), $p<0.001$(i), $p=0.018$ (j), $p<0.029$ (k), $p<0.001$ (l), $p<0.001$ (m) and $p<0.001$ (n). Bar indicates mean value while error bars indicate standard error. Means with different letters within one system, are significant different from each other (post hoc multiple comparisons after Kruskal-Wallis). X-axis in each diagram represent four different land-use systems (F- forest, J- jungle rubber, R-rubber plantation and O- oil palm plantation).

The mean number of handicraft species was highest in jungle rubber followed by forest and oil palm plantation whereas lowest in rubber plantation. The statistical significant difference was found only between forest and rubber plantation, and jungle rubber and rubber plantation ($p \leq 0.02$) (Fib. 9g).

Forest and jungle rubber had equal number (mean) of ornamental species which was highest and were followed by oil palm plantation. The lowest mean number of ornamental species had been found in rubber plantation. Although the Kruskal-Walis one way analysis of variance shows the significant difference ($p=0.029$), the post hoc pairwise comparisons did not showed any significant difference between any pairs (Fig. 9k). Similarly forest and jungle rubber had nearly equal number of magic species and were followed by rubber plantation, however lowest mean number of magic species had been found in oil palm plantation. The statistical comparison showed only the mean difference between forest and oil palm plantation ($p=0.004$), and jungle rubber and oil palm plantation ($p=0.009$), were significant (Fig. 9h).

The mean number of nutrient enrichment species was higher in agricultural system than forest. In agricultural system, rubber plantation had highest number followed by oil palm plantation and jungle rubber respectively. However, the statistical significant difference was found only between the pair forest and rubber plantation ($P=0.016$) (Fig. 9j).

3.3 Relationship between total plant species richness and useful plant species richness

Simple linear regression showed a positive relationship between useful plant species richness and total species richness, however the extent varied in different land-use systems (Fig.10a). Thus the higher number of useful plant species richness could be expected with the increasing number of total species richness in each land-use system. Further simple linear regression models revealed that the total species richness were able to explain useful plant species richness in each land use (Appendix 1). In case of forest, total species richness did describe 80% of useful plant species richness ($F= 23.583$, $P= 0.003$ and $R^2=0.797$) while in jungle rubber 93% ($F= 75.963$, $P<0.000$, $R^2= 0.927$). It is interesting to mention that in rubber plantation, total species richness did reveal about 99% ($F= 397.396$, $P<0.001$, $R^2= 0.985$) of useful plant species richness and in oil palm plantation around 96% ($F=156.495$, $P<0.001$, $R^2= 0.963$).

Similarly, a positive relationship between total individual number and useful plant individual number was found in all land-use categories (Fig. 10b). The simple linear regression models also showed the total individual number was able to describe useful plant individuals (Appendix 2). Like as earlier, total number of individuals in rubber did explain about 98% ($F=321.243$, $P<0.001$, $R^2= 0.982$) of useful plant individuals in rubber which is higher comparing to others. This was followed by jungle (97%) ($F=226.150$, $P<0.001$, $R^2= 0.974$) oil palm (82%) ($F=27.059$, $P=0.002$, $R^2= 0.819$) and lowest in forest (59%) ($F=8.586$, $P=0.026$, $R^2= 0.589$).

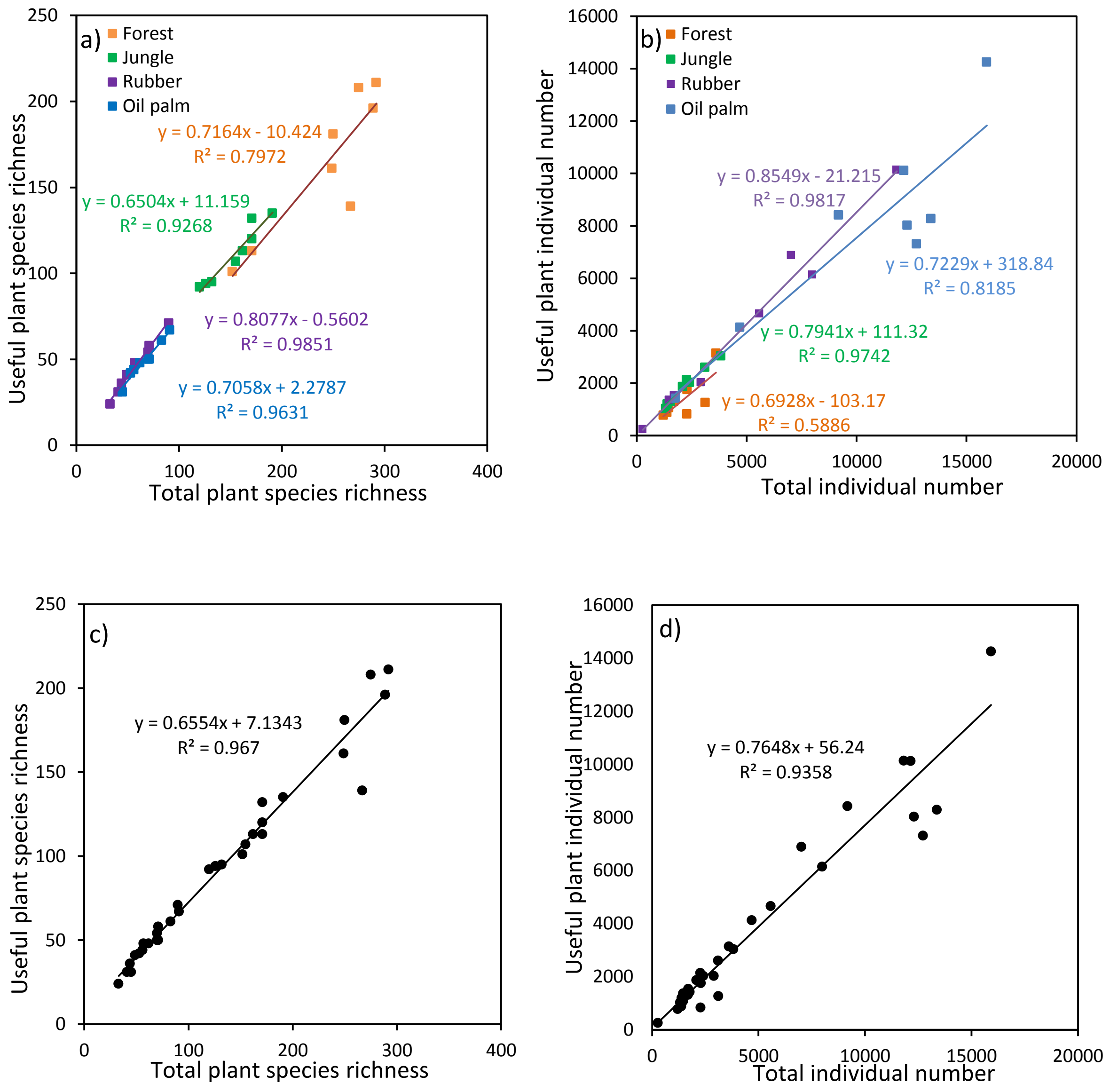


Figure 10: Simple linear regression models: useful plant species richness plotted against total species richness (a) and useful plant species individual number plotted against total individual number (b). Overall useful species richness plotted against total species richness (c) and useful plant individual number against total individual number (d). The four different colors used in figure (a) and figure (b) indicate value of four different land-use systems.

While plotting the useful plant species richness against total plant species richness without considering the different land-use systems, the linear regression line showed the positive correlation between these two variables (Fig. 10c). Further, the total species richness did describe 97% of useful plant species richness (F= 879.806, P=0.000 R^2=0.967) (Appendix 3). Similarly, the total individual number did explain 94 % of useful plant individual number (F=437.142, and P<0.000, R^2=0.936) (Appendix 4) and the corresponding regression line between these two variables also showed a positive correlation (Fig. 10d).

4. Discussion

Land-use system determines the availability of plant species in the area. When the land-use change occurs, the change in the microclimatic conditions brings change in the composition of vegetation (Danielsen *et al*., 2009; Yaap *et al*., 2010). Moreover, other factors which are vital for plant growth (soil pH, nutrient concentration and organic matter content) vary in different land-use systems (Koerner *et al*., 1997; Flinn *et al*., 2005) which may be favourable for some species while unfavourable for others. Agricultural systems are driven by the economic aspects so farmers focus on the few species that can fulfil economic needs. For example, in intensively managed agricultural land-use systems (oil palm and rubber plantations), almost all native species are removed for the plantation of the major species (oil palm and rubber). Frequent management techniques are applied for the betterment of the major species and to suppress the other undergrowth that has low economic value. So, there will be strong declined in the total plant diversity in these land-use systems comparing to the intact forest (Rembold *et al*., 2017). The decline in total plant diversity, lead to the narrower choice of species, may ultimately lead to low useful plant diversity. Therefore, it is not surprising that we found a decrease in useful plant diversity with increase in land-use intensity.

The understanding on the useful plant diversity with their various ethno-botanical uses is important to provide guidance for the rational uses of resources (Tabuti *et al*., 2003; Kamatenesi-Mugisha and Oryem-Origa, 2005). To this end, our results provide detail understanding about variation of useful plant diversity and use categories between different land-use systems, as well as the association between total plant diversity with useful plant diversity.

4.1 Useful plant species diversity and abundance across different land-use systems

Plot-based inventories of useful plant species in the four land use systems in our study area showed a clear difference between land-use systems in terms of species diversity. Our finding partially supported the Hypothesis1 (H1) hypothesizing that forest has more useful plant species diversity than agricultural land-use systems. Forest had significantly higher useful plant species diversity than oil palm plantation and rubber plantation but forest had no any significant difference in useful plant diversity with that of the jungle rubber. This indicates that forest and jungle rubber were rich in useful plant species diversity while other agricultural land-use system (rubber plantation and oil palm plantation) were poor in useful plant diversity. The finding regarding non- significant difference between forest and jungle rubber emphasized the importance of jungle rubber (among other agricultural land-systems) for the maintenance of useful plant diversity.

We found the strong decline in number of useful plant species with increasing land-use intensity. Jungle rubber, rubber plantation and oil palm plantation had only 77%, 31% and 29% of useful plant species found in forest respectively. This is consistent with study by Chittababu and Parthasarathy (2000) in tropical evergreen forest in India where decreasing useful plants species richness (useful understory plant species) by 54% in disturbed forest comparing to undisturbed forest has been observed. Similarly, Kessler *et al*. (2005) in Indonesia found that tree species richness declined gradually from primary forest to forest gardens, secondary forests, and cacao plantations. Kurniawan (2016) also found higher tree species diversity in forest and jungle rubber than in the converted land-use systems (rubber and oil palm plantation). In our study area also, Rembold *et al*. (2017) found highest number of plant species in forest than other land-use systems. Similarly, Böhnert *et al*. (2016) observed strong declines of vascular epiphytes diversity in our study region at landscape level but at plot level, epiphyte diversity in oil palm plantation was not significantly different from forest. In contrast, we found that useful plant species richness in plot level was significantly higher in forest than in agricultural plantations (rubber plantation and oil palm plantation) in our study area. From these studies, we can speculate that the effect of land-use change can vary between different plant groups.

Out of 769 useful plant species found in our study area, 35% (267 species) were exclusively found in forest and 14% (105 species) were exclusively found in jungle rubber. But in other agricultural land-use systems, only 1% (10 species) and 4% (29 species) of the total useful plant species found in our study area were exclusively found in rubber and oil palm plantations respectively. The highest number of the endemic useful plant species (exclusively found) in forest indicates that the increasing deforestation in the study area had put vast amount of endemic forest species (useful plant species) at risk of extinction. The loss was dependent on the type of land-use system adapted. For example, the effect was low whenever forest converted into jungle rubber and the effect was high whenever the forest converted into monoculture plantation. This shows that lowland rainforest are incomparable with the other agricultural land-use system for the maintenance of endemic useful plant diversity, however jungle rubber could serve as a buffer for endemic useful plant species in the context of disappeared condition of forest.

While looking over the similarity between different land-use systems in terms of number of useful plant species, jungle rubber had highest number of useful plant species overlapped with forest (264 species) but oil palm plantation had the highest number of useful plant species overlapped with rubber plantations (101 species). Rembold *et al.* (2017) in the same study area also found similar type of result where jungle rubber had highest number of plant species (350 species) overlapped with forest and oil palm had highest number of plant species (125 species) overlapped with rubber plantation. This indicates that with the present context of increasing deforestation rate for agricultural expansion in tropical areas, jungle rubber could be the most viable option (among other agricultural land-use systems) to cope with the challenge for the maintenance of total plant species diversity on one hand and to fulfil the growing human needs on other hand (through maintaining useful plant species diversity). The highest useful plant species diversity in jungle rubber among other agricultural plantations might be due to the fact that agricultural plantation are based on the plantation of few species (mainly single species in monoculture plantations) over the area, while jungle rubber system is managed with variety of plant species to get variety of products so jungle rubber resembles the characteristics of forest (Penot, 2004).

Species accumulation curve also showed that the forest was rich in useful plant species richness, followed by jungle rubber. These two land-use systems had more or less similar useful plant richness till the end of sample plot. Similarly, rubber plantation and oil palm plantation were poor in useful plant species richness. With the current sampling effort, although these curves did not reach saturation, we could clearly see the differences between forest with that of rubber plantation and oil palm plantation. However, continued sampling would most likely increase the number of useful plant species in each system, especially in forest and jungle rubber. This finding suggests that more sampling effort is necessary in order to aggregate the total number of useful plant species in that area.

Simpson‟s diversity index was also highest in forest than other agricultural systems however at plot level jungle rubber and oil palm plantation were comparable to forest. The reason for the non-significant difference in Simpson‟s diversity index between oil palm plantations (though having less useful plant species in oil palm plantation) and forest may be due to the nature of Simpson index as it is less sensitive to species richness and put emphasize on the most abundant species (Magurran, 2004). Similarly, species evenness (Pielou‟s eveness) was also highest in forest and was comparable with only jungle rubber at plot level. Both results (Simpson index and evenness) demonstrate that the forest was not only rich in useful plant species diversity but also had more even distribution of useful plant species. The statistical non-significant difference in Simpson index and evenness between forest and jungle rubber emphasize that the jungle rubber is comparable to forest not only in useful plant species diversity but also in evenly distribution of useful plant species.

Analysing the data regarding species abundance (number of individuals) only, we found the reverse of species richness; this means that species abundance was highest in agricultural land-use systems and lowest in the forest. This is due to the fact most abundant species in the forest was *Selaginella intermedia* (1773 individuals) while the other species individual number was less than 500 in forest. But in case of agricultural land, particularly in oil palm plantation, some species like *Clidemia hirta* (15764 individuals) *Centotheca lappacea* (10365 individuals), *Asystasia gangetica* (10365 individuals) and another 8 more species (having more than 1000 individuals) were growing in higher amount which made oil palm plantation to stand in the first position in terms of individuals number. However, such species have limited economic value (though we considered these species also as useful plant species in our study) and also considered as invasive species. Instead of increasing economic returns, the presence of these species (invasive species) in plantations decrease local species diversity (Pyšek, *et al*., 2012) and increase management cost (weeding and herbicides) (Rembold *et al.,* 2017) as these plants species competes with other plant species to fulfil nutrients and light requirements. This will ultimately effect on ecosystem functioning and human wellbeing in long run (Pejchar and Mooney, 2009). The growth of these invasive species in excess amount in the agricultural land is due to the higher availability of light conditions (Danielsen *et al*., 2009). But in the case of forest, the lack of canopy openness creates low sunlight leads to the prevention of undergrowth and invasive species.

Our finding follows the similar pattern with the study by Wenzel (2015) about vascular epiphytes in our study area, where individual number of vascular epiphytes was higher in oil palm plantation than forest. Incontradiction to our study, Wenzel (2015) also found the highest number of individuals(vascular ephiphytes) in jungle rubber and lowest in rubber plantations. Anglaaere *et al.*, (2011) also reported highest abundance of useful tree species in forest than other land-use systems. This shows that number of individuals under different plant groups also varies with adopted land-use system. The possible reason for a higher number of some plant communities (particularly epiphytes plants) in oil palm plantation is due to amassing of organic matters in the leaf axils of the oil palm (Altenhövel, 2013). Böhnert *et al.* (2016) has also speculate the intentional destruction of some plant communities (epiphytes) by farm workers leads to the low abundance of ephiphytes in rubber plantation. Since our study was based on all types of useful vascular plant species (includes both epiphytes and non-epiphytes plants), we can conclude that microclimatic condition, availability of organic matters and farmer preference determine the abundance of plant species in different land-use systems.

4.2 Variation of useful plant species categories in different land-use systems

Our finding shows that the different categories of useful plant species richness varied with the different land-use systems. Though forest had more useful plant species richness in overall, however, didn‟t have all use categories of useful plant species (useful plant species categories) higher than agricultural land. This indicated that our finding partially supported hypothesis 2 hypothesizing that forest has highest species richness under all use categories of useful plants. Species richness under fuelwood, medicine, timber and poison categories were highest in the forest than agricultural plantation, but species richness under other use categories like erosion control, fodder, and nutrient enrichment were highest in agricultural plantations. In all categories of useful plant species richness, we found non-significant difference between jungle rubber and forest indicates that jungle rubber is also comparable to forest to provide various various categories of useful plant species. This finding is particularly important as it could provide the guidelines for the adoption of land-use systems based on need of people.

We found forest comprised of both single purpose and multipurpose species number higher than agricultural land-use systems. The networking diagram (Fig.7) had shown that the timber, food and medicine categories had good linkage with each other. This indicates that whenever the land-use system is rich in one useful category, there will be the high chance of having other useful categories because of multipurpose use nature of that species. It is obvious that forest comprises of mainly timber species than agricultural land-use systems. So the significant number of useful plant species under food and medicine categories in the forest might be due to the multiplepurpose natures of timber species. This finding particularly demonstrates that the management of forest could serve multiple returns from the useful plants species rather than other agricultural plantations.

Segnon *et al.,* (2014) reported the significantly higher number of edible (food) species richness in the semi-arid area comparing to arid area. While comparing microclimatic condition in our study area, Shekhar Badu *et al*., (2017) found that forest had cooler and moist microclimatic conditions comparing to other agricultural land-use systems. Analysing these two studies, we can speculate that the cool and moist microclimate in the forest is one of the major factor for the highest number of food species in forest.

Our finding is in line with Anglaaere *et al*. (2011) where higher number of non-timber species (in overall) in forest than coca-farm was observed in Ghana. In agricultural system, generally farmers give priority for the major crops. They destroy other plant species if they feel that other plants are hindering their major crops because of shade and root competition (Anglaaere *et al*. (2011). This leads to the low plant species diversity in agricultural land. In our study area (agricultural plantation), the major focus of farmers was on rubber and oil palm production, So species richness under most of the categories were lowest than forest. Incontrast, species richness under some categories (nutrient enrichment, erosion control) were highest in agricultural land in our study area. As tropical soil is poor in nitrogen content due to lack of humus layer, nitrogen is the most limiting factor for the agricultural production (Gutteridge and Shelton, 1994). Moreover, the problem of soil erosion and land degradation is severe in agricultural land (rubber and oil palm plantations) (Guillaume *et al.* (2016). To fulfil this gap, farmers focus on some plant species along with major crops (Anglaaere *et al*., 2011). These plant species have some other benefits as some can be used for fodder, food, fuelwood, etc. For example, cultivation of some leguminous crops is popular in agricultural land in the tropics (Gutteridge and Shelton, 1994). Although in our study area (agricultural land-use systems), none of the plant species were cultivated besides rubber and oil palm but farmer might have protected some naturally growing such species for the conservation of their land. So it isn‟t surprising that we found mixed result about species richness under different use categories among different land-use systems.

Sheil *et al.* (2006) found that the forest as the most important sources for all different categories of useful plant species (food, medicine, light construction, heavy construction, boat construction, firewood etc) comparing to other land-use systems. Combining this finding with our study, we can speculate that forest not only composed of highest diversity of most of the categories of useful plant species but also composed of most important species for the human beings. With the limited available time to conduct this research, we could not make comparison about the economic value as well as sustainable harvestable amount of each useful plant species categories across different land-use systems in our study area. People are still converting rainforest in a perilous manner to get economic returns from agricultural plantations, so it is indeed very essential to explore the possibility of forest to fulfil human needs. This could serve for not only prevention of forest conversion but also raise the income of people through the sustainable harvesting of forest products.

4.3 Relationship between total plant species richness and useful plant species richness

In all cases, we found the significant linear relationship between total plant richness and useful plant species richness as well as total plant abundance and useful plant abundance. We found the highest value of R in agricultural land, but lowest in the forest. This shows that we can predict total useful plants from total plant species with greater confidence in agricultural land than forest.

In our study area, 56% (548 species) of total forest species were useful while more than 65% (421 species in jungle rubber, 168 species in rubber plantations and 157 species in oil palm) of plant species found in each agricultural land-use system were useful. This means that forest comprised of lots of species, however, proportionally only few species were useful. This might be the factor responsible for the low prediction ability of useful plant species from total plant species in forest land. Besides that, the reduced proportion of useful plants in forest might be due to lack of knowledge about the uses of some plant species. We had information from the published papers only but there might be plenty of uses of plant species that are not published yet. On the other side, agricultural land-uses are managed based on the plantation of more useful species and control less useful species and or useless species. Several factors such as market accessibility and economic value determine priority of plant species in their land (Snelder *et al.,* 2007; Byg *et al.,* 2007). People are familiar about the uses of plant species growing in their agricultural land and most of the plant species in agricultural land are also documented in literatures due to which the proportion of useful plant species becomes higher. This leads to the higher confidence in the prediction of useful plant species through total plant species in agricultural land.

Previous research in our study area (Rembold *et al*., 2017) also found the decreasing total plant diversity with increasing agricultural intensifications. This means that forest had highest plant diversity whereas agricultural plantations had lowest plant diversity. Our finding regarding useful plant diversity followed the similar trend indicates that there should be a relationship between total plant diversity and useful plant diversity. This also supports our hypothesis that we can predict useful plant species diversity from total plant diversity.

Our finding is in line with Salick *et al*. (1999) who found the proportional decrease in the useful plant species richness as the total plant species richness decrease and vice versa. Begossi (1996) also reported the fact that region with higher plant species richness possess more useful plant species than the lesser one. The major reason for such types of relationship between total plant richness and useful plant richness might be due to the broader chance of obtaining useful plant species wherever broad ranges of total plant species are available. Similarly, Sheil and Salim (2012) found a direct relationship between useful plant species and total plant species (richness and abundance), but in terms of linear relationships, they found mix results among the community used to identify useful plant species during social survey. This means that some communities were familiar with some useful plant species while some communities weren"t familiar. This indicates that the number of unidentified species also affect on strength of relationship between useful plant species richness and total plant species richness. In our study area also, out of 1382 plant species, we could not identify 312 plant species up to species level, so we considered these species as useless species. The diversity of useful plant could be further increased and the better relationship could be developed, if we consumed more time to conduct the research and to identify these species.

Many researches (Aduradola, 2004; Asase *et al.,* 2010; Kessler *et al*., 2005; Rembold *et al*., 2017) in tropical region were conducted about total plant diversity. As tropical forest contains vast number of plant species, the problem in the available literature and identification may take long time to identify useful plant species. So our finding regarding the linear relationship between total plant species richness and useful plant species richness might be of particular interest for the researchers to predict useful plants in these land use whenever limited time and resources provided.

5. Conclusion

Tropical rainforest is remarkable not only in terms of overall plant diversity, but also in terms of useful plant diversity. Most plant species in tropical rainforest are useful or potential to be used for several functions for human beings. Our study showed that the conversion of tropical rainforest to other land-use system lead to the loss of useful plant diversity but the intensity of the loss varied with the adopted land-use system. The highest number of useful plant species overlapped between jungle rubber and forest, and the non-significant difference in useful plant species diversity between forest and jungle rubber demonstrates that the jungle rubber is comparable to forest in terms of useful plant species diversity. This indicates that with the prevalent condition of increasing deforestation in the study area, the adoption of the jungle rubber agroforest system can serve as the most viable option for the maintenance of useful plant diversity. Our finding regarding highest number of endemic useful plant species in forest indicates that the vast loss of forest area in the study region put these endemic species at the edge of extinction. The loss of these endemic forest species cannot be compensated from other land-use systems however, the loss could be minimize in overall through adopting jungle rubber land-use system.

We found that agricultural land were highly infested with invasive species (we also considered these invasive species as useful plant species based on available literatures) so the overall abundance of useful plant species became highest in agricultural land (mainly oil plam plantation). The presence of these invasive species in agricultural land not only threat local plant species diversity but also can minimize the economic returns as such species have very limited uses for human beings.

One remarkable result of this study was that forest had not all categories of useful plant species richness higher than agricultural land. Some useful plants species categories such as erosion controlling species and nutrient enrichment species richness were higher in agricultural land (plantations) than forest. This is due to the fact that agricultural land are highly prone to erosion, so the necessity for controlling erosion and maintaining producitivity in agricultural land lured farmer to protect such species with major crops in agricultural land. Other useful plant categories richness like timber, medicine, food and fuelwood were higher in forest than agricultural land indicating that the forest could serve as an important source to provide important forest products necessary for human beings.

Another finding of this study is infact very important for predicting the amount of total useful plants in the tropical rainforest. We noticed the statistically significant linear relationship between total plant richness and useful plant richness, also total plant individual and useful plant individual number in each land-use categories. This shows the reliability of plot based plant diversity studies for the documentation of ethno-botanical uses with using limited resources and time. This finding will be the milestone for the estimation of useful plant species from total plant species in tropical areas.

With the limited time available to conduct this research, we couldnot make comparision between land-uses systems interms of sustainable harvestable amounts of each categories of useful plants and the possible financial returns. It is still questionable; is forest really sufficient to provide required amount of different categories of human need in our study area? This type of study is indeed very necessary to decide the rationale use of land in the present context of increasing conversion of forest for the sake of economical returns. This can be the new task for the researchers to get over view of useful plant diversity and their possible role for the fulfillment of human needs.

6. Bibliography

Abood, S. A., Lee, J. S. H., Burivalova, Z., Garcia-Ulloa, J. and Koh, L. P., 2015. Relative contributions of the logging, fiber, oil palm, and mining industries to forest loss in Indonesia. *Conservation Letters*, *8*(1), pp.58-67.

Aduradola, A. M., 2004. Impact of farming activities on vegetation in Olokemeji forest reserve, Nigeria. *Global Nest*, *6*(2), pp.131-140.

Allen, K., Corre, M. D., Tjoa, A. and Veldkamp, E., 2015. Soil nitrogen-cycling responses to conversion of lowland forests to oil palm and rubber plantations in Sumatra, Indonesia. *PloS one*, *10*(7), p.e0133325.

Alvarez-Buylla, E. R., Garcia-Barrios, R., Lara-Moreno, C. and Martínez-Ramos, M., 1996. Demographic and genetic models in conservation biology: applications and perspectives for tropical rain forest tree species. *Annual Review of Ecology and Systematics*, *27*(1), pp.387-421.

Anglaaere, L. C., Cobbina, J., Sinclair, F. L. and McDonald, M. A., 2011. The effect of land use systems on tree diversity: farmer preference and species composition of cocoa-based agroecosystems in Ghana. *Agroforestry systems*, *81*(3), pp.249-265.

Altenhövel, C., 2013. Diversity of vascular epiphytes in lowland rainforest and oil palm plantations in Sumatra, Indonesia.

Asase, A., Ofori-Frimpong, K. and Ekpe, P. K., 2010. Impact of cocoa farming on vegetation in an agricultural landscape in Ghana. *African journal of ecology*, *48*(2), pp.338-346.

Balick, M. J. and Mendelsohn, R., 1992. Assessing the economic value of traditional medicines from tropical rain forests. *Conservation biology*, *6*(1), pp.128-130.

Balslev, H., Valencia, R., Paz y Mino, G., Christensen, H. and Nielsen, I., 1998. Species count of vascular plants in one hectare of humid lowland forest in Amazonian Ecuador. In: Dallmeier, F. & Comiskey, J.A. (eds.) Forest biodiversity in North, Central and South America, and the Caribbean: Research and monitoring. pp. 585–594. UNESCO, Paris, FR.

Barraclough, S. and Ghimire, K., 1990. The social dynamics of deforestation in developing countries: principal issues and research priorities. *Discussion paper/United Nations Research Institute for Social Development.*

Begossi, A., 1996. Use of ecological methods in ethnobotany: diversity indices. *Economic botany*, *50*(3), pp.280-289.

Belcher, B., Imang, N. and Achdiawan, R., 2004. Rattan, rubber, or oil palm: cultural and financial considerations for farmers in Kalimantan. *Economic Botany*, *58*(sp1), pp.S77-S87.

Beukema, H., Danielsen, F., Vincent, G., Hardiwinoto, S. and Van Andel, J., 2007. Plant and bird diversity in rubber agroforests in the lowlands of Sumatra, Indonesia. *Agroforestry Systems*, *70*(3), pp.217-242.

Böhnert, T., Wenzel, A., Altenhövel, C., Beeretz, L., Tjitrosoedirdjo, S. S., Meijide, A., Rembold, K. and Kreft, H., 2016. Effects of land-use change on vascular epiphyte diversity in Sumatra, Indonesia. *Biological Conservation*, *202*, pp.20-29.

Budidarsono, S., Susanti, A. and Zoomers, A., 2013. Oil palm plantations in Indonesia: the implications for migration, settlement/resettlement and local economic development. In *Biofuels-Economy, Environment and Sustainability*. InTech.

Byg, A., Vormisto, J. and Balslev, H., 2007. Influence of diversity and road access on palm extraction at landscape scale in SE Ecuador. *Biodiversity and Conservation*, *16*(3), pp.631-642.

Cardinale, B. J., Matulich, K. L., Hooper, D. U., Byrnes, J. E., Duffy, E., Gamfeldt, L., Balvanera, P., O‟Connor, M. I. and Gonzalez, A., 2011. The functional role of producer diversity in ecosystems. *American journal of botany*, *98*(3), pp.572-592.

Carlson, K. M., Curran, L. M., Asner, G. P., Pittman, A. M., Trigg, S. N. and Adeney, J. M., 2013. Carbon emissions from forest conversion by Kalimantan oil palm plantations. *Nature Climate Change*, *3*(3), pp.283-287.

Chapin Iii, F. S., Zavaleta, E. S., Eviner, V. T., Naylor, R. L., Vitousek, P. M., Reynolds, H. L., Hooper, D. U., Lavorel, S., Sala, O. E., Hobbie, S. E. and Mack, M. C., 2000. Consequences of changing biodiversity. *Nature*, *405*(6783), pp.234-242.

Chittibabu, C. V. and Parthasarathy, N., 2000. Understory plant diversity in a tropical evergreen forest in the Kolli hills, Eastern Ghats, India. *Ecotropica*, *6*(2), pp.129-140.

Colwell, R. K. and Coddington, J. A., 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *345*(1311), pp.101-118.

Corley, R. H. V., and Tinker, P. B., 2003. "The Oil Palm", 4th edn., Blackwell publishing, Oxford.

Daily, G. C., Alex, S., Ehrlich, P. R., Goulder, L., Matson, P. A., Mooney, H. A., Postel, R., Schneider, H., Tilman, D. and Woodwell, G. M., 1997. Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. *Issues in Ecology*, *1*, pp.1–18.

Danielsen, F., 1995. Impact of logging and plantation development on species diversity: a case study from Sumatra. *Management of tropical forests: towards an integrated perspective*, pp.73-92.

De Foresta, H. and Michon, G., 1996. The agroforest alternative to Imperata grasslands: when smallholder agriculture and forestry reach sustainability. *Agroforestry systems*, *36*(1), pp.105-120.

Drescher, J., Rembold, K., Allen, K., Beckschäfer, P., Buchori, D., Clough, Y., Faust, H., Fauzi, A. M., Gunawan, D., Hertel, D. and Irawan, B., 2016. Ecological and socio-economic functions across tropical land use systems after rainforest conversion. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1694), p.20150275.

Ekadinata, A., Widayati, A. and Vincent, G., 2004. Rubber agroforest identification using object-based classification in Bungo District, Jambi, Indonesia. In *25th Asian Conference on Remote Sensing, Chiang Mai, Thailand,* pp.22-26.

Euler, M., Schwarze, S., Siregar, H. and Qaim, M., 2016. Oil palm expansion among smallholder farmers in Sumatra, Indonesia. *Journal of Agricultural Economics*, *67*(3), pp.658-676.

FAO, 2014. „Biodiversity: Plants". Available at: http://www.fao.org/biodiversity/components/plants/en/.

FAO, 2005. Global Forest Resources Assessment. Food and Agricultural Organization of the United Nations, Rome, Italy.

FAO, 2009. How to Feed the World in 2050. Background paper for High Level Expert Forum - How to Feed the World in 2050. Food and Agricultural Organization of the United Nations, Rome, Italy.

FAO, 2015. The Global Forest Resources Assessment 2015: How are the world"s forests changing? Food and Agricultural Organization of the United Nations, Rome, Italy.

Feintrenie, L. and Levang, P., 2009. Sumatra"s rubber agroforests: advent, rise and fall of a sustainable cropping system. *Small-scale Forestry*, *8*(3), pp.323-335.

Feintrenie, L., Chong, W. K. and Levang, P., 2010. Why do farmers prefer oil palm? Lessons learnt from Bungo district, Indonesia. *Small-scale forestry*, *9*(3), pp.379-396.

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brühl, C. A., Donald, P. F. and Phalan, B., 2008. How will oil palm expansion affect biodiversity?. *Trends in ecology and evolution*, *23*(10), pp.538-545.

Flinn, K. M., Vellend, M. and Marks, P. L., 2005. Environmental causes and consequences of forest clearance and agricultural abandonment in central New York, USA. *Journal of Biogeography*, *32*(3), pp.439-452.

FAOSTAT, 2016. FAO online statistical service, Food and Agriculture Organization of the United Nations, Rome, Italy, available at: http://faostat3.fao.org/ (last access: 04.12.2016).

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N. and Foley, J. A., 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences*, *107*(38), pp.16732-16737.

Goldsmith, F. B. ed., 2012. *Tropical rain forest: a wider perspective* ,10. Springer Science & Business Media.

Gotelli, N. J. and Colwell, R. K., 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology letters*, *4*(4), pp.379-391.

Gouyon, A., De Foresta, H. and Levang, P., 1993. Does „jungle rubber" deserve its name? An analysis of rubber agroforestry systems in southeast Sumatra. *Agroforestry systems*, *22*(3), pp.181-206.

Guillaume, T., Holtkamp, A. M., Damris, M., Brümmer, B. and Kuzyakov, Y., 2016. Soil degradation in oil palm and rubber plantations under land resource scarcity. *Agriculture, Ecosystems & Environment*, *232*, pp.110-118.

Gutteridge, R. C. and Shelton, H. M., 1994. The role of forage tree legumes in cropping and grazing systems. *Forage tree legumes in tropical agriculture*, pp.3-11.

Heuserr, M. J. J., 1998. Putting diversity indices into practice. In *Assessment of Biodiversity for Improved Forest Planning,* pp. 171-180.

Heywood, V., 1999. Use and potential of wild plants in farm households. *FAO Farm Systems Management Series 15,* 113p.

Hoekstra, J. M., Boucher, T. M., Ricketts, T. H. and Roberts, C., 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology letters*, *8*(1), pp.23-29.

Joshi, L., Wibawa, G., Akiefnawati, R., Mulyoutami, E., Wulandari, D. and Penot, E., 2006. Diversified rubber agroforestry for smallholder farmers–a better alternative to monoculture. In *Information booklet for Workshop on Rubber Development in Lao PDR: Exploring Improved Systems for Smallholder Production*, pp. 9-11.

Joshi, L., Wibawa, G., Beukema, H., Williams, S. and van Noordwijk, M., 2000. Technological change and biodiversity in the rubber agroecosystem of Sumatra. *Tropical Agroecosystem*, pp.133-155.

Kamatenesi-Mugisha, M. and Oryem-Origa, H., 2005. Traditional herbal remedies used in the management of sexual impotence and erectile dysfunction in western Uganda. *African Health Sciences*, *5*(1), pp.40-49.

Kehlenbeck, K., Asaah, E. and Jamnadass, R., 2013. Diversity of indigenous fruit trees and their contribution to nutrition and livelihoods in sub-Saharan Africa: examples from Kenya and Cameroon. *Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health*, pp.257-269.

Kessler, M., Kebler, P. J., Gradstein, S. R., Bach, K., Schmull, M. and Pitopang, R., 2005. Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. *Biodiversity and conservation*, *14*(3), pp.547-560.

Kew, R. B. G., 2016. The state of the world‟s plants report–2016. Royal Botanic Gardens, Kew.

Koerner, W., Dupouey, J. L., Dambrine, E. and Benoit, M., 1997. Influence of past land use on the vegetation and soils of present day forest in the Vosges mountains, France. *Journal of ecology*, *85(3)*, pp.351-358.

Kotowska, M. M., Leuschner, C., Triadiati, T. and Hertel, D., 2016. Conversion of tropical lowland forest reduces nutrient return through litterfall, and alters nutrient use efficiency and seasonality of net primary production. *Oecologia*, *180*(2), pp.601-618.

Kruskal, W. H. and Wallis, W. A., 1952. Use of ranks in one-criterion variance analysis. *Journal of the American statistical Association*, *47*(260), pp.583-621.

Kurniawan, S., 2016. Conversion of lowland forests to rubber and oil palm plantations changes nutrient leaching and nutrient retention efficiency in highly weathered soils of Sumatra, Indonesia.

Lambin, E. F. and Meyfroidt, P., 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*, *108*(9), pp.3465-3472.

Laumonier, Y., Uryu, Y., Stüwe, M., Budiman, A., Setiabudi, B. and Hadian, O., 2010. Eco-floristic sectors and deforestation threats in Sumatra: identifying new conservation area network priorities for ecosystem-based land use planning. *Biodiversity and Conservation*, *19*(4), pp.1153-1174.

Laurance, W. F., Sayer, J. and Cassman, K. G., 2014. Agricultural expansion and its impacts on tropical nature. *Trends in ecology & evolution*, *29*(2), pp.107-116.

Magurran, A., 2004. *Measuring Biological Diversity* (2nd edn), Blackwell, Oxford.

Magurran, A. E., 1988. *Ecological diversity and its measurement*, Princeton University Press/Croom Helm, London

Margono, B. A., Turubanova, S., Zhuravleva, I., Potapov, P., Tyukavina, A., Baccini, A., Goetz, S. and Hansen, M. C., 2012. Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. *Environmental Research Letters*, *7*(3), pp.34010-34025.

Michon, G., 2005. *Domesticating forests: how farmers manage forest resources*. IRD, CIFOR and ICRAF, Bogor, Indonesia.

Myers, N., 1988. Tropical forests: much more than stocks of wood. *Journal of Tropical Ecology*, *4*(2), pp.209-221.

Obidzinski, K., Andriani, R., Komarudin, H. and Andrianto, A., 2012. Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia. *Ecology and Society*, *17*(1).

Pejchar, L. and Mooney, H. A., 2009. Invasive species, ecosystem services and human well-being. *Trends in ecology & evolution*, *24*(9), pp.497-504.

Penot, E., 2004. From shifting agriculture to sustainable rubber agroforestry systems (jungle rubber) in Indonesia: a history of innovations processes.

Pye-Smith, C., 2011. *Rich Rewards for Rubber?: Research in Indonesia is Exploring how Smallholders Can Increase Rubber Production, Retain Biodiversity and Provide Environmental Benifts*. World Agroforestry Centre.

Pyšek, P., Jarošík, V., Hulme, P. E., Pergl, J., Hejda, M., Schaffner, U. and Vilà, M., 2012. A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. *Global Change Biology*, *18*(5), pp.1725-1737.

Rademaekers, K., Eichler, L., Berg, J., Obersteiner, M. and Havlik, P., 2010. Study on the evolution of some deforestation drivers and their potential impacts on the costs of an avoiding deforestation scheme. *Prepared for the European Commission by ECORYS and IIASA*. Rotterdam, Netherlands.

Rembold, K., Mangopo, H., Tjitrosoedirdjo, S. S. and Kreft, H., 2017. Plant diversity, forest dependency, and alien plant invasions in tropical agricultural landscapes. *Biological Conservation*, *213*, pp.234-242.

Richardson, R. B., 2010. „on Environmental Sustainability‟, pp. 3520–3548. doi: 10.3390/su2 113520.

Rist, L., Feintrenie, L. and Levang, P., 2010. The livelihood impacts of oil palm: smallholders in Indonesia. *Biodiversity and conservation*, *19*(4), pp.1009-1024.

Salick, J., Biun, A., Martin, G., Apin, L. and Beaman, R., 1999. Whence useful plants? A direct relationship between biodiversity and useful plants among the Dusun of Mt. Kinabalu. *Biodiversity and Conservation*, *8*(6), pp.797-818.

Seymour, F., Heist, M. Van, Azevedo, T., Hill, D., Berggrav, K., Pravettoni, R., Gauthier, M., Gilbert, S., Guzmán-gallegos, M., Lahn, B., Nellemann, C., Jørstad, H., Knagenhjelm, J., Olsen, V., Løvold, L., Ranum, H., Hofsvang, E., Steineger, E., Stave, S. E. and Odegard, J. T., 2014. „State of the rainforest 2014‟.

Shapiro, S. S. and Wilk, M. B., 1965. An analysis of variance test for normality (complete samples). *Biometrika*, *52*(3/4), pp.591-611.

Shekhar Badu, C., Meijide, A., Gunawan, D. and Knohl, A., 2017, April. Comparison of microclimate in various land-use systems in Sumatra, Indonesia. In *EGU General Assembly Conference Abstracts, 19*, 19375p.

Segnon, A. C. and Achigan-Dako, E. G., 2014. Comparative analysis of diversity and utilization of edible plants in arid and semi-arid areas in Benin. *Journal of ethnobiology and ethnomedicine*, *10*(1), 80p.

Sheil, D. and Salim, A., 2012. Diversity of locally useful tropical forest wild-plants as a function of species richness and informant culture. *Biodiversity and Conservation*, *21*(3), pp.687-699.

Sheil, D., Puri, R., Wan, M., Basuki, I., Heist, M.V., Liswanti, N., Rachmatika, I. and Samsoedin, I., 2006. Recognizing local people's priorities for tropical forest biodiversity. *AMBIO: A Journal of the Human Environment*, *35*(1), pp.17-24.

Simpson, E. H,. 1949. Measurement of diversity. *Nature*, *163*, 688p.

Snelder, D. J., Klein, M. and Schuren, S. H. G., 2007. Farmers preferences, uncertainties and opportunities in fruit-tree cultivation in Northeast Luzon. *Agroforestry Systems*, *71*(1), pp.1-17.

Sodhi, N. S., Koh, L. P., Brook, B. W. and Ng, P. K., 2004. Southeast Asian biodiversity: an impending disaster. *Trends in Ecology & Evolution*, *19*(12), pp.654-660.

Statistik, B. P., 2014. Jambi Dalam Angka 2014. Jambi, Indonesia.

Stirling, G. and Wilsey, B., 2001. Empirical relationships between species richness, evenness, and proportional diversity. *The American Naturalist*, *158*(3), pp.286-299.

Tabuti, J. R. S., Dhillion, S. S. and Lye, K. A., 2003. Traditional medicine in Bulamogi county, Uganda: its practitioners, users and viability. *Journal of Ethnopharmacology*, *85*(1), pp.119-129.

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W. H., Simberloff, D. and Swackhamer, D., 2001. Forecasting agriculturally driven global environmental change. *Science*, *292*(5515), pp.281-284.

Turner, I. M., 2001. *The ecology of trees in the tropical rain forest*. Cambridge University Press.

Villamor, G.B., Le, Q. B., Djanibekov, U., van Noordwijk, M. and Vlek, P. L., 2014. Biodiversity in rubber agroforests, carbon emissions, and rural livelihoods: an agent-based model of land-use dynamics in lowland Sumatra. *Environmental Modelling and Software*, *61*, pp.151-165.

Wenzel, A., 2015. Diversity of vascular epiphytes in lowland rainforests and jungle rubber agroforestry systems in Sumatra, Indonesia.

Whitmore, T. C., 1998. *An introduction to tropical rain forests*. Second edition. Oxford University Press, Oxford.

Whitemore, T. C. and and Burhnam, C. P., 1984. *Tropical rain forests of the Par East.* Second edition. Oxford University Press, Oxford.

Wibawa, G., Hendratno, S. and van Noordwijk, M., 2005. Permanent smallholder rubber agroforestry systems in Sumatra, Indonesia. *Slash-and-burn agriculture: the search for alternatives*, pp.222-231.

Yaap, B., Struebig, M. J., Paoli, G. and Koh, L. P., 2010. Mitigating the biodiversity impacts of oil palm development. *CAB Reviews*, *5*(19), pp.1-11.

7. Appendix

Appendix 1: Results of simple linear regression models between useful plant species richness and total species richness in different land uses

Land-use systems	F	P	R^2	Adjusted R^2
Forest	23.583	0.003	0.797	0.763
Jungle	75.963	0.000	0.927	0.915
Rubber	397.396	0.000	0.985	0.983
Oil palm	156.495	0.000	0.963	0.957

Appendix 2: Results of simple linear regression models between useful plant individual number and total individual number in different land uses

Land-use systems	F	P	R^2	Adjusted R^2
Forest	8.586	0.026	0.589	0.520
Jungle	226.150	0.000	0.974	0.970
Rubber	321.243	0.000	0.982	0.979
Oil palm	27.059	0.002	0.819	0.788

Appendix 3: Results of simple linear regression model between useful plant species richness and total plant species richness

	Useful plant species richness			
	F	P	R^2	Adjusted R^2
Total plant species richness	879.806	0.000	0.967	0.966

Appendix 4: Results of simple linear regression models between useful plant individual number and total plants individual number

	Useful plant individual number			
	F	P	R^2	Adjusted R^2
Total plants individual number	437.142	0.000	0.936	0.934

Appendix 5: Number of plant species in each category and their intersection (species overlapped) to other categories. These useful categories are color (Col), erosion control (Ero), fibre (Fib), fodder (fod), food (Foo), fuelwood (Fue), handicraft (Han), magic (Mag), medicine (Med), nutrient enrichment (Nut), ornamental (Orn), poison (Poi), rubber (Rub) and timber (Tim).

Categories	Col	Ero	Fib	Fod	Foo	Fue	Han	Mag	Med	Nut	Orn	Poi	Rub	Tim
Col	74	5	10	2	45	19	4	4	57	5	16	11	4	52
Ero	5	24	7	10	11	4	4	3	16	8	6	4	1	11
Fib	10	7	77	4	31	8	17	7	47	4	16	7	5	28
Fod	2	10	4	27	13	1	1	1	15	5	4	1	0	6
Foo	45	11	31	13	292	40	12	8	187	10	49	31	16	161
Fue	19	4	8	1	40	128	7	4	54	4	4	6	5	121
Han	4	4	17	1	12	7	49	3	19	2	9	2	1	35
Mag	4	3	7	1	8	4	3	19	12	0	3	3	1	13
Med	57	16	47	15	187	54	19	12	394	12	62	51	12	155
Nut	5	8	4	5	10	4	2	0	12	16	5	3	1	8
Orn	16	6		4	49	4	9	3	62	5	82	13	2	45
Poi	11	4	7	1	31	6	2	3	51	3	13	69	3	34
Rub	4	1	5	0	16	5	1	1	12	1	2	3	24	11
Tim	52	11	28	6	161	121	35	13	155	8	45	34	11	449

Appendix 6: References lists used for identification of useful value of plant species

Blundell, A. G., 2007. Implementing CITES regulations for timber. *Ecological Applications*, *17*(2), pp.323-330.

Boer, E. and Ella, A. B. (Editors), 2001. Plant Resources of South-East Asia No 18. Plants producing exudates. Prosea, Bogor, Indonesia. 189 pp.

Brink, M. and Escobin, R. P. (Editors), 2003. Plant Resources of South-East Asia No 17. Fibre plants. Prosea Foundation, Bogor, Indonesia. 456 pp.

Chandrashekara, U. and Thasini, V., 2016. Non-Crop Edible Plants and Medicinal Plants in Homegarden Agroforestry System of Palakkad District, Kerala. *International Journal of Ecology and Environmental Sciences*, *42*(2), pp.183-191.

Chopra, R. N., Nayar, S. L., Chopra, I. C., 1956. Glossary of Indian Medicinal Plants. Council of Scientific and Industrial Research, New Delhi. pp.72–99.

Cortes, D., Torrero, M. Y., Pilar, D. O. M., Luz, C. M., Cavé, A. and Hadi, A. H., 1989. Norstephalagine and atherospermidine: two smooth muscle relaxant aporphines from Artabotrys maingayi. *Journal of natural products*, *53*(2), pp.503-508.

Dash, S. K. and Padhy, S., 2006. Review on ethnomedicines for diarrhoea diseases from Orissa: prevalence versus culture. *J Hum Ecol*, *20*(1), pp.59-64.

de Guzman, C. C. and and Siemonsma, J. S.(Editors), 1999. Plant Resources of South-East Asia No 13. Spices. Backhuys Publishers, Leiden, the Netherlands. 400 pp.

de Padua, L. S., Bunyapraphatsara, N. and Lemmens, R. H. M. J (Editors), 1999. Plant Resources of South-East Asia No 12(1). Medicinal and Poisonous plants 1. Prosea foundation, Bogor, Indonesia. 711 pp.

de Winter, W. P. and Amoroso, V. B. (Editors), 2003. Plant Resources of South-East Asia No 15(2). Cryptogams: Ferns and fern allies. Prosea foundation, Bogor, Indonesia. 268 pp.

Dransfield, J. and Manokaran, N. (editors), 1994. Plant Resources of South-East Asia No 6. Rattans. Prosea Foundation, Bogor, Indonesia. 137 pp.

Faridah Hanum, I. and van der Maesen, L. J. G. (Editors), 1997. Plant Resources of South-East Asia No 11. Auxiliary plants. Backhuys Publishers, Leiden, the Netherlands. 389 pp.

Flach, M. and Rumawas, F. (Editors), 1996. Plant Resources of South-East Asia No 9. Plants yielding non-seed carbohydrates. Prosea Foundation,Bogor,Indonesia. 237 pp.

Gan, M., Zhang, Y., Lin, S., Liu, M., Song, W., Zi, J., Yang, Y., Fan, X., Shi, J., Hu, J. and Sun, J., 2008. Glycosides from the root of Iodes cirrhosa. *Journal of natural products*, *71*(4), pp.647-654.

GOI, nd. Government of India. Ministry of Environment and Forest & Climate Change. Botanical Survey of India retrived from http://efloraindia.nic.in/efloraindia/taxonList.action?i d=573&type=4

Guidebook, M. and Part, S. A., (no date). „Group E : Vines & Climbers", *Young*, pp. 433–490.

Hamid, A., 1999. *Derris* Lour.[Internet] Record from Proseabase. de Padua, L.S., Bunyapraphatsara, N. and Lemmens, R.H.M.J. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia. http://www.proseanet.org. Accessed from Internet: 30-Apr-2017

Hiern, W. P., 1873. *A monograph of Ebenaceae*. University Press.

Indonesia, P. E., 1995. Medicinal herb index in Indonesia. Jakarta-Indonesia.

Irwanto, R. R. P., 2001. *Polygala paniculata* L. [Internet] Record from Proseabase. van Valkenburg, J.L.C.H. and Bunyapraphatsara, N. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia. http://www.proseanet.org. Accessed from Internet: 22-Apr-2017.

Kusuma, I. W., Arung, E. T. and Kim, Y. U., 2014. Antimicrobial and antioxidant properties of medicinal plants used by the Bentian tribe from Indonesia. *Food Science and Human Wellness*, *3*(3), pp.191-196.

Lemmens, R. H. M. J. and Bunyapraphatsara, N. (Editors), 2003. Plant Resources of South-East Asia No. 12(3). Medicinal and poisonous plants 3. Prosea foundation, Bogor, Indonesia. 664pp.

Lemmens, R. H. M. J. and Wulijarni-Soetjipto, N. (Editors), 1992. Plant Resources of South-East Asia No 3. Dye and tannin-producing plants. Prosea foundation, Bogor, Indonesia. 195pp.

Lemmens, R. H. M. J., Soerianegara, I. and Wong, W. C. (Editors), 1995. Plant Resources of South-East Asia No. 5(2). Timber trees: Minor commercial timbers. Prosea foundation, Bogor, Indonesia. 655 pp.

Mamidala, E. and Gujjeti, R. P., 2013. Phytochemical and antimicrobial activity of Acmella paniculata plant extracts. *J. Bio Innov*, *1*, pp.17-22.

Maneenoon, K., Sirirugsa, P. and Sridith, K., 2008. Ethnobotany of Dioscorea L.(Dioscoreaceae), a major food plant of the Sakai tribe at Banthad Range, Peninsular Thailand. *Ethnobotany Research and Applications*, *6*, pp.385-394.

Mannetje, L. 't. and *Jones, R. M., 1992. Plant resources of South-East Asia No 4. Forage.* Prosea foundation, Bogor, Indonesia. 300 pp.

Mariani, R., Sukandar, E. Y. and Suganda, A. G., 2014. Antimicrobial activity from Indonesian urticaceae. *International Journal of Pharmacy and Pharmaceutical Sciences*, *6*(4), pp.191-193.

Mendonça, R. J., Maurício, V. B., de Bortolli Teixeira, L., Lachat, J. J. and Coutinho-Netto, J., 2010. Increased vascular permeability, angiogenesis and wound healing induced by the serum of natural latex of the rubber tree Hevea brasiliensis. *Phytotherapy Research*, *24*(5), pp.764-768.

Panda, S. K., Mohanta, Y. K., Padhi, L., Park, Y. H., Mohanta, T. K. and Bae, H., 2016. Large scale screening of ethnomedicinal plants for identification of potential antibacterial compounds. *Molecules*, *21*(3), p.293.

Priyadi, H., Takao, G., Rahmawati, I., Supriyanto, B., Nursal, W. I. and Rahman, I., 2010. *Five Hundred Plant Species in Gunung Halimun Salak National Park, West Java: A Checklist Including Sundanese Names, Distribution, and Use*. CIFOR.

Rahadiantoro, A. and Danarto, S. A. 2015. „Potential Uses of Plant in Waru-waru and Teluk Semut Subregion , Sempu Island", pp.42–46.

Rizwana, J. N., Nazlina, I., Razehar, A. M., Noraziah, A. S., Ling, C. Y., Muzaimah, S. S., Farina, A. H., Yaacob, W. A., Ahmad, I. B. and Din, L. B., 2010. A survey on phytochemical and bioactivity of plant extracts from Malaysian forest reserves. *Journal of Medicinal Plants Research*, *4*(3), pp.203-210.

Setyawan, A. D. W. I. 2009. „Traditionaly utilization of Selaginella; field survey and literature review", *Nusantara Bioscience, 1*(3), pp.146–158. doi: 10.13057/nusbiosci/n010307.

Shrisha, D. L. and An, K., 2011. Bioprospecting of selected medicinal plants for antibacterial activity against some pathogenic bacteria. *Journal of medicinal plants research*, *5*(17), pp.4087-4093.

Siemonsma, J. S. and Piluek, K. (Editors), 1994. Plant Resources of South-East Asia No 8. Vegetables. Prosea, Bogor, Indonesia. 412 pp. Soepadmo, E., Wong, K. M. and Saw, L. G. 2002. *Tree Flora of Sabah and Sarawak*. doi: 10.1017/CBO9781107415324.004.

Soerianegara and Lemmens, R.H.M.J. (Editors), 1994. Plant Resources of South-East Asia No 5(1). Timber trees: Major commercial timbers. Prosea, Bogor, Indonesia. 610pp.

Sosef, M. S. M. and van der Maesen, L. J. G., 1997. *Rhynchospora corymbosa* (L.) Britton[Internet] Record from Proseabase. Faridah Hanum, I & van der Maesen, L.J.G. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia. http://www.proseanet.org. Accessed from Internet: 22-Apr-2017

Sosef, M. S. M., Hong, L. T. and Prawirohatmodji, S. (Editors), 1998. Plant Resources of South-East Asia No. 5(3). Timber trees: Lesser-known timbers. Prosea foundation, Bogor, Indonesia. 859 pp.

Subedi, A., Kunwar, B., Choi, Y., Dai, Y., van Andel, T., Chaudhary, R. P., de Boer, H. J. and Gravendeel, B., 2013. Collection and trade of wild-harvested orchids in Nepal. *Journal of ethnobiology and ethnomedicine*, *9*(1), p.64.

Sulvi, P., Umar, S. and Murdijati, G., 2013. Umami potential from crude extract of Bekkai lan (Albertisia papuana Becc.) leaves, an indegenous plant in East Kalimantan-Indonesia. *International Food Research Journal*, *20*(2).

Tanzin, R., Rahman, S., Hossain, M. S., Agarwala, B., Khatun, Z., Jahan, S., Rahman, M. M., Mou, S. M. and Rahmatullah, M., 2013. Medicinal potential of pteridophytes--an antihyperglycemic and antinociceptive activity evaluation of methanolic extract of whole plants of Christella dentata. *Advances in Natural and Applied Sciences*, *7*(1), pp.67-74.

Useful tropical plants database 2017. available at http://tropical.theferns.info/

van der Vossen, H. A. M. and Umali, B. E. (Editors), 2002. Plant Resources of South-East Asia No 14. Vegetables oils and fats. Prosea Foundation,Bogor,Indonesia. 229pp.

van der Vossen, H. A. M. and Wessel, M. (Editors), 2000. Plant Resources of South-East Asia No 16. Stimulants. Backhuys Publishers, Leiden, the Netherlands. 201pp.

van Valkenburg, J. L. C. H. & Bunyapraphatsara, N., 2001. *Clerodendrum* L.[Internet] Record from Proseabase. van Valkenburg, J. L. C. H. and Bunyapraphatsara, N. (Editors). PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia. http://www.proseanet.org. Accessed from Internet: 29-Apr-2017

van Valkenburg, J. L. C. H and Bunyapraphatsara, N. (Editors), 2002. Plant Resources of South-East Asia No. 12(2). Medicinal and Poisonous plants 2. Prosea foundation, Bogor, Indonesia. 782 pp.

Verheij, E. W. M and Coronel, R. E. (Editors), 1992. Plant Resources of South-East Asia No. 2. Edible fruits and nuts. Prosea foundation, Bogor, Indonesia. 446 pp.

Von Reis, S. and Lipp, F. J., 1982. *New plant sources for drugs and foods from the New York Botanical Garden Herbarium*. Harvard University Press.

Websites

http://efloraindia.nic.in/efloraindia/taxonList.action?id=3794&type=4
https://florafaunaweb.nparks.gov.sg/special-pages/plant-detail.aspx?id= 3742
http://lkcnhm.nus.edu.sg/dna/organisms/details/616
http://www.asianplant.net/Anacardiaceae/Drimycarpus_luridus.htm
http://www.asianplant.net/Ebenaceae/Diospyros_borneensis.htm
http://www.asianplant.net/Euphorbiaceae/Hancea_penangensis.htm
http://www.asianplant.net/Melastomataceae/Pternandra_coerulescens.htm

8. Statement of declaration

I hereby declare that this thesis entitled „Effect of land-use change on the diversity of useful plants in Sumatra (Indonesia)" has been completed as the result of my own work and investigations, except where otherwise stated. This work has not been submitted before to any other university for any kind of degree.

Signed: ……………….. (Kamal Raj Aryal)

Date: 13 September