Effects of land-use change on ecological plant traits and strategies in Sumatra (Indonesia)

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Auswirkungen von Landnutzungsänderungen auf baumökologische Merkmale und Strategien in Sumatra (Indonesien)

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Statement of declaration

I hereby declare that this thesis entitled **“Effects of land-use change on ecological plant traits and strategies 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.

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Date Thakur Prasad Magrati

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Summary

Land-use change imposes the strong impact on plant-animal interactions which in turn have important implications for evaluating plant functional groups and their functional traits. The plant functional traits characteristics and their ecological roles are the most important to determine the ecological restoration, productivity, stability and the underlying mechanisms for ecosystem functioning.

In this study, a total of 156,006 individual plants and ecological traits of 992 plants species were recorded from four different land-use systems in Sumatra (Indonesia). We used a dataset of plot based plant species richness, composition and abundance data collected during a previous vegetation survey. By carrying out a comprehensive literature survey, ecological traits were assigned to each species as far as possible. Based on species distribution and their ecological traits, we calculated the trait proportion, functional composition and functional diversity of plants across four land-use systems. We observed the effects of land-use changes on each traits in species and individual's plant level, their variability and functional diversity using statistical tools such as Pearson’s chi-squared test, ANOVA, Kruskal-Wallis rank sum test, Tukey’s HSD and post-hoc multiple comparison to detect the effects and relationships. We also observed the similarities and dissimilarities of traits using NMDS ordination based dissimilarity of traits. I further analyzed the relationships between functional diversity and taxonomic diversity.

Overall, the ecological plant traits and their functional composition are larger in proportions in forest and jungle rubber than in monoculture plantations. Land-use has a significant effect on ecological plant trait's abundance and their functional composition. The pollinators such as insects (bee, beetle, fly and moth), bat, bird and wind have considerable influence in all land-use systems. The insects such as bee and beetle found considerably dominant than fly and moth across four land-use systems. Bat and bird pollination also found dominant however; wind pollination was higher in monoculture plantations as compared to the other systems. At both species and individual level, all land systems were dominated by animal-dispersed plants. The forest and jungle rubber have more heterogeneous ecological plant traits than monoculture plantations. Land-use change also has a significant effect on functional and taxonomic diversity. To conclude, the conversion of forest to agroforests and rubber plantations have significantly altered the impacts of pollinators and dispersers from diverse system to monoculture plantations and also varied the functional roles of diverse community.

The monoculture plantations were susceptible to decline the functional diversity for ecosystem functioning.

Zusammenfassung

Landnutzungsänderungen haben einen starken Einfluss auf Pflanze-Tier-Interaktionen, welche wiederum wichtige Auswirkungen bei der Evaluation von pflanzlichen funktionellen Gruppen und ihrer Eigenschaften haben. Die funktionellen Merkmale von Pflanzen sowie ihre ökologischen Funktionen sind sehr wichtig, um ökologische Restauration, Produktivität, Stabilität sowie deren zugrundeliegenden Mechanismen zu ermitteln.

In der vorliegenden Studie wurden 156.006 pflanzliche Individuen sowie die ökologischen Merkmale von 992 Pflanzenarten aus vier unterschiedlichen Landnutzungssystemen in Sumatra (Indonesien) erfasst. Wir verwendeten einen Datensatz, der pflanzliche Artenvielfalt, Artenzusammensetzung und deren Häufigkeit auf Plot-Level umfasste. Die Daten waren im Rahmen einer früheren Studie erhoben worden. Durch umfassende Literaturrecherchen wurden Pflanzen soweit wie möglich ökologische Merkmale zugeordnet. Auf Grundlage Verbreitung und Ausprägung ökologischer Merkmale der Arten berechneten wir das Merkmalsverhältnis, die funktionelle Zusammensetzung und die funktionale Diversität von Planzen in vier Landnutzungssystemen. Wir beobachteten die Auswirkungen von Landnutzungsveränderungen auf jedes Merkmal auf Arten- und Individuen-Ebene, ihre Variabilität und funktionelle Diversität, indem wir statistische Tests wie beispielsweise Pearson’s Chi-Quadrat-Test, ANOVA, Kruskal-Wallis Rangsummentest, Tukey’s HSD und Post-hoc-Mehrfachvergleichstest anwendeten, um Auswirkungen und Beziehungen zu ermitteln. Außerdem beobachteten wir die Ähnlichkeiten und Unterschiede zwischen Merkmalen mit Hilfe von NMDS-Ordinierung, die auf Unterschieden zwischen Merkmalen beruht. Zudem analysierte ich die Beziehungen zwischen funktioneller und taxonomischer Diversität.

Insgesamt sind die pflanzlichen Merkmale und die funktionelle Zusammensetzung von Merkmalen höher im Wald und in Kautschuk-Agroforstsystemen als in Monokultur-Plantagen. Landnutzung hat signifikante Auswirkungen auf Merkmalsabundanz und deren funktionelle Zusammensetzung. Bestäuber wie beispielsweise Insekten (Bienen, Käfer, Fliegen und Motten), Fledermäuse, Vögel und Wind haben einen erheblichen Einfluss in allen Landnnutzungssystemen. Insekten wie Bienen und Käfer waren in den verschiedenen Landnutzungssystemen dominant gegenüber Fliegen und Motten. Bestäubungen durch

Fledermäuse und Vögel waren ebenfalls dominant, während Windbestäubung in Monokultur-Plantagen höher war als in den anderen Systemen. Zudem wurden alle Landnutzungssysteme, sowohl auf Arten- als auch Individuen-Ebene, von Pflanzen dominiert, die von Tieren verbreitet werden. Andererseits weisen Wald und Kautschuk-Agroforstsystemen heterogenere ökologische Pflanzenmerkmale auf als Monokulturen. Landnutzungs-veränderungen haben ebenfalls einen signifikanten Einfluss auf funktionelle und taxonomische Diversität. Zusammenfassend hat die Koversion von Wald zu Agroforst-systemen und Kautschukplantagen die Auswirkungen auf Bestäuber und Verbreiter und ihrer Funktionen in Gemeinschaften von diversen Systemen zu Monokultur-Plantagen signifikant verändert. Die Monokultur-Plantagen waren anfällig gegenüber dem Zurückgang von funktioneller Diversität für die Funktion von Ökosystemen.

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1. Introduction

1.1. The EFForTS-Project

This thesis was carried out in collaboration with the DFG funded Collaborative Research Center 990 (CRC 990), entitled "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems" (EFForTS) in Sumatra, Indonesia (Drescher et al. 2016) EFForTS is a long term interdisciplinary research project deals on both ecological and socio-economic dimensions of rainforest conversion to three different agricultural land-use system (rubber plantation, oil palm plantation, jungle rubber agroforests) in Jambi province (Faust, et al. 2013). This long-term research project has focused to alleviate in-depth understanding of the root causes and consequences of rainforest transformation into agricultural systems for biodiversity, ecosystem functions as well as human well-being. EFForTS combines on three major lines of research: (i) environmental processes, (ii) biota and ecosystem services, and (iii) human dimensions.

The project area in Jambi province of central Sumatra, plots were established in two lowland rainforests (Harapan and Bukit) for forest (Drescher et al. 2016). A core plot was designed to collect data for environmental processes, biota and ecosystem services while data on human dimensions were collected in the socio-economic survey design. In 2012, 8 core plots per system were established. Each core plot measures 50 × 50 m and contains 5 × 5 m subplots at fixed positions assigned randomly in each of the four land-use systems (lowland rainforest, jungle rubber, rubber monoculture and oil palm monoculture), resulting in a total of 32 plots in the project area.

The EFForTS is a collaborative research project involving in 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 German Research Foundation (DFG) manages the financial support in the framework of the Collaborative Research Centre 990. (For more details about the EFForTS project see Drescher *et al*., 2016).

1.2. Tropical (lowland) rainforest and biodiversity in Indonesia

The global tropical rainforests are the richest and the vast assemblage of terrestrial vegetation on the earth (Couvreur, Forest, and Baker 2011) and characterized as the home of diverse plants and animals life. Tropical rainforests have been playing crucial role as an exclusive reservoir for biodiversity conservation and tropical ecosystem restoration (Sodhi et al. 2004). They are considered as the most valuable forest for mitigating greenhouse gas emissions, carbon cycle as well as supporting the livelihood of forest dependent communities (Knagenhjelm 2014) and harbor approximately 80% of the documented species investigated in the world, even though they occupy only 6% land surface area of the earth (WWF 2011). The global environment and widespread use of biochemical have been extensively changed by the human beings and the transformation of natural resources encouraging towards the loss of biological diversity (Chapin et al. 2000; Turner 2007). The rapid agricultural expansion and land use changes in the tropical rainforest biome is ultimately triggering the deforestation and forest degradation due to high population growth and their increased demands of agricultural products (Tilman et al. 2001). Because of the intensification of agricultural land, deforestation and forest degradation and intensive logging posing a deleterious effects on the composition of forest communities and often at the expense of degrading environmental conditions (Foley et al. 2005; Gibbs et al. 2010; Sala et al. 2000). Furthermore, tropical rainforest is the major evidence of evolutionary and ancient ecosystem with privileged organisms. According to the Gibbs et al (2011), more than 55 % of primary forest and 28% of human influenced forest in tropical region have deforested for agricultural farming during the period of 1980 and 2000 (2010). FAO (2009) has predicted that 70% of increasing food demand is necessary to address the climbing trend of population by 2050. Therefore, it is highly fragile and sensitive to human disturbances (Laurance 2015). The main factors of threatening tropical rainforest are the deforestation and forest degradation due to clearance for agricultural land use, logging, mining and industrial development that are causing the serious loss of 13 million hectares per year globally (FAO 2005).

Southeast Asia covers 35% (294.4 million hectares) of the global land area (FAO 2010) and it harbors four of the Earth’s 34 biodiversity hotspots with the integration of species complexes (de Bruyn et al. 2014) however, it is experiencing an undisputed threat due to intensive felling and clearing of forest for agricultural farming (Wilcove et al. 2013). Deforestation is being key problem of losing forest at a faster pace than other sector of natural resources in the world and it 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). There are three main parts of the tropical rainforest occupancy i.e. the American rainforest, African rainforest and the Indo-Malayan rainforest. Indonesia is the important block of Indo-Malayan rainforest (Knagenhjelm 2014) and it accounts the third largest tropical rain forest rich country in the world (FAO 2015). According to Global Forest Resource Assessment 2015, the forest covers about 91 million hectares which encompasses approximately 51% primary forest, 5% plantation for timber production forest and remaining 44% forests are naturally grown (FAO 2015). Likewise, primary forest declined at a rate of 0.5% per year within five years period (2010 to 2015) and deforested at a rate of 1.1% per year during the period from 1990 to 2015 so that it can be summarized that Indonesia lost about 27.5 million hectares of forest coverage within the period of 1990 to 2015 (FAO 2015). Moreover, Indonesia encompasses the most diverse landscape comprising the dense tropical rainforest to undulated mountain tops and valleys with rich biodiversity and harbors the most diversified plants and endemic wildlife species in the world (UNESCO 2018). The country has been experiencing the richest biodiversity and the topmost biodiversity hotspot (Myers et al. 2000). Land use change is excessive in Indonesia and leading towards the highest deforestation in the world which losses 2 million ha yr^{-1}(Hansen 2013). Deforestation in Indonesia is proliferating due to the broad coverage of palm and rubber plants cultivation which exports the large amount of palm oil and rubber in different countries in the world (Koh, Wilcove, and Koh 2002).

Similarly, Sumatra region, Indonesia alone already lost the forest cover in an estimated rate of 550 000 hectares per annum with in the period between 1990 to 2007 (Laumonier et al. 2010). On the other hand, land use changes are the most starring drivers of global climate change and emerged as a key component of environmental change (Turner 2007). The changes of land to forests, agricultural lands, pasture lands, waterways, plantations and urban areas and they have extended in recent decades and have posed the significant losses of biological diversity due to alteration of resources, fragmentation of habitats, soil and water degradation as well as severe exploitation of resources (Foley et al. 2005).

According to Sodhi et al (2004), the high rate of deforestation causing the loss of biodiversity by 42% of any tropical forests area. It shows that huge loss of rainforest causing the devastating effect on biodiversity, regulating ecosystem function, sustainability of land use and the economy of the rural people (Chapin et al. 2000). Indonesian tropical rainforests have been providing the suitable habitat for vast number of endemic vegetation i.e. nearly 60% of total vascular plants which have significant role on conservation of biological diversity (Sodhi et al.

2004). Besides this, Biodiversity networks have inter-connected with the important values of human societies as the characteristics of ecosystem i.e. cultural, intellectual, aesthetic and spiritual values (Chapin et al. 2000; Sala et al. 2000). In addition, alteration of biodiversity has significant impacts on changing the ecosystem functioning which ultimately affects the economy of communities through the provision of ecosystem goods and services (Diaz and Cabido 2009; Chapin et al. 2000). And some human communities such as small land holders or customary land users are highly affected due to the block of rainforest conversion which forced to look at the new professions due to decreased forest resources or move away for their livelihood (Andrianto 2012).

1.3. Land-use change in Sumatra, Indonesia

The land use change is the major cause of lowland rain forest decline in Sumatra (Böhnert et al. 2016). It is an issue of Sumatra but it is a cumulative force of global importance. There are some key drivers of changes such as human-driven changes have unprecedented effects on structural and functional ecosystems of the earth (Turner 2007). Globally, agricultural expansion has been playing collective role on deforestation in tropical region (FAO 2015). In addition, the expansion of monoculture plantations for palm oil and rubber in forest land causing serious threats of deforestation of Sumatra's Island for 2.9 million hectares between 2000 and 2012 (Margono et al. 2014). The large scale logging, jungle rubber agroforests and *Acacia* spp. plantations for pulp production increased the conversion of lowland forest between 1970 and 2000 (Beukema et al. 2007). Similarly, the conflicting economic interests and increased needs of food and resources are encouraging conversion of lowland forest to cultivate oil palm and other cash crops (Foster et al. 2011; Savilaakso et al. 2014). And the recent investigations and research have found that oil palm plantations have displaced the valuable tropical rainforests and degraded to rapid losses of species diversity, density and plant biomass (Foster et al. 2011; Drescher et al. 2016) and ultimately sobering threat to ecosystem functioning (Laumonier et al. 2010).

1.3.1. Agricultural land-use systems

In Sumatra, the human modification of tropical forests has crossed over centuries (Feintrenie and Levang 2009). But forest modification began during the early 1900's, when the rubber *(Hevea brasiliensis)* seed was introduced and practiced intercropping within the native forest (Gouyon, Foresta, and Levang 1993). The demand of food, timber, fuel, bio-fuel speeded up the conversion of forest land to agricultural land (Gibbs et al. 2010; Lambin and Meyfroidt

2011). These practices are intensively cultivated to enhance the incomes of smallholders in Sumatra, Indonesia (Euler et al. 2017; Andrianto 2012). According to FAO, the major cause of deforestation in the tropics of Sumatra is agricultural intensification (2015). The farmers are highly motivated for the oil palm plantation in the agricultural land because of good knowledge, easy access to infrastructure and experience in farming and processing of oil palm plantation (Euler et al. 2017).

1.3.2. Jungle rubber agroforest system

The conversion of tropical forest into jungle rubber agroforest systems has been started in Sumatra at the beginning of the 20th century and initially cultivated in private estates in the form of monoculture and rubber trees were planted intermixed with natural vegetation (Penot 2004). This form of agroforest system is alike to the secondary or human influenced forest where wild plant species intercropped with rubber trees (Beukema et al. 2007). According to Feintrenie and Levang (2009), jungle rubber species occupy one-third of total individuals where two-third covers non-rubber species i.e. fruits, medicines, resin, and timber trees. The jungle rubber agroforest system is multipurpose plants species with low investment and better income (Gouyon, Foresta, and Levang 1993) and main source of income for 7 million people in Kalimantan, Sumatra, Indonesia (Wulan, Budidarsono, and Joshi 2006). Besides this, this system has also high environmental and soil conservation values compared to monoculture plantations (Penot 2004). Therefore, this system is taken as an important option for biodiversity in degrade condition of forest (Böhnert et al. 2016).

1.3.3. Monoculture rubber plantation

The monoculture rubber plantation is a well-managed system characterized by more than 99% rubber trees growing in most of the cases (Pye-Smith C 2011). The productivity under this system is three times higher than the jungle rubber system (Penot 2004). The increased demand in the global market and rocketing price have pressurized to change the jungle rubber into more productive monoculture rubber plantations (Feintrenie and Levang 2009). The traditional jungle rubber is replaced by the rubber monoculture system where international agencies encouraged to continue this system in a greater extent (Pye-Smith C 2011). According to the FAOSTAT ((2016), the monoculture rubber along with jungle rubber was around 1.8 million hectares in 1990 and expanded at 3.5 million hectares in 2013 worldwide. Whereas, monoculture system requires high investment for management, cultivation and establishment (Pye-Smith C 2011). The large area expansion of this system has also some threat to forest, biodiversity, environment and soil conservation as the jungle rubber system has negative impact (Penot 2004; Pye-Smith C 2011).

1.3.4. Monoculture oil palm plantation

Oil palm plantation was started in Jambi by large public-sector companies (Krishna et al. 2017) where smallholder inclusion was emphasized by the Indonesian government through the so-called “nucleus estate and smallholder”(NES) schemes during 1980s and 1990s (Kem 2017; Jelsma et al. 2017). Smallholder oil palm farmers in Indonesia contribute for an estimated 40.8% of the total Indonesian oil palm cultivation area (Jelsma et al. 2017). Most of farmers are highly engaged to cultivate the oil palm due to rising demand, high profitability as well as government policy for technical and financial support (Jelsma et al. 2017) and it demonstrates much higher benefit cost ratios and financial returns to farmers than other types of agricultural products such as rubber or rattan (Belcher et al. 2004). So, the dramatic expansion of oil palm cultivation occurred between 1990 and 2013. The total area plantation was only 700 thousand hectare in 1990 and it enormously increased to 7 million hectares in 2013 (FAOSTAT 2016). Therefore, Indonesia has been standing in the topmost position in the list of palm oil producing and exporting country in the world (Feintrenie and Levang 2009).

The wide range of oil palm plantation in Indonesia is the major cause of deforestation. Between 1990 and 2005, 1.7-3 million hectares of Indonesian forests were lost due to oil palm expansions, which accounts 50% loss of the total forest loss during this period (Fitzherbert et al. 2008). The monoculture plantations of oil palm will further dominate the landscape of Indonesia, particularly in Sumatra (Carlson et al. 2013) which ultimately losing the tropical biodiversity and ecosystem functioning (Laurance 2015) and resulting threat to well-being and ecosystem service in a long run (Daily et al. 1997).

1.4. Plant functional traits

Plants are the fundamental and significant component of ecosystem functioning, has an irretrievable function and play role for the maintenance of ecological plants and their structure and composition as well as diversity for ecological constancy (Masarovičová, Májeková, and Vykouková 2015). While estimating the role of ecology in plant community, it is mandatory to understand the individual components, basic characteristics and its relationships with local environment (Masarovičová, Májeková, and Vykouková 2015). Similarly, functional approach connects with the physiological ecology, population ecology and ecology of plant communities along with environmental situations (Violle et al. 2007). According to the Violle et al (2007), plant functional traits are important for the derivation of morphological, physiological and phenological traits and have impact on plant quality shaping through their dynamism such as growth, reproduction and survival. These features stand for the plant functional groups in the major aspects of functions i.e. function on level of organism, environmental factors and effects on ecosystem level (Masarovičová, Májeková, and Vykouková 2015; Diaz and Cabido 2009). Whereas, ecological plant traits are generally related to the plant-animal interactions within particular ecosystem which is more reactive and traits values are determined by the biotic interaction with prevailing environmental conditions within particular vegetation community (Webb et al. 2002; Soliveres et al. 2014). In the beginning, Hodgson et al (1999), classified the functional traits into soft and hard traits. Hard traits were focused to the function of interest though these were difficult to quantify such as photosynthesis, respiration, transpiration or growth rates, stomata conductance etc. As we focused on traits related to ecological functions, soft traits were easy to quantify and evaluate: woodiness, growth form, life cycle, pollination, seed dispersion, fruit type, fruit dimensions, seed mass and volume, reproduction, chromosome number etc. Plant-animal interaction depends upon the availability of energy and resources and microclimate produced by abutting plant species in a particular community that often facilitate to co-existence in nature (Hupp 2016; Maestre et al. 2005). In addition, plant-animal interactions play the profound role to impact on ecological communities and their structure and composition, and therefore ascertain the species pattern of dispersion, ecosystem quality and stability (Brooker et al. 2007). These functional roles are driven by environmental conditions and crucial to understand how they are responsible with differing environmental scenarios (Soliveres et al. 2014; Brooker et al. 2007). Functional traits of plants not only demonstrates the use of environmental and climatic resources and adjustment to the locality but also impact the functional composition of plant communities (Masarovičová, Májeková, and Vykouková 2015) and it appears to be interesting approach to handle the plant ecology and link the dynamisms of individual populations and their resemblance to ecosystem functioning (Májeková et al. 2016).

1.5. Functional diversity and ecological plant traits

Functional diversity is the valuable component of biodiversity which assemblages the range of values of different patterns such as presence of species and ability to compete (Song et al. 2014) and also the influence of biological communities on ecosystem functioning and distribution of traits in a particular ecological community (Goswami et al. 2017; Song et al. 2014). It is specifically conceptualized to pursue the ecosystem and their reactive action like ecosystem dynamics, nutrient availability, stability etc. Functional diversity and species diversity are correlated on the basis of environmental conditions and disturbance, whether they have supportive or unsupportive correlation in terms of ecosystem processes, properties and stability (Song et al. 2014; Foster et al. 2011; Diaz and Cabido 2009). Ecosystem reflects the complex interaction between biotic and abiotic community (Goswami et al. 2017) which can alter the significant ecosystem dynamics if there is a little fluctuation in either of the two components.

The ecological plants traits i.e. pollination syndrome, dispersal syndrome and other plant traits are inevitable for ecological functioning. This enhances the process of transitions including pollination and seed dispersion by animals and other abiotic agents i.e. wind, water etc. are detrimental (Neuschulz et al. 2016) and it reveals potential breaking points in the regeneration cycle of plants, which is mandatory for environmental conservation efforts (Wang and Smith 2002). The type of plants and their pollination and seed dispersion depend upon the seasonal variation and have subsequent effects on plant germination and survival rates, vegetation structure and dynamics (Cain, Milligan, and Strand 2000). As we concentrated in ecological plant traits i.e. woodiness, growth form, life cycle, life form, fruit type, fruit dryness and dehiscence, pollination and seed dispersal are widely linked to ecological functions. These functions or ecological services are mutualistic interactions that benefits plants and have significant conservation implications (Egerer, Fricke, and Rogers 2018; Corlett 1998). Likewise, the dynamisms and life cycle of plants are associated with the interactions of biotic and abiotic agents and maintain multi-functionality for ecosystem functioning (Midgley 2012; Egerer, Fricke, and Rogers 2018). The ecological functions of organisms, insects, birds and animals are more importantly related to the processes that shape the productivity, functional diversity and complexity of ecosystem (Midgley 2012) as well as influence the structure and composition of ecological communities that determine the distribution of vegetation and ecological plant traits (Soliveres et al. 2014). Furthermore, such an ecological processes and interactions of plant traits affect the functional and phylogenetic diversity of plant communities (Schöb, Butterfield, and Pugnaire 2012).

1.6. Research questions

Earlier studies already investigated the consequences of land-use change on taxonomic plant diversity (Böhnert et al. 2016; Drescher et al. 2016; Faust, et al. 2013). Here, the consequence for ecological plant traits and strategies were studied. Comparative analysis of different ecological plant traits across four land-use systems were carried out and the relationship between the different scales of functional diversity indices within different land use practices in the sites was analyzed. Furthermore, we tried to explore the relationships between taxonomic diversity and functional diversity related to ecological function.

1.7. Research hypothesis

This study is based on three main hypotheses; (H1) ecological plant traits are significantly different between land-use systems; (H2) functional diversity differ between land use systems; (H3) taxonomic diversity and functional diversity are related to ecological function.

2. Methods

This study is completely based on a previous vegetation survey that was carried out by Rembold et al, (2017). 1382 species were recorded from that study, out of which 312 species were not yet identified to species level. For this study of ecological plant traits, a total of 992 species, 808 genera and 91 families were carried out an extensive literature survey about the ecological plant traits that were found in the published volumes of Flora Malesiana ((D.J., Mabberley, C.M., panel, A.M., Sing, 1995)), Tree Flora of Sabah and Sarawak (E. Soepadmo and K.M. Wong, 1995) and Tree Flora of Java (Backer, C.A and R.C. Bakhuizen Van Den Brink, J.R., 1963). With the knowledge of distribution of each species among the four land-use systems, we investigated the consequences of land-use change on ecological plant traits and therefore functional diversity.

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 Jambi Province, which was used to be one of the largest regions of tropical lowland rainforest in Southeast Asia, (Fig.1). Jambi, one of the 34 provinces of Indonesia, is situated on the eastern coast of central Sumatra. It covers 50160 km^2 (Statistik, 2014) expanding from the southern Malacca Strait in the east to the Barisian Mountain range in the west. The rainforests of Jambi province have been suffering from the highest deforestation rate around the globe (Achard et al. 2002) and the rainforest cover has heightened the exploitation due to rapid increase of population, timber logging and intensification of traditional agricultural system (Drescher et al. 2016). In 2013, rainforest covered only 30% of Jambi region whereas 55% was already changed into agricultural land and 10% land was degraded (Drescher et al. 2016).

The vegetation survey was carried out in four land use systems: forest, jungle rubber, rubber plantations, and oil palm plantations (Rembold et al. 2017). Jambi’s rainforest has been exploited since long history due to high dependency of population on timber products as well as lack of improved skills and techniques in agroforestry system (Statistik, 2014, Andaya BW, 1993). The core plot in rainforest area established to encompass the primary degraded forest (Drescher et al. 2016). During the time of plot selection in 2012, the oil palm plantations, rubber plantations and rubber trees in the jungle rubber systems were aged between 8 to 15 years, 7 to 16 years and 15 to 40 years respectively (Drescher et al. 2016; Kotowska et al.

2016). All plantations were owned and managed by smallholders (up to 50-ha landholdings) (Kotowska et al. 2016).

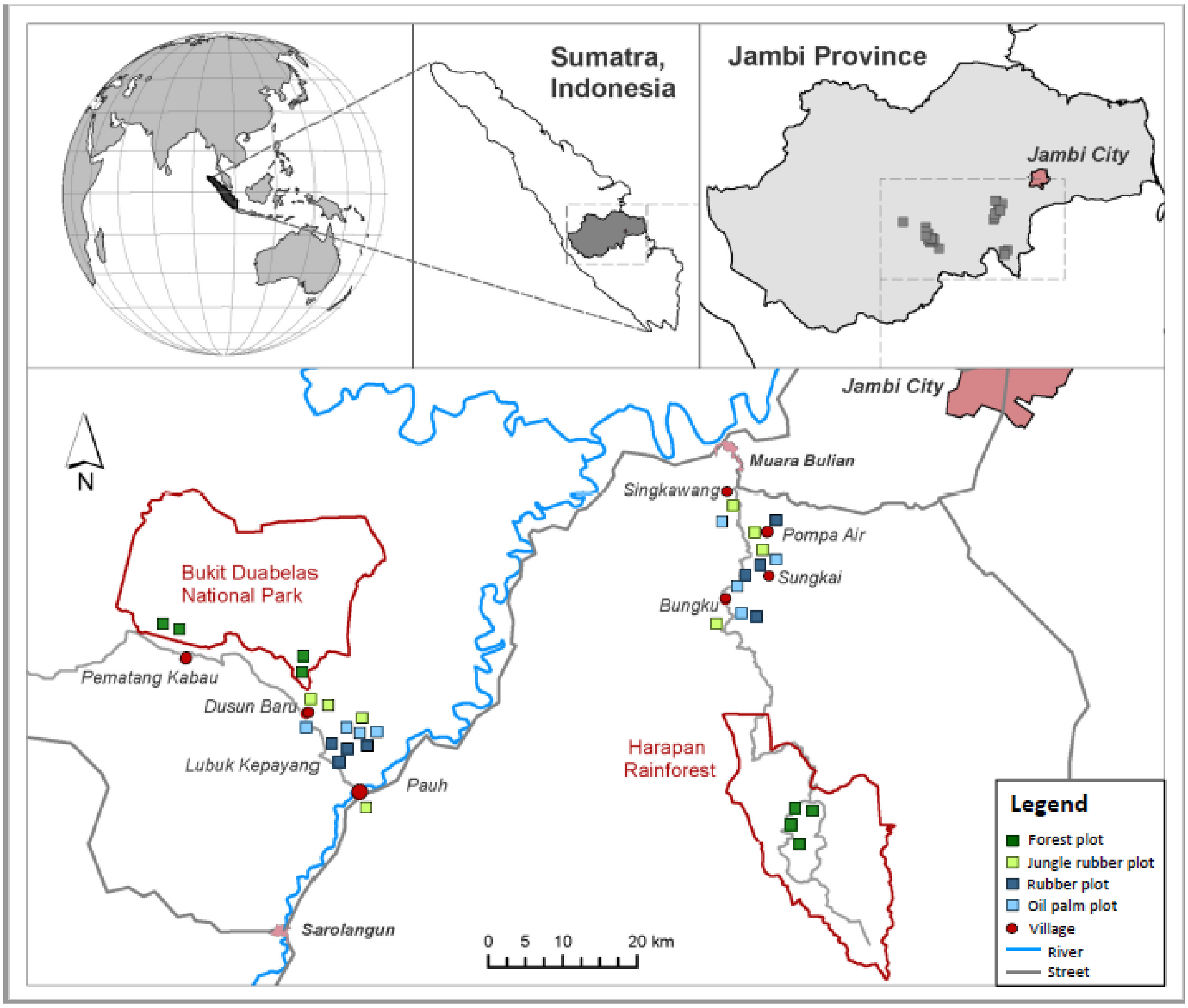


Figure 1: location of core plots near Bukit Duebelas National Park and Harpan Rainforest in the EFForTS study area in Jambi Province of Sumatra, Indonesia (Rembold et al.2017).

2.2. Sampling design

Eight plots were established in each of the four land use systems in 2012, resulting in a total of 32 study plots. Each core plot measuring 50 × 50 m and containing five 5 × 5 m subplots at fixed positions (Drescher et al. 2016; Kotowska et al. 2016). It was assured that the soil and climatic conditions were comparable and were representative of both study regions at 40-100 m a.s.l. (Kotowska et al. 2016). The trees measured during the inventory of the respective plots were >10 cm Diameter at Breast Height (DBH) and plants with DBH <10 cm were measured in five subplots per plot (160 subplots in total).

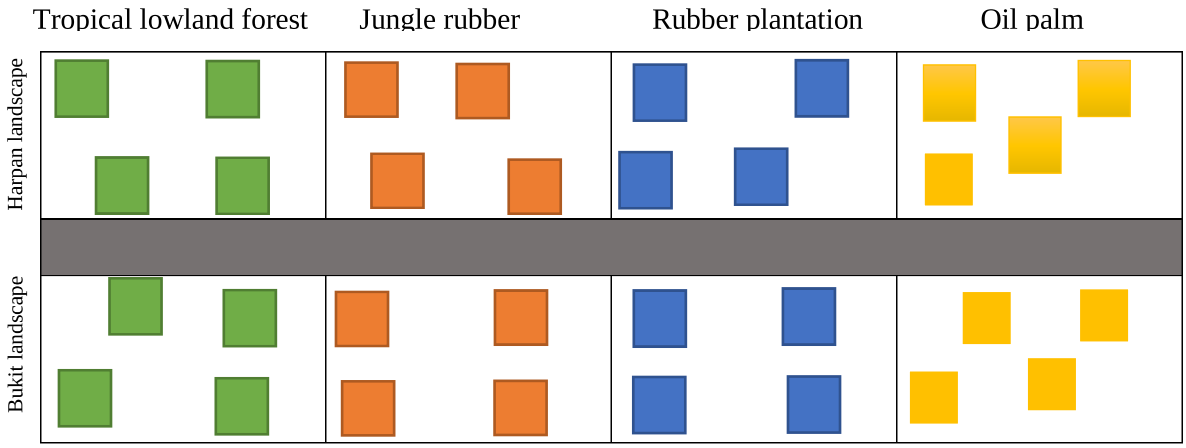


Figure 2: Allocation of plots across four land-use systems and eight plots per system.

2.3. Data collection

2.3.1. Vegetation survey

This study is based on a previous vegetation survey carried out during the first project phase (Rembold et al. 2017). The vegetation survey provided data on 1382 plant species including plot based species richness, composition and abundance across four land-use systems (forest, jungle rubber, rubber plantations and oil palm plantations) and the height and growth form of each individual diameter at breast height, and location of the tree.

2.3.2. Literature survey

To investigate the different ecological traits of species found in the vegetation survey (such as woodiness, life form, plant height, pollination syndrome, fruit type, dispersal syndrome, reproduction, etc., see Table 1 for a complete list of plant traits) an extensive literature survey was carried out to find out the effects of land use change on ecological or functional plant traits in the study sites.

For this, I started to collect or derive the required plant trait information from the published volumes of Flora Malesiana ((D.J.,Mabberley, C.M., panel, A.M.,Sing, 1995)), Tree Flora of Sabah and Sarawak (E. Soepadmo and K.M. Wong, 1995) and Tree Flora of Java (Backer, C.A and R.C. Bakhuizen Van Den Brink,J.R., 1963). Then, we verified with plant trait database (TRY, 2018) of different functional traits using 992 identified species. Most traits were categorical but some traits were numeric i.e. plant height, fruit dimensions, seed dimensions and chromosome numbers. We also searched information from the online portals named 'Naturalis' database, 'The International Plant Names Index (IPNI)' database, and 'The Plant List' database. We collected three different level of information: species level, genus level and family level. Then categorized the trait information priority ranking to select the best values or information of traits from the sources i.e. first priority to get trait the information was given flora of malesiana data base then if information was not available in flora of malesiana we took from tree flora of sabah and sarawak and then tree flora of java. If the information from the species level was not available we derived information from genus level and family level to finalize the trait data. The collected final traits information was compiled and merged with species abundance and land use system database to finalize the data for analysis.

Table 1 : Categorization of all trait states used in analysis (Pérez-Harguindeguy et al. 2013)

Ecological traits	**type**	**Trait state lists (units)**
Woodiness	categorical	woody, non-woody, variable
Growth form	categorical	Tree, shrub, herb, shrub/tree, herb/shrub, herb/shrub/tree, other
Climber	categorical	obligatory, facultative, self-supporting
Lifecycle	categorical	Annual, biennial, annual/biennial, perennial, variable
Life form	categorical	chamaephyte, cryptophyte, hemicryptophyte, phanerophyte, therophyte,
Fruit type	categorical	achene, baccate, berry, capsule, drupe, follicle, lomentum, nut, pod, pome, schizocarp, siliqua, utricle, other
Dehiscence	categorical	dehiscent, indehiscent
Fruit dryness	categorical	dry, fleshy
Dispersal syndrome	categorical	anemochorous, autochorous, endozoochorous, epizoochorous, hydrochorous, zoochorous
Reproduction sexual	categorical	dioecious, monoecious, bisexual
Pollination syndrome	categorical	wind, water, bee, beetle, moth, fly, insect, bird, bat, other

*(ecological plant traits, type and trait state lists with units were used as given described by the (Pérez-Harguindeguy et al. 2013).

2.4. Statistical analysis

To test the composition of ecological plant traits across land use system, we applied Pearson's chi-squared test R version 3.4.1(Taudiere and violle 2015) for counting data of each traits and further separated the data land use wise. Chi-squared test produced the information about data counting and distribution pattern of traits. The percentages of ecological plant traits in the four land use system were tested for significance differences using analysis of variance (ANOVA), Kruskal Wallis rank sum tests (Kraft and Ackerly 2010) and observed the variations traits across of land use systems producing stacked bar graph.

To test for differences in functional diversity across the land-use systems, we used the species abundance table as plots by species matrix and trait data as species by traits matrix to derive numerical return values of each individual trait using 'functcomp' function of FD in R 'vegan'package (Violle et al. 2007). 'Functcomp' function calculated the numerical values of each trait across four land use systems. We further used the Shapiro-wilks to test whether functional composition of traits were normally distributed or not (Boehmke 2018). To ascertain whether functional composition of traits differ among four land use system, we analyzed ANOVA (Kraft and Ackerly 2010), Kruskal Wallis rank sum test and Tukey's Honest Significance Difference (HSD) and post-hoc test for multiple comparison data (Kembel and Jr 2011). The trait composition and tests results were plotted in the form of box plot with letters for multiple comparisons of means value with errors and standard deviations.

The functional composition of traits was derived from R package 'FD' was crucial to calculate the functional diversity indices. The variations of functional diversity indices were tested in ANOVA, Kruskal Wallis rank sum test and Tukey's HSD as written above which described the functional diversity variations across four land use systems. In addition, we calculated the non-metric multidimensional scaling (NMDS) of traits across land use system was studied applying the function 'metaMDS' in vegan package of R to measure the closeness and similarities of traits with their distribution pattern of traits along with research plots. The NMDS visualized the functional plant traits proximities pattern (Kruskal 1964; Borgatti 1997). The stress function referred to ordination distance across all dimensions with stress value ranging from 0 to 1. Stress function represented the better non-metric and linear fit of traits. Higher the stress value more distortion of traits and vice versa (Kruskal 1964).

To investigate the relationships between taxonomic diversity and functional diversity to ecological function, we used the 'dbFD' function of FD package in R version 3.4.1 to calculate the distance based functional diversity indices i.e. functional richness, functional evenness, functional dispersion and Rao’s quadratic entropy. For this analysis, we used the species by traits data and plots by species data and further calculated the weighted mean of traits to analyze the distance based diversity indices. The species richness from abundance table was used to find out the relationship between functional diversity indices and species richness of study area. The correlation effects were observed in chart matrix of all indices with species richness. We further calculated the correlation of diversity indices and species richness in Microsoft Excel using scatter plot in simple correlation and regression function and also tested the significance differences of functional diversity indices across four land use system.

3. Results

Ecological traits from a total of 156,006 individuals and traits of 992 species from 808 genera and 91 families were collected and analyzed. This included 999 trees, 362 shrubs and 258 herbs within species. And also the different land-use system recorded the different number of individuals per land-use system. The most species-rich system was forest (724) and followed by jungle rubber (509), rubber (209) and oil palm (199). In regards of total individual numbers, forest had the highest total species number but recorded lowest number of individuals (17,071) and jungle rubber (17,982) reached only about half of the individual numbers of rubber plantations (38,791) and less than a quarter of oil palm (82,161). Overall, forest and jungle rubber had higher species richness with higher traits composition and less number of individuals but monoculture plantations (rubber and oil palm) in contrast had the lower species richness with lower traits composition but observed the higher numbers of individuals.

3.1. The composition of ecological plant traits across different land-use system

3.1.1. The composition of ecological plant traits at species level across four land-use system

The distribution of the ecological plant traits at species and individuals level found significant differences across the land-use systems (Fig. 3 and 4). The forest had the highest proportions of woodiness (91.38%) at species level but at individual level found nearly 77% which was approximately 13% less than the woodiness found in species level. The proportions of perennial, self-supporting and phanerophyte plant traits composition at species level depicted higher and followed by jungle rubber (71.28%) and monoculture plantations (rubber 71% and oil palm 58% respectively). The monoculture plantations occurred nearly one third of woodiness at species level. At individual level, forest (77%) and jungle rubber (76.68%) found more than three quarter of total woody species and observed slight variation in proportions however; monoculture plantations were dominated by non-woody species such as rubber (32.98%) and oil palm plantations (43%). In overall, more than two third proportions of woodiness observed with lower proportions of non-woody traits at species level however, approximately 50% of the total numbers of individuals in an average were woody at individual's level. At species level, more than 80% species were self-supporting with less than 20% species were obligatory across land-use systems. And the individual land-use system significance test performed the significant differences of woodiness across the land-use system at both species and individual levels (Table: 2 and 3). The trait growth form; trees in forest and jungle rubber found approximately two third of total growth form and followed by monocultures (47% and 40% respectively). Besides this, shrubs were almost equal in proportions across land-use systems. Herbs had higher proportions in oil palm plantations (41.03%) and followed by rubber plantations (27.69%), jungle rubber (12.5%) and was least in forest (8.33%).

Similarly, the traits regarding reproduction accounted the highest proportions of monoecious plants species in forest (52.5%) and followed by rubber and oil palm plantations (41.23% and 39.79% respectively). Bisexual plant species recorded the highest proportions in jungle rubber (56.83%) however; it observed approximately equal proportions in forest and monoculture plantations (30.69%, 33.50% and 32.65% respectively). We had also observed the asexual production and found the least species across land-use systems. The significance test assessed significance variations of sexually reproduced plant species but it did not vary the asexual plant species. (Table 2).

The species with berry, drupe and capsule fruits contained higher proportions as compared to the other fruits. The species in the forest dominated by the drupe (36%), berry (24.7%) fruits followed by capsule, follicle, pod and nut fruits. So, the majority of the species across four land-use systems had drupe, berry and capsule fruits as compared to the other fruits. The species with nut fruits distributed almost equal in forest, and monoculture plantations but jungle rubber system had the least nut fruits. The pod fruits had similar proportions in all systems but it observed higher species with pod fruits in oil palm plantations. The significance test did not show the variations across land-use systems. The oil palm plantations recorded the highest species with indehiscent fruits (82.65%) and followed by the species in forest (62.15%). About 40% species in rubber plantations had indehiscent fruits and had least in jungle rubber (27.4%). However, both jungle rubber and rubber plantations had higher proportions of species with dehiscent fruits but was least in oil palm plantations (17.35%). The forest species had around 37.84% and the significance test did not vary the species with fruit dehiscent across land-use systems. Approximately two third proportions of species had dry fruits and remaining proportions of species had fleshy fruits across land-use systems. The significance test did not show the variations of species with fruit dryness across land-use systems.

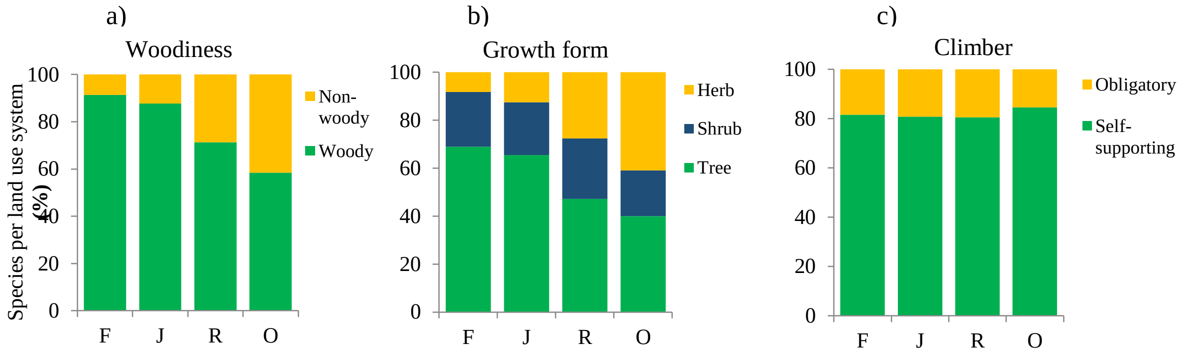
While considering the pollination syndrome at both species (Fig. 3i and 3j) and individual level (Fig. 4b and 4c). The majority of plant species across land-use systems were pollinated by bee and bat. However, the highest proportions of species in rubber plantations were pollinated by bird. The pollination syndrome was characterized into four categories such as insect (i.e. bee, beetle, fly and moth), bat, bird and wind syndromes were taken into account. Regarding the insect pollination, bee and beetle pollination had the greater impact in turn across four land-use systems. Approximately 50% of the total plant species across four land-use systems were pollinated by bee but slight variations could be observed. Similarly, nearly one third species were beetle pollinated and Moth and fly pollinated species were almost equal across the land-use systems. Bat pollinated species were higher in forest (60.89%) and jungle rubber (54.78%) followed by species of monoculture plantations (42.31%, 44.68% rubber, oil palm plantations respectively) and the species with bird pollination had equal impact (20%). However, the species with wind pollination in monoculture plantations were higher (38%, 36% in rubber and oil palm plantations respectively) as compared to forest (22.77%) and jungle rubber 28.03%).

Similarly, in individual plants level, more than 50% of total plant individuals found in forest. The jungle rubber was pollinated by bee and nearly one third species were pollinated by beetle but fly and moth had pollinated the least. The plants with more than 60% were pollinated by bee in monoculture plantations. Beetle had significant impact in the number of individuals in monoculture plantations (rubber 38.84% and oil palm 33.59%) but there was the least impact of fly and moth. More than two third plant individuals were pollinated by bat in forest, jungle rubber and oil palm plantations however; the least individuals in rubber plantations were bat pollinated. Likewise, approximately 21% of individuals in forest and rubber plantations were wind pollinated followed by oil palm plantations (15.79%) and jungle rubber (13.7%). So, bee and beetle pollinated species and individual plant’s proportions were almost similar across land-use systems at both species and individuals level. About 40% species were pollinated by wind at species level however, less than 20% individual plants were wind pollinated at individual level. In addition, the proportion of moth and fly pollinated species were higher at species level (>12%) but it was <10% individuals were pollinated by them at individual level.

The significant test showed significant variations of pollinators across land-use systems at both species and individuals level. The insect pollination had no considerable variations in species and individual level.

The all land-use systems harbored large proportions of animal-dispersed plant species (zoochorous) and numbers of individuals. At species level(Fig. 3l), more than 75% of species in forest and jungle rubber systems were dispersed by the animals and the seeds of nearly 15% species were dispersed by wind (anemochorous) and followed by water (hydrochorous) 7-8% but self-dispersed (autochorous) species were the least (<2%) in both forest and jungle rubber. About 66% of seeds in oil palm plantations were animal-dispersed and followed by rubber plantations (34.62%). Similarly, more than one third proportions of plant species in rubber plantations were wind dispersed species and followed by water and self-dispersion. About 17% species in oil palm plantations were wind dispersed and followed by self-dispersion (9%) and water (8%).

At individual level(Fig. 4d), forest composed of 48.98% animal-dispersed plant individuals and followed by wind-dispersed individuals (29.17%), water (21.04%) but self-dispersed individuals were less than 1% in both forest and jungle rubber systems. In jungle rubber system, large number of individuals (81.45%) was animal-dispersed plants and followed by water (15%) and the least was wind-dispersed (3.09%) plants. Similarly, approximately 60% individuals in monoculture plantations were animal-dispersed. Nearly one fourth individuals in oil palm plantations were water-dispersed however, self-dispersed individuals were around 17% but wind-dispersed individuals were least in oil palm plantations (3.10%). In contrast, more individuals were wind-dispersed in rubber plantations (12.14%). The significance test showed the significant variations of dispersal syndromes across four land-use systems in individual's plant level. In overall, the animal-dispersed species and the number of individuals were considerably higher in both levels as compared to other dispersal syndrome.



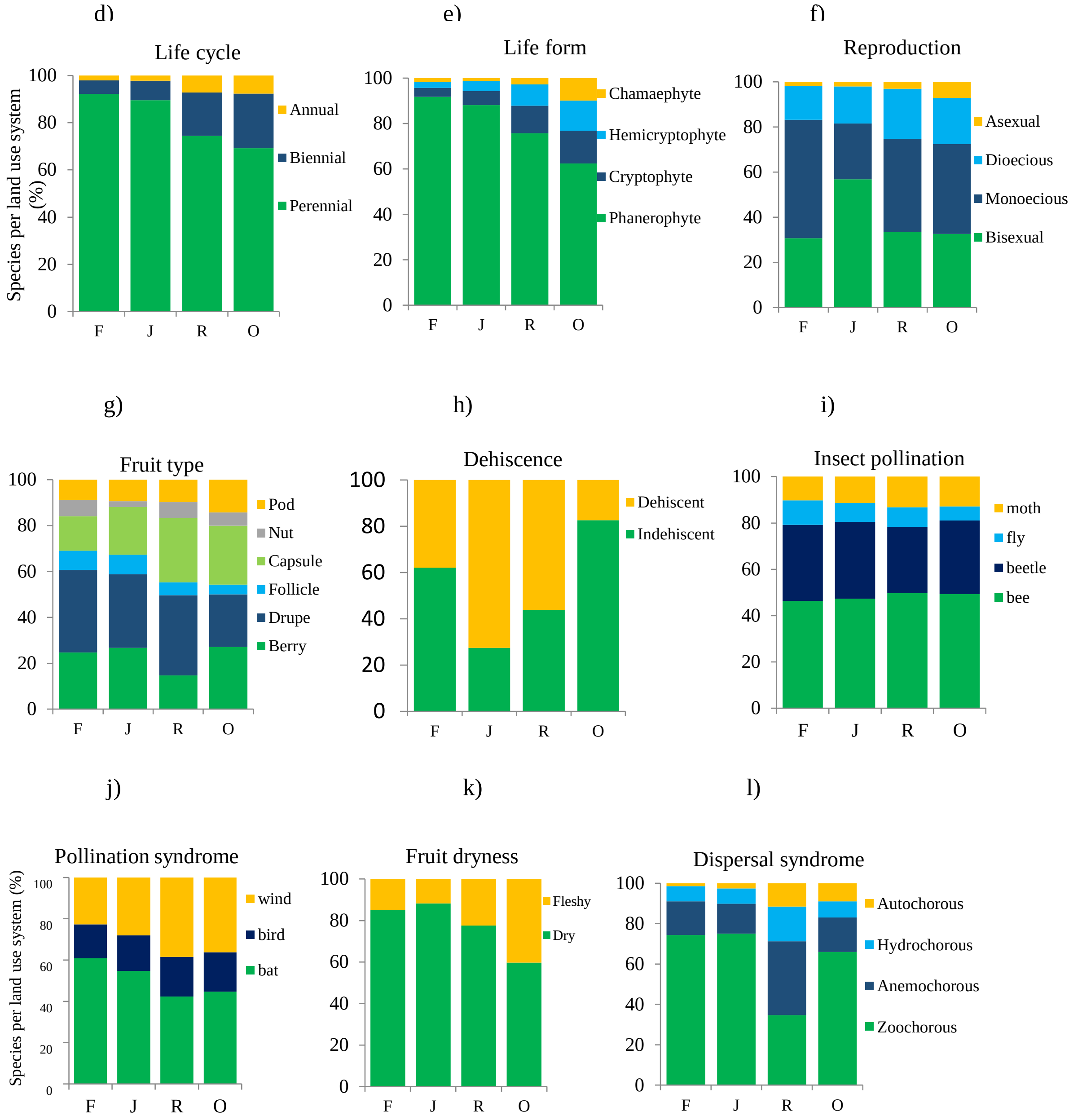


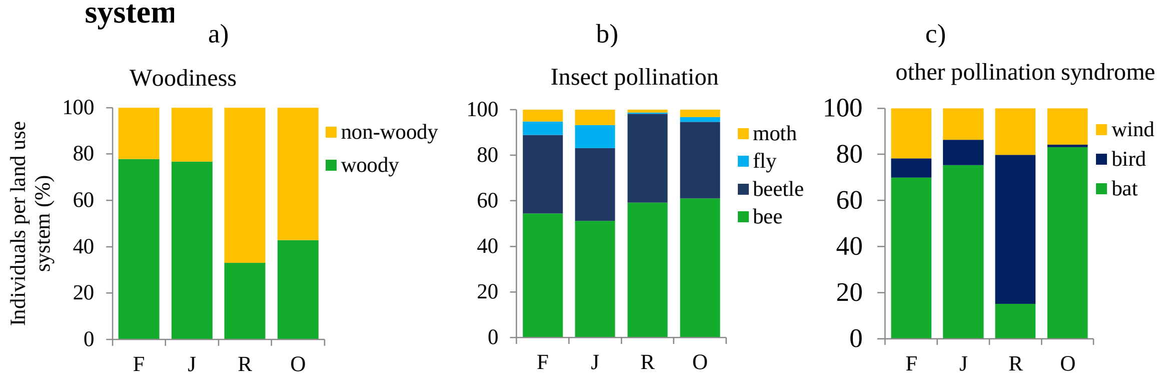
Figure 3: Total number of plant traits categorized across four different land-use systems (F- forest, J- jungle rubber, R-rubber plantation, and O- oil palm plantation) with respect to species per land use systems (a), woodiness (b), growth form and structure of vegetation (c), climber (d) life cycle (e), life form (f), asexual and sexual reproduction (g), pollination syndrome (h), fruit type (i), dehiscence (j), fruit dryness (k), dispersal syndrome .

Table 2: The results from Pearson's Chi-squared test of significances of plant traits at species level

The table summarized that the most of the ecological plant traits showed similar effects across four land-use system but some traits such as non-woody, herb, annual and biennial plants, cryptophyte form of plant life, self and animal dispersal mechanisms showed the significant variations across land-use systems.

Ecological traits	Pearson's chi-squared test (X^2)	Degree of freedom	P-value at 0.05
woody	601.22	3	p>0.00012
Non-woody	5.3282	3	P<0.1493
Herb	5.7519	3	P<0.1243
Shrub	115.46	3	p>0.0001
Tree	488.3	3	p>0.0001
Obligatory	97.482	3	p>0.0001
Self-supporting	115.46	3	p>0.0001
Annual	0.78182	3	P<0.8538
Biennial	1.0244	3	p<0.7954
Perennial	565.75	3	p>0.0001
Chamaephyte	10.8	3	P>0.0125
Cryptophyte	1.5688	3	P<0.665
Hemicryptophyte	2.1905	3	P<0.5338
Phanerophyte	596.53	3	p>2.2e-16
Asexual	4	3	P<0.2615
Bisexual	239.18	3	p>2.2e-16
Dioecious	46.223	3	P>5.084e-16
Monoecious	373.75	3	p>2.2e-16
Bee	144.89	3	p>0.0001
Beetle	93.318	3	p>2.2e-16
Fly	50.848	3	P>5.722e-16
Moth	25.672	3	p>1.117e-11
Bat	120.22	3	p>0.0001
Bird	22.215	3	P>5.884e-05
Wind	22.323	3	P>0.000539
Berry	92.764	3	P>0.00001
Drupe	133.02	3	P>0.00001
Follicle	39.81	3	P>1.169e-08
Capsule	21.697	3	P>7.543e-05
Nut	30.869	3	P>9.058e-07
Pod	17.569	3	P>0.000539
Dehiscent	342.92	3	P>2.2e-16
Indehiscent	67.695	3	P>1.329e-14
Dry	24.016	3	P>2.479e-05
Fleshy	396.82	3	P>2.2e-16
Anemochorous	19.087	3	P>0.00026
Autochorous	2.04	3	P<0.5641
Hydrochorous	213.97	3	P>2.2e-16
Zoochorous	0.333	3	P<0.9536

3.1.2. The composition of ecological plant traits at individual level across four land-use system



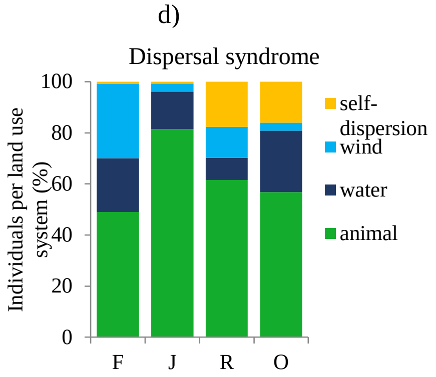


Figure 4: Individuals plant traits categorized across four different land-use systems (F- forest, J- jungle rubber, R-rubber plantation, and O- oil palm plantation) with respect total individuals per land-use system (a), woodiness (b), insect pollination (c), other pollination syndrome and (d) dispersal syndrome.

Table 3: The results from Pearson's Chi-squared test of significances of plant traits at individual level

The results showed the significant differences of plant traits across the four land-use system.

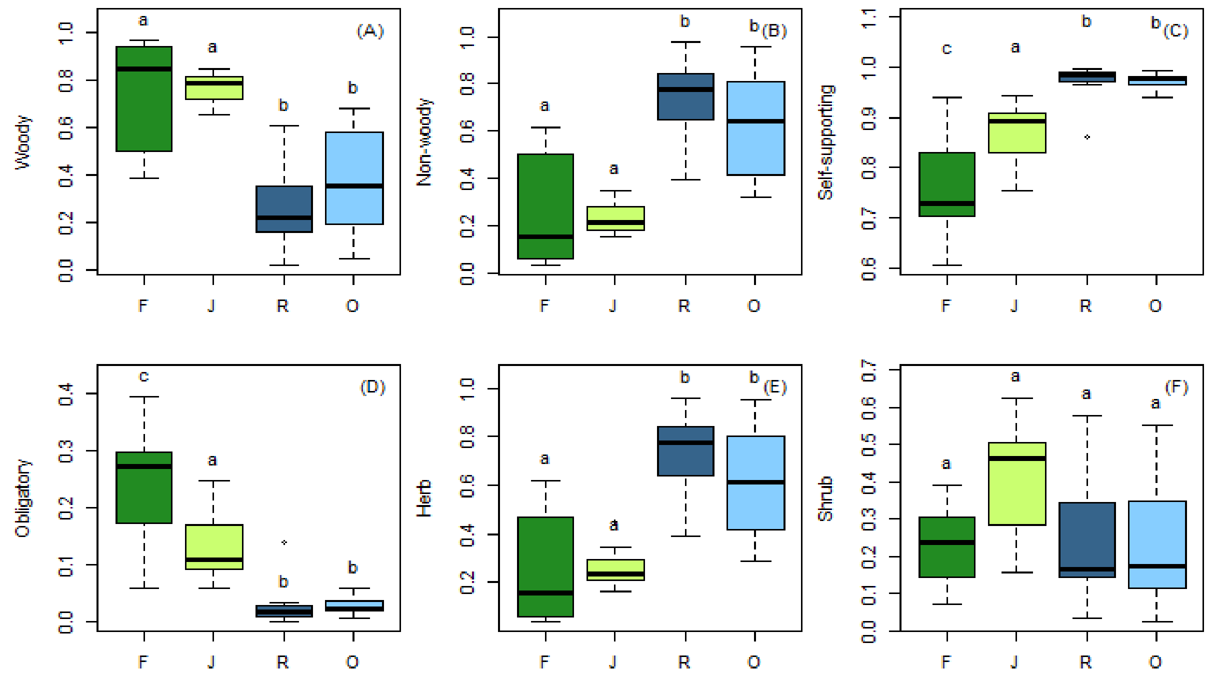
Ecological plant traits	Pearson's chi-squared test	degree of freedom	P-value
Woody	21774	3	P>0.0001
Non-woody	64839	3	P>0.0002
Bee	40190	3	P>0.0001
Beetle	19623	3	P>2.2e-16
Fly	774.15	3	P>2.2e-16
Moth	29929	3	P>2.2e-16
Bat	27002	3	P>0.0005
Bird	25627	3	P>2.2e-16
Wind	3473.3	3	P>0.0001
Anemochorous	3581.4	3	P>0.0001
Autochorous	23271	3	P>0.0001
Hydrochorous	29446	3	P>2.2e-16
Zoochorous	39221	3	P>0.0001

3.2. Functional composition of plant traits at species level across land-use systems

3.2.1. Woodiness, climber and growth form

The variations of functional composition of plant traits were observed across four land-use systems. The trait woodiness illustrated the greater proportion of functional composition in forest and jungle rubber and followed by the monoculture plantations. In contrast, non-woody trait composition showed the clear opposite proportions. However, the proportions of functional compositions did not vary between forest and jungle rubber as well as rubber and oil palm plantations as shown in the figures with same letters. The functional composition of self-supporting traits was higher in monoculture plantations and followed by forest and jungle rubber but obligatory trait showed the lower compositional proportions which differed significantly across land-use systems. The functional response of plant traits to the land use-systems reflected the divergent ecological roles of all traits (Junker and Larue-Kontić 2018).

The functional composition of herb species resulted large proportions in monoculture plantations with similar functional roles but it was nearly less than half proportions in forest and followed by jungle rubber. The shrubs in jungle rubber showed the highest composition and followed by the monoculture plantations and forest. But functional composition across land-use systems did not vary. Tree in forest and jungle rubber had significantly higher composition and followed by the oil palm plantations but it was least in rubber plantations. The significant test showed strong variations of woodiness, climber and growth form of functional composition across land-use systems except the shrub growth form.



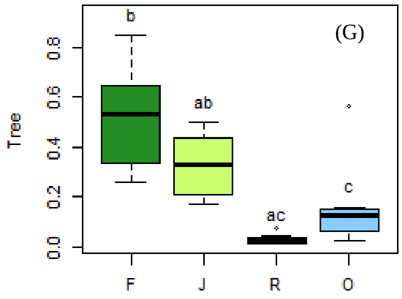


Figure 5:Ecological plant traits woodiness, climber and growth form (A), woody (B), non-woody (C), obligatory (D), and self-supporting E), herb F), shrub and G), tree in four different land-use systems (n= 8 plots per system) Kruskal-Wallis one-way analysis of variance showed significance level of differences; (A), p=0.0001 (B), p=0.0004 (C), p=0.0001 and (D), p<0.00067 (E), p=0.004 F), p=0.1027 and G), p=0.0001. 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).

3.2.2. Life cycle and life form

The functional composition of forest comprised of potentially larger proportion of annual and perennial plant species. The significance test of both life cycle and life form showed significant variations across the land-use systems except annual plants. The jungle rubber declined the composition of annual plants and remained at the least proportion. Monoculture plantations found considerably higher composition of perennial and biennial plants in an average however, forest and jungle rubber decreased with large variations. Rubber plantations composed of higher Chamaephyte followed by the oil palm plantations and forest. Similarly, the functional composition of cryptophyte and hemicryptophyte were higher in monoculture plantations. Furthermore, phanerophyte showed larger composition in both forest and jungle rubber system but did not vary in composition. However, phanerophyte was relatively lower in monoculture plantations.

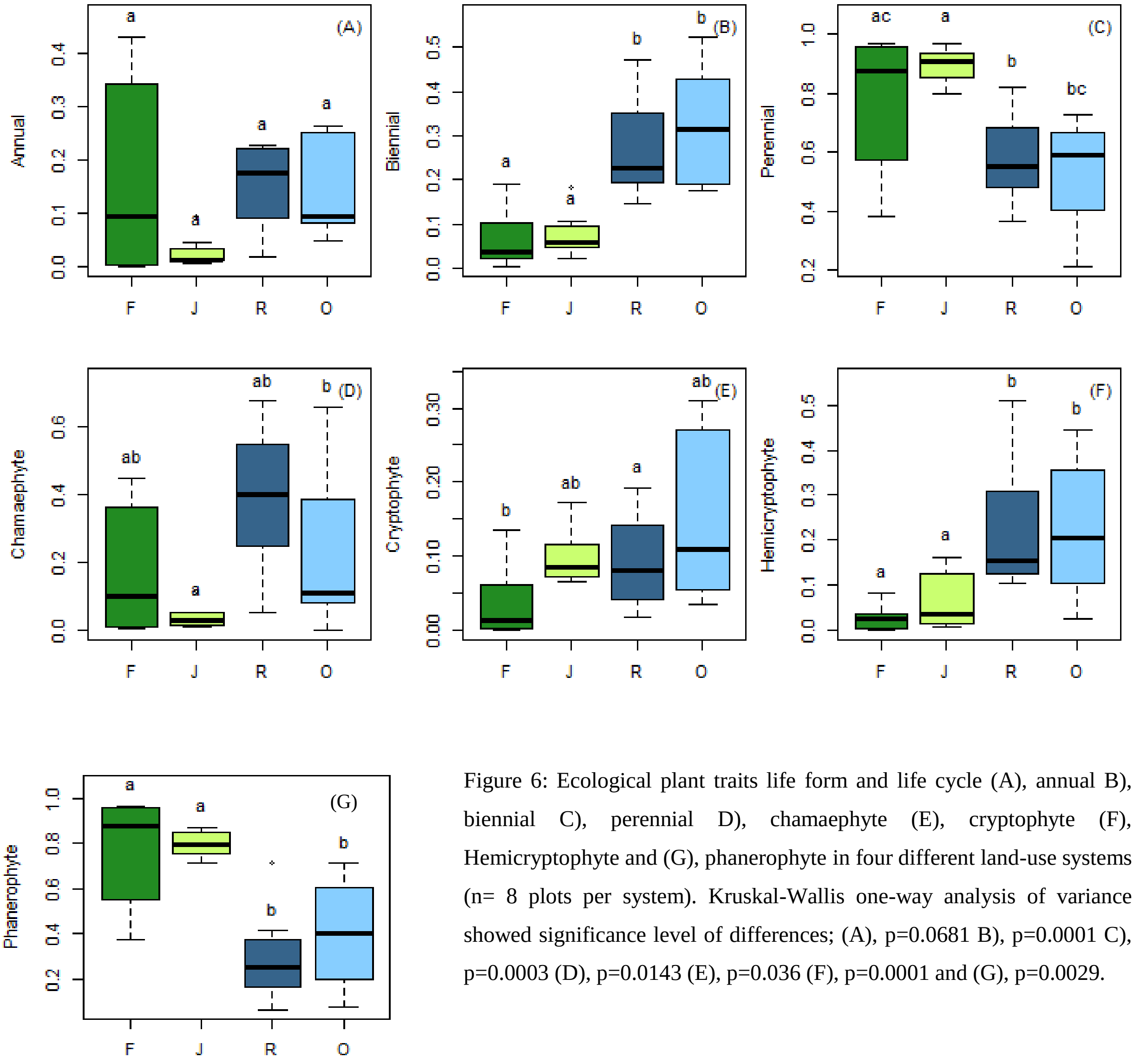


Figure 6: Ecological plant traits life form and life cycle (A), annual B), biennial C), perennial D), chamaephyte (E), cryptophyte (F), Hemicryptophyte and (G), phanerophyte in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences; (A), p=0.0681 B), p=0.0001 C), p=0.0003 (D), p=0.0143 (E), p=0.036 (F), p=0.0001 and (G), p=0.0029.

3.2.3. Reproduction and pollination

The functional composition of plant species with monoecious reproduction recorded the highest proportion and followed by the jungle rubber and monoculture plantations. The composition of bisexually reprodued plants had higher functional composition in forest and showed lower proportion in jungle rubber and monoculture plantations. We also observed the asexual reproduction across all land-use systems with significant decrease of asexual plants. Contrary to the asexual reproduction, composition of dioecious plants species found higher in monoculture planations and followed by jungle rubber and forest system. So, the bisexual reproduction composed of larger proportion across land-use systems except forest and the plants reproduced by monoecious reproduction accounted the higher in forest as compared to other systems.

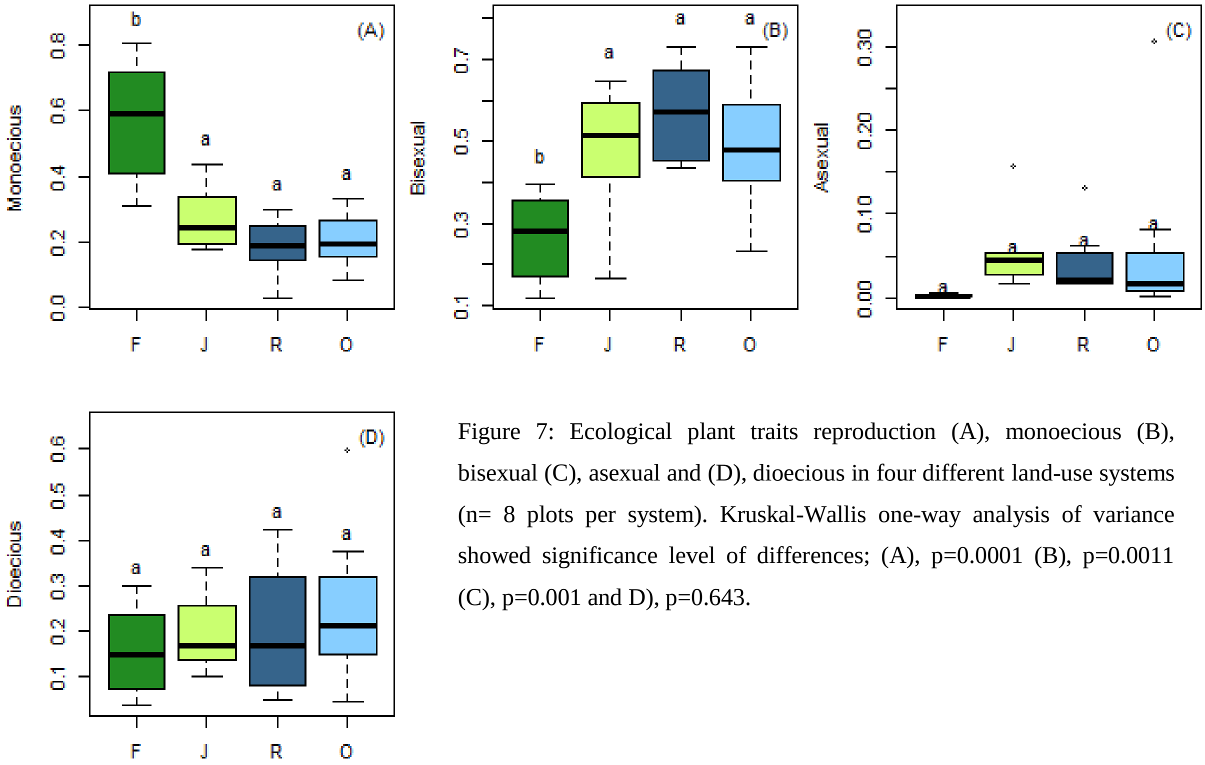


Figure 7: Ecological plant traits reproduction (A), monoecious (B), bisexual (C), asexual and (D), dioecious in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences; (A), p=0.0001 (B), p=0.0011 (C), p=0.001 and D), p=0.643.

3.2.4. Pollination syndrome

3.2.4.1. Insect pollination

As we found in the results, the functional composition of insect pollination such as beetle, fly and moth differed significantly across the land-use systems whereas bee did not vary significantly. Overall, the insect pollinators were more influencial and showed higher composition of trait proportion. Beetle had greater pollination impact on forest and rubber plantations but was the least in jungle rubber and oil palm plantations. Likewise, fly demonstrated the larger functional composition in jungle rubber and monoculture plantations but it was the least in forest. The insect pollinator, moth occurred the least composition in rubber plantations however, it showed the higher composition in jungle rubber and followed by forest and oil palm plantations. It represented that different insects had different preferences and visitation rates to attract toward the plant community. Bee showed the non-significance differences of functional roles across land-use system but beetle showed quite different roles and focused in forest and oil palm plantations. However, fly focused to the jungle rubber and monoculture plantations than in forest system.

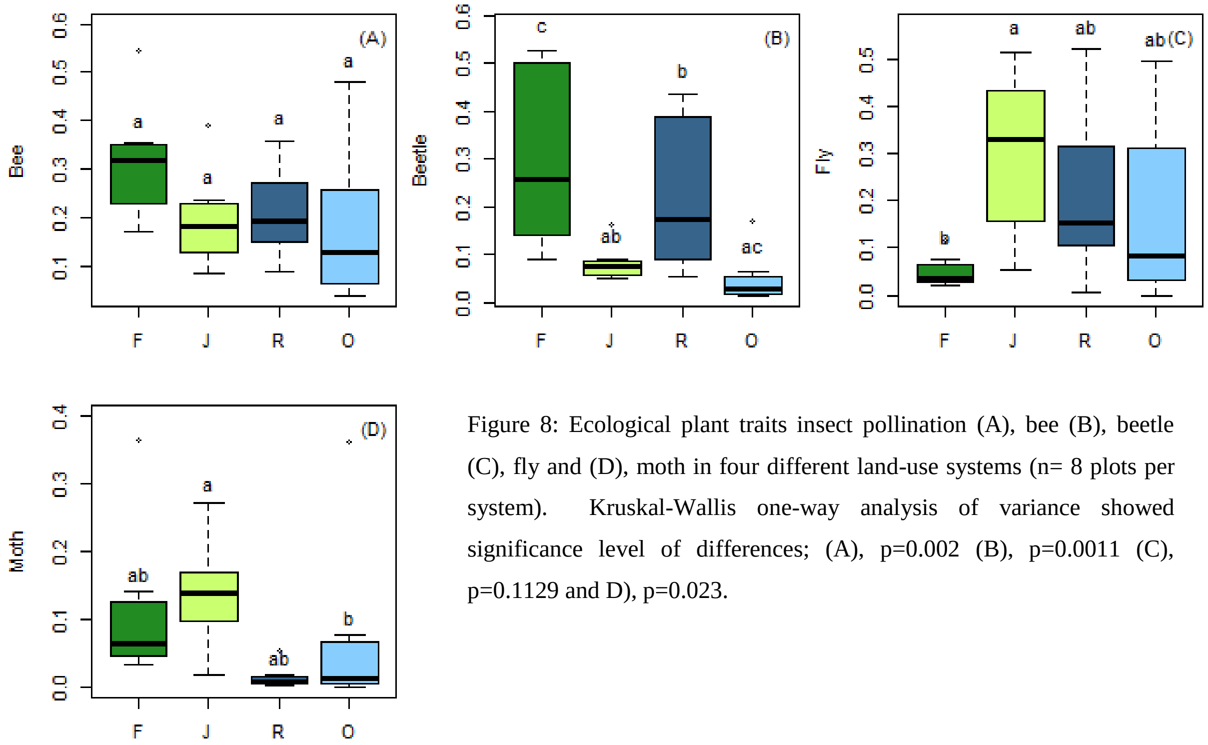


Figure 8: Ecological plant traits insect pollination (A), bee (B), beetle (C), fly and (D), moth in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences; (A), p=0.002 (B), p=0.0011 (C), p=0.1129 and D), p=0.023.

3.2.4.2. Bat, bird and wind pollination syndrome

The functional composition of bat and bird did not differ significantly across the land-use systems but observed the considerable variations in functional composition. Bird pollination composed of the higher functional composition in forest and rubber plantations but jungle rubber and oil palm plantations had almost equal functional composition. The functional composition of wind pollination reached the highest in oil palm plantations followed by rubber plantations and jungle rubber but wind pollination observed the least composition in forest system. It depicted that bird preferred more diverse community than monoculture systems such as rubber and jungle rubber system. The functional composition of bird pollination did not differ significantly across land-use systems. So, it could be expected more ecological function in a highly diversed ecological community by bird. Moreover, the wind had also great impact on monoculture plantations and showed significantly higher pollination rates in rubber plantations and estimated the higher functional composition than in forest and jungle rubber system.

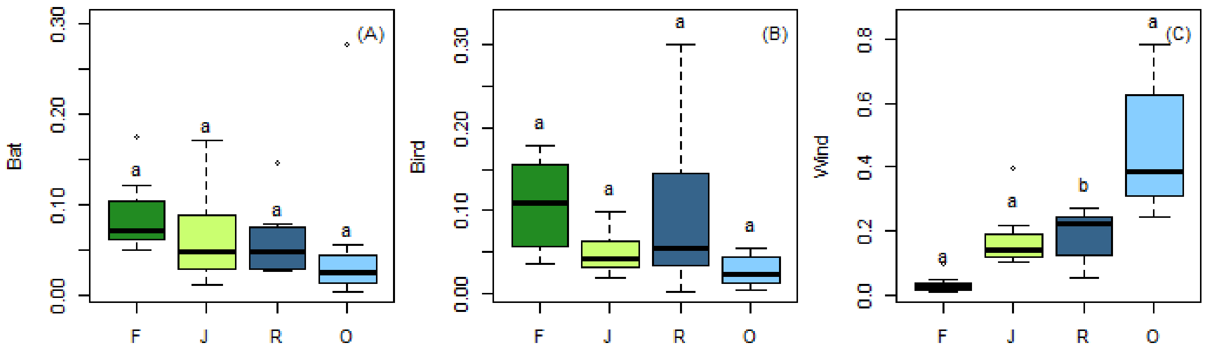


Figure 9: Ecological plant traits pollination (A), bat (B), bird and (C), wind in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences; (A), p=0.1129 (B), 0.05 (C), p=0.0001.

3.2.5. Fruit type

The functional composition plants with berry fruits were higher in jungle rubber and followed by monoculture plantations. The significance test of forest observed the significance differences across the land-use systems. Plants with drupe fruits reached the highest in rubber plantations and followed by forest, oil palm plantations and jungle rubber system. Similarly, the functional composition of capsule fruits observed the higher in forest and oil palm plantations and followed by jungle rubber and rubber plantations. The composition of plants with fruits capsule, drupe, nut and pod were non-significant whereas berry and follicle fruits differed significantly across land-use systems. The forest and oil palm plantations had generally lower functional composition plants with berry and capsule fruits but drupe fruits were quite higher. Drupe fruits noticed the higher functional composition in oil palm system. Furthermore, the composition of follicle fruits revealed significant differences across land-use systems with higher functional composition in forest and jungle rubber followed by oil palm plantations but it was the least in rubber plantations. On the other hand, nut fruits had higher functional value in rubber plantation (12%) however, it declined in other systems. The pod fruit observed higher in rubber and oil palm plantations and followed by forest and jungle rubber.

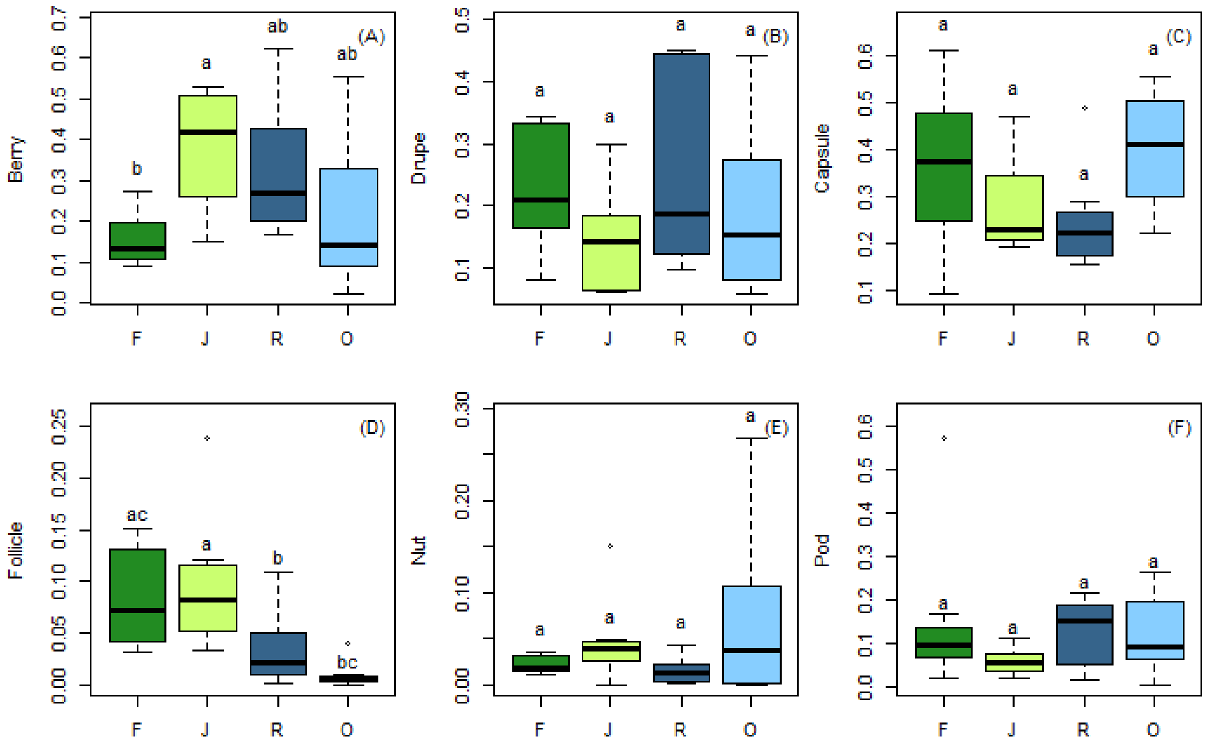
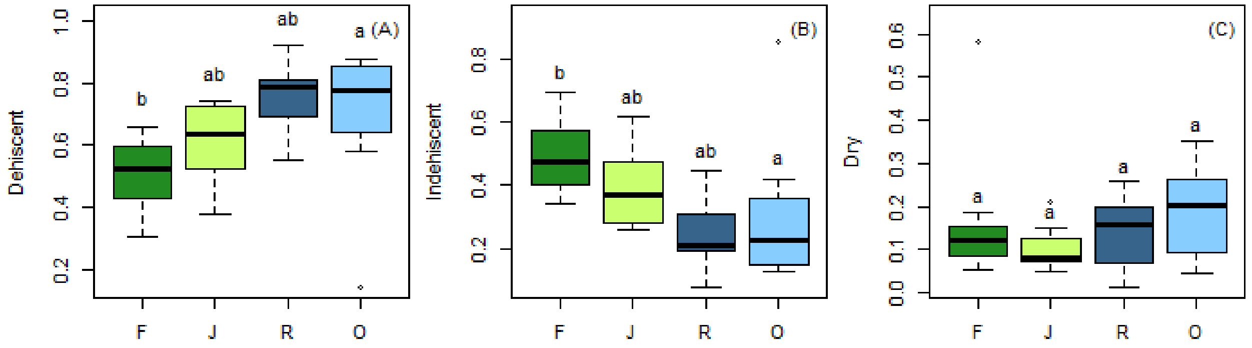


Figure 10: Ecological plant traits fruit type (A), berry (B), capsule (C), drupe (D), follicle (E), nut and (F), pod in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p=0.0119 (B), p=0.078 (C), p=0.2468 (D), p=0.0.004 (E), p=0.0.2925 and (F), p=0.0.253.

3.2.6. Dispersal syndrome, fruit dehiscence and dryness

The functional composition of fruit dehiscence and dryness showed the significantly different functional composition across land-use systems. The functional composition of plants with dehiscent fruits were higher in monoculture plantations and followed by jungle rubber and forest systems but did not show the significant differences in jungle rubber and rubber plantations. Similarly, plants with indehiscent fruits had the higher functional composition in jungle rubber and rubber plantations and followed by forest and oil palm plantations. The fruit dryness had no significant variations in functional composition across land-use systems. All four land-use systems harbored the higher functional composition of plants with fleshy fruits in contrast to plants of dry fruits.

The wind-dispersed (anemochorous) plants were significantly higher in forest and had in turn greater functional composition but it was the least in other system. The significance test did not show the variations of wind-dispersed plants between jungle rubber and monoculture plantations. Likewise, the functional composition of self-dispersed (autochorous) plants noticed higher proportions in monoculture plantations but it was the least and had lower composition in forest and jungle rubber system. The significant test of water-dispersed (hydrochorous) plants showed non-significance across the land-use systems and had greater functional composition in monoculture plantations and followed by jungle rubber and forest system. So, water-dispersed plants increased in monoculture plantations as compared to the forest and jungle rubber. The animal-dispersed plants had significantly higher functional composition and had higher roles for seed dispersion and recruitment of plants across land-use systems. The functional composition of animal-dispersed plants was considerably higher in jungle rubber and followed by monoculture plantations and forest. The functional composition of animal-dispersed seed did not differ between forest and rubber plantations as well as in jungle rubber and oil palm plantations.



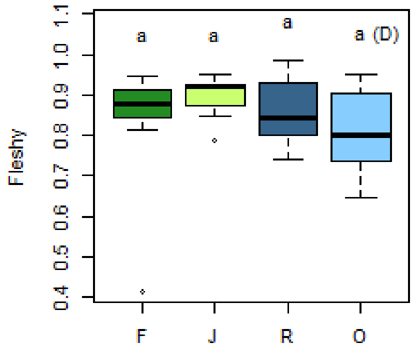


Figure 11: Ecological plant traits: dehiscence and dryness (A), dehiscent (B), indehiscent (C), dry fruit and (D), fleshy fruit in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p=0.001 (B), p=0.025 (C), p=0.47 (D), p=0.49

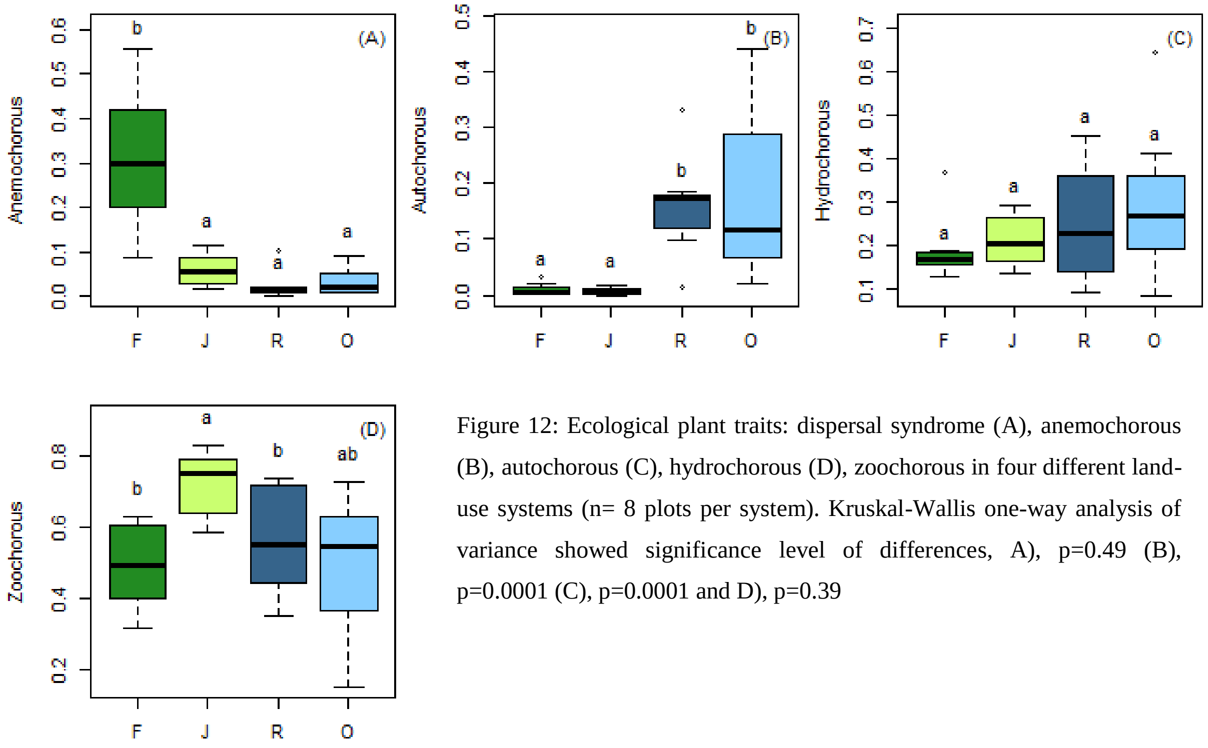


Figure 12: Ecological plant traits: dispersal syndrome (A), anemochorous (B), autochorous (C), hydrochorous (D), zoochorous in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences, A), p=0.49 (B), p=0.0001 (C), p=0.0001 and D), p=0.39

3.3. Functional composition of plant traits at individual level in different land-use systems

The trait composition at individual plants level assessed to estimate the comparisons among the ecologically the most important traits across land-use systems. Some traits such as woodiness, pollination syndrome i.e. insect (bee, beetle, fly and moth), bat, bird and wind and seed dispersal syndrome i.e. autochorous, anemochorous, hydrochorous and zoochorous were compared with the species occurred in four land-use systems. According to the results, we found the variations in trait functional composition across the land-use systems.

3.3.1. Woodiness

The composition of woody trait experienced the highest functional composition in forest and jungle rubber and followed by rubber and oil palm plantations. Overall, the functional composition of woody trait across land-use systems found significantly different but the significance test between forest and jungle rubber as well as monoculture plantations did not vary in functional composition. Forest and jungle rubber displayed the highest composition of woody traits with non-significance functional composition. Similarly, the non-woody trait showed the highest in monoculture plantations however, forest and jungle rubber presented lower functional composition across the land-use systems. As compared to the species level, the woodiness at individual level showed similarity in functional composition across land-use systems.

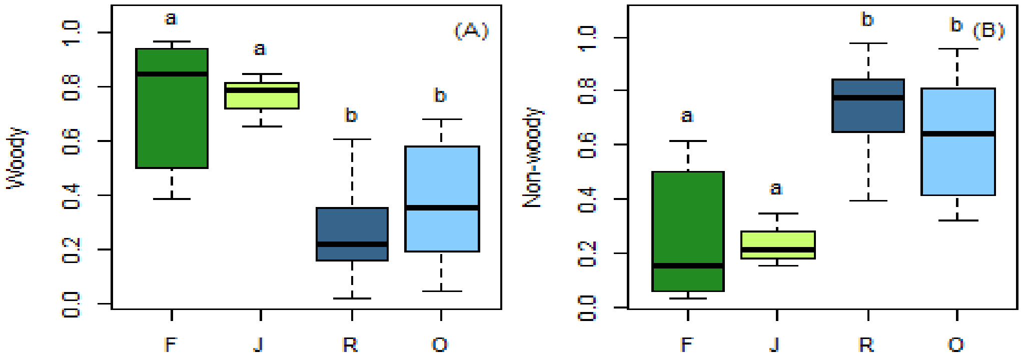
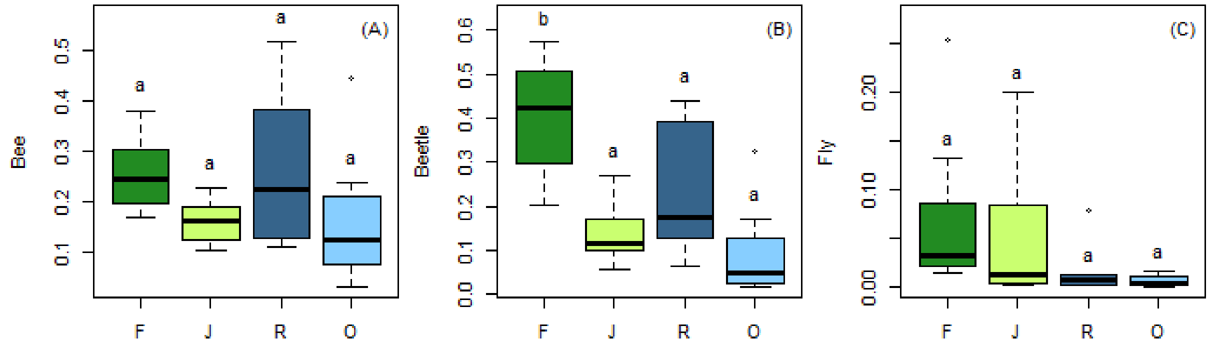


Figure 13: Ecological plant traits in individual level: woodiness (A), woody (B), non-woody in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p>2.2e-16 (B), p>0.0001

3.3.2. Pollination syndrome

3.3.2.1. Insect pollination

The functional composition of bee and fly pollinated plant composition did not vary significantly however; beetle and moth pollinated plant's composition differed significantly across four land-use systems. Bee pollinated plants accounted higher composition in rubber plantations and followed by forest, oil palm plantations and jungle rubber. The insect; beetle pollinated plant's composition displayed the highest functional composition in forest and followed by rubber plantations, jungle rubber and oil palm plantations. It played influential roles in forest and rubber plantations but it was the least in jungle rubber and oil palm plantations. Fly had similar functional composition in forest and jungle rubber but was the least in monoculture plantations. Similarly, moth pollinated plant's had the higher functional composition in forest and had less than half in other systems. And the functional composition at individual level did not show noticeable variations in functional composition as compared to species level.



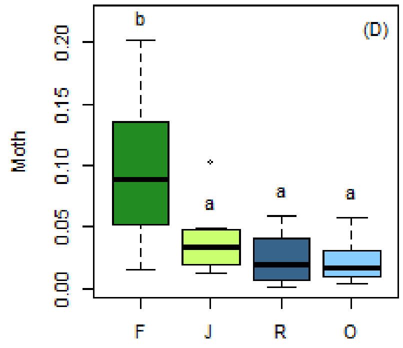


Figure 14: Ecological plant traits at individual level: insect pollination (A), bee (B), beetle (C), fly and (D), moth in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p=0.001 (B), p=0.0025 (C), p=0.0001 (D), p=0.0001

3.3.2.2. Bat, bird and wind pollination

The pollinators; bat, bird and wind showed significance differences across land-use systems. Bat showed the highest functional composition in jungle rubber and followed by monoculture plantations while bat visited the least in forest system. Similarly, bird had higher functional composition in monoculture plantations and was lower in jungle rubber and forest. The results illustrated that bird preferred agro-based monoculture plantations than forest and jungle rubber. The wind pollination was significantly higher in oil palm plantations as compared to the other systems.

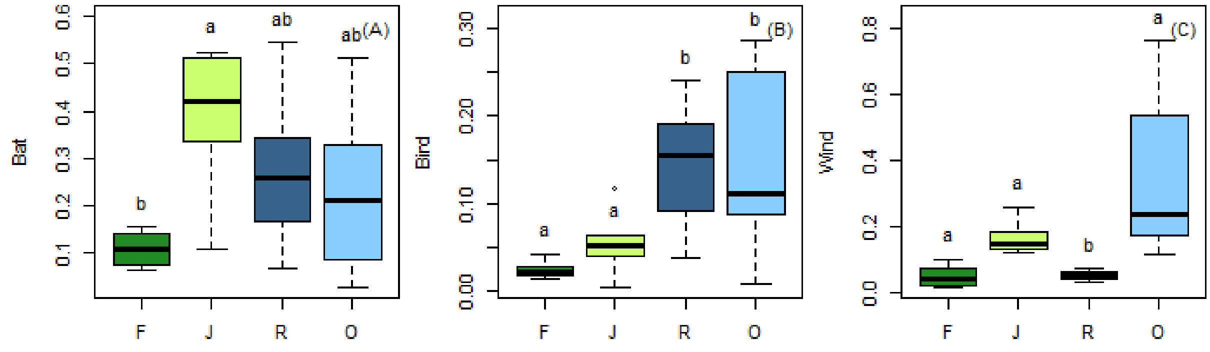


Figure 15: Ecological plant traits at individual level: insect pollination (A), bee (B), beetle (C), fly and (D), moth in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p<0.0001 (B), p>0.003 and (C), p>2.2e-16.

3.3.3. Dispersal syndrome

Wind-dispersed (anemochorous) plants had the highest functional composition in forest but it was the least in other systems and the significant test showed variations across the land-use systems. The results of self-dispersion (autochorous) showed significantly higher in monoculture plantations but it was non-significance in forest and jungle rubber. Similarly, water-dispersed (hydrochorous) plants had non-significance differences across land-use systems but the functional composition showed higher in monoculture plantations followed by jungle rubber and forest. The animal-dispersed (zoochorous) plants had the higher composition in jungle rubber and monoculture plantations followed by forest. And the significant test displayed significant variations across land-use systems.

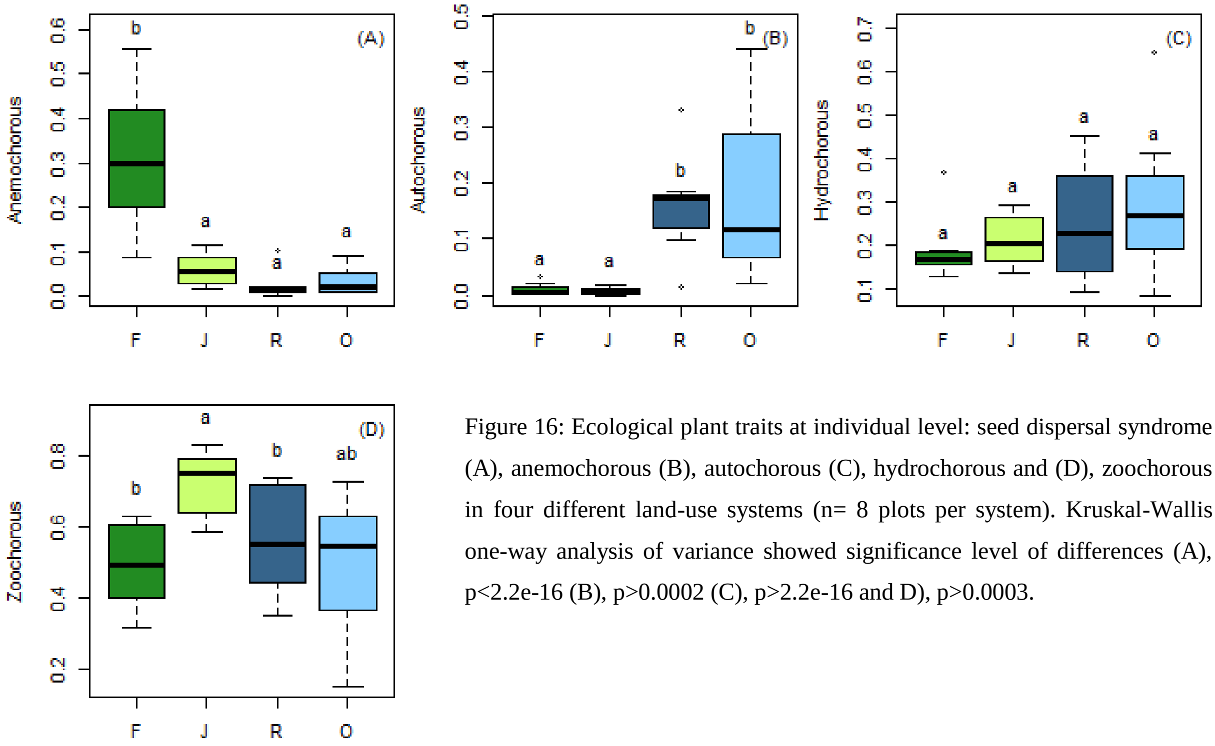


Figure 16: Ecological plant traits at individual level: seed dispersal syndrome (A), anemochorous (B), autochorous (C), hydrochorous and (D), zoochorous in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p<2.2e-16 (B), p>0.0002 (C), p>2.2e-16 and D), p>0.0003.

3.4. Functional traits dissimilarity

3.4.1. Multi-dimensional scaling of functional plant traits

We observed the non-metric multidimensional scaling (NMDS) ordination based dissimilarity of ecological plant traits across four land-use systems and visualized the significant variations in the compositional dissimilarity. The NMDS ordination revealed the distinct plant trait groups for forest and jungle rubber (Fig.17) but two monoculture plantations performed higher compositional similarity to each other. The monoculture plantations i.e. rubber and oil palm plantations showed similarities based on the higher degree of overlap in confidence area. On the other hand, the traits composition in jungle rubber and forest systems were clear separations from the other systems. Forest and jungle rubber plots resulted the significant amount of higher traits composition. It appeared outside the confidence area and also within forest confidence area indicating a higher traits composition similarity to jungle rubber plots than to other monoculture plantations.

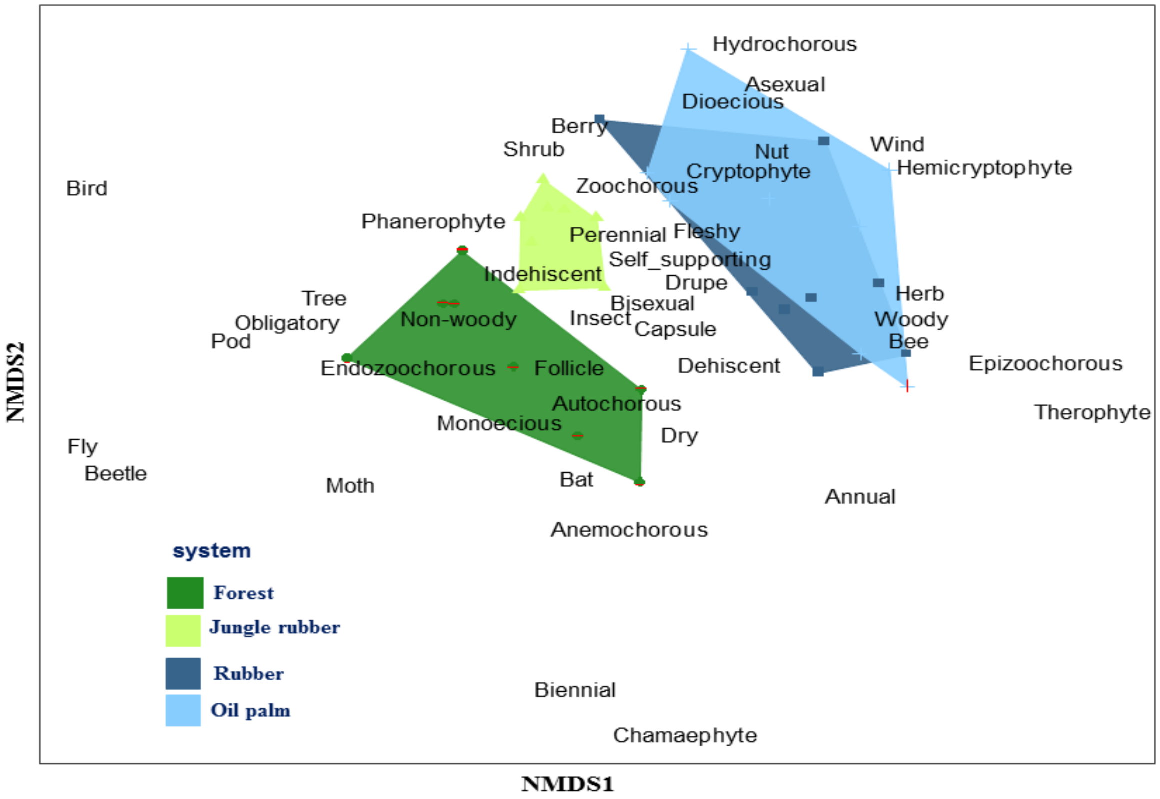


Figure 17: Functional traits composition of the four land-use system as produced by the non-metric multidimensional scaling (NMDS) ordination based on Bray-Curtis dissimilarity of traits between plots (n=8 plots per system). Polygon shows core part of the corresponding system of ecological plant traits.

3.5. Relationships between functional diversity indices and taxonomic diversity at species and individual level

This is a vital component of biodiversity which encompasses the wide range of functional ecological traits of plants that can be measured by the functional diversity indices i.e. functional richness, evenness, dispersion etc. Functional diversity is an assessment of functional traits that influences the multiple aspects of distribution pattern and functional roles for ecosystem functioning in a particular ecological community (Goswami et al. 2017; Song et al. 2014). On the other hand, taxonomic diversity of plants valuate the various pairs of species and individuals in different land-use systems based on the already collected data set from experimental plots and had illustrated in the form of functional diversity indices. Functional diversity indices assemblage the linking of multiple aspects of species dominancy and the numbers of individuals and their functional distinctness (Braun 2015). The taxonomic diversity examined the species richness of all experimental plots to relate with functional diversity indices across four land use systems. The analysis of this relationship revealed simply no linear correlation between taxonomic diversity and indices of functional diversity at species level (Fig. 18b, 18c and 18d) and individual level (Fig. 19a, 19b, 19c and 19d). The diversity indices values were highly scattered at species level as compared to individual's level. But the functional evenness at individual level characterized by the lower evenness as the species richness increased over the area but it did not experience at species level. It could be assumed that the occurrence of numbers of individuals within species differed in functional evenness which affected the functional diversity in a particular ecological community. The functional richness and taxonomic diversity were partly correlated (Fig 18a and 19a). The taxonomic diversity differed with the type of land use systems of study area. The functional richness increased first with increased taxonomic diversity but the variation in relationships could be the cause of diversified species and their number of individuals in forest and jungle rubber. In other words, very low taxonomic diversity in monoculture plantations lead to non-linear relationship and jointly explained more variance in terms of functional diversity

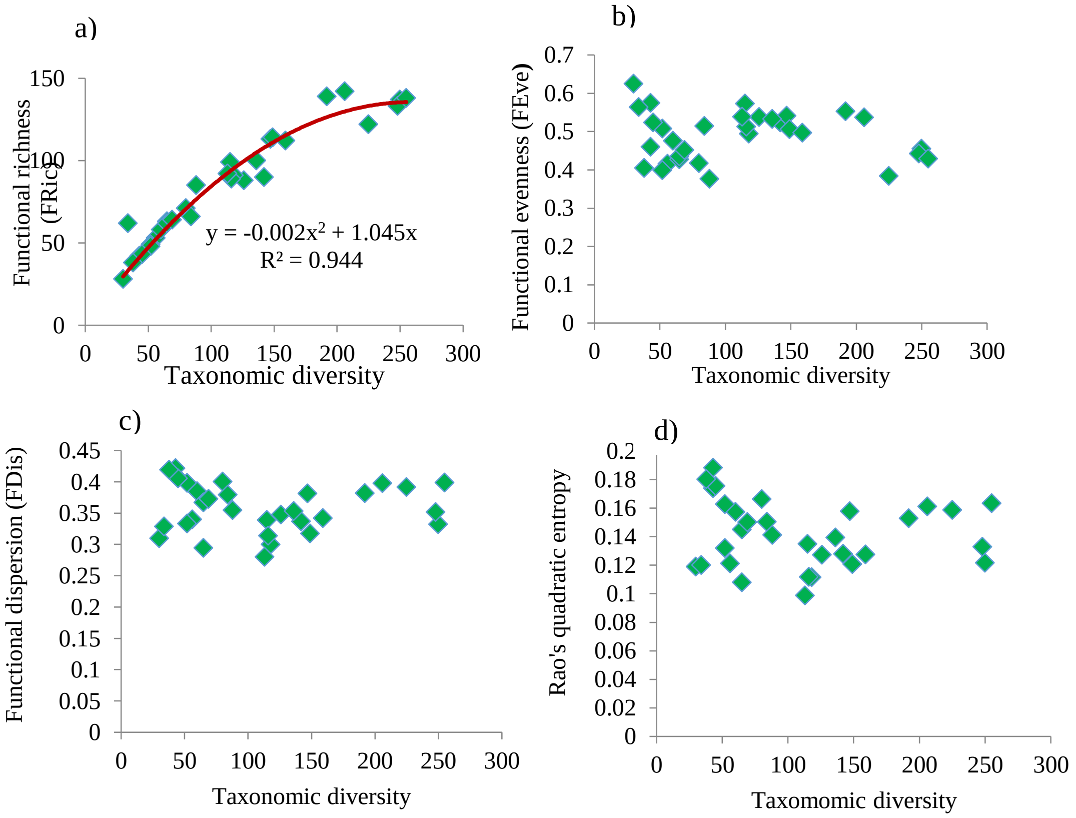


Figure 18: Relationship between the species richness and functional diversity indices at species level a), functional richness b), functional evenness c), functional dispersion d), and Rao's quadratic entropy.

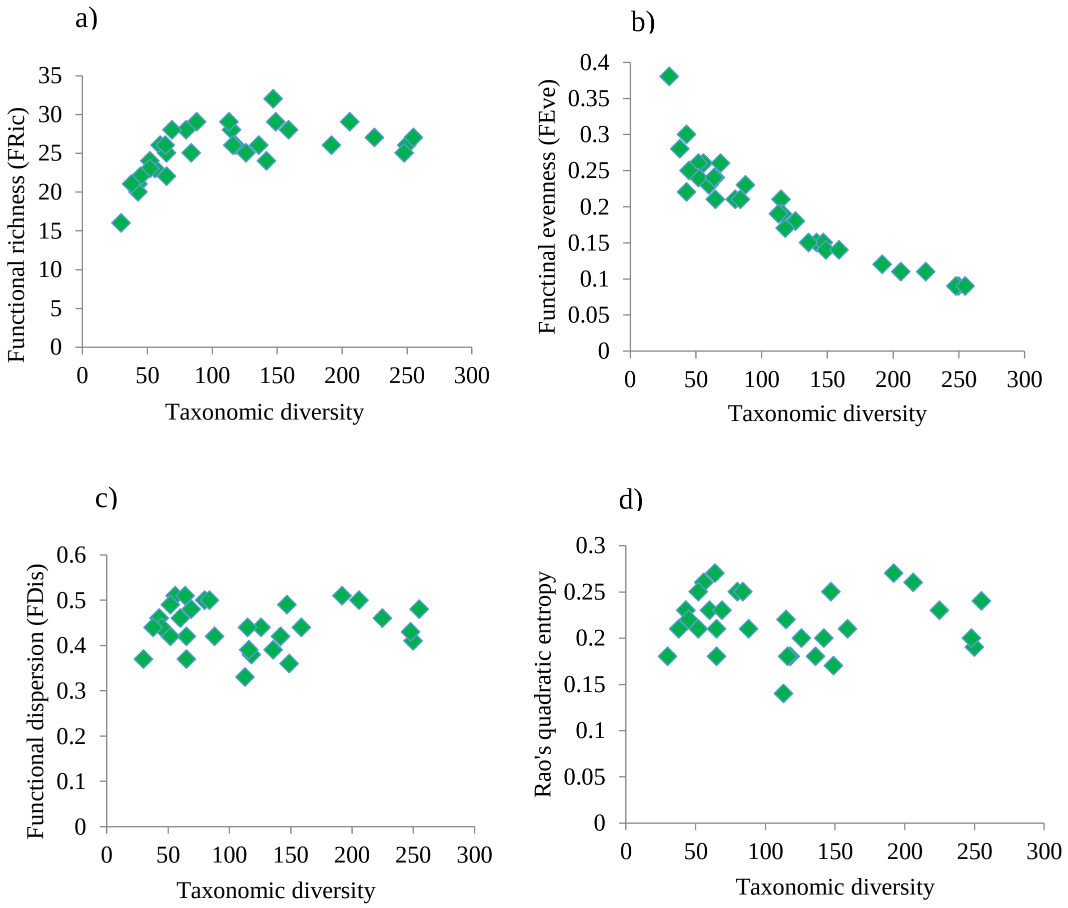


Figure 19: Relationship between the species richness and functional diversity indices at individual level a), functional richness b), functional evenness c), functional dispersion d), and Rao's quadratic entropy.

The relationship between functional diversity and taxonomic diversity showed a correlation (R^2 =0.9854 and confidence interval 95%) and the significance test of functional diversity indices with taxonomic diversity at species level did not show the significant variations at $p>0.001$ (Fig. 20a). Similarly, at individual level, it showed the correlation at $R^2 = 0.5711$ with significance test at $p>0.0035$ (Fig. 20b). The correlation between species level functional diversity and taxonomic diversity showed higher correlation than individual level as produced in the results. The species level relationships did not show linear correlation. And the individual level also showed non-linear correlation between functional diversity and taxonomic diversity. The species level had higher correlation than in individual plants level and found that the higher correlation at species level lead to the better functional diversity as shown in the trend line (Fig. 20a) but the individuals level estimated the declining trend of functional diversity after reaching to the maximum level (Fig. 20b).

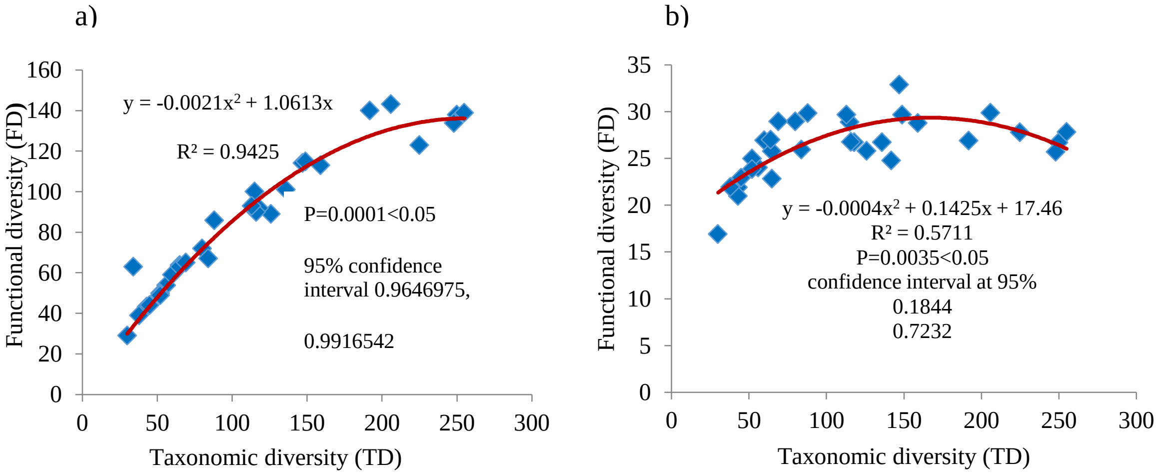


Figure 20: Relationship between functional diversity (FD) and taxonomic diversity (TD) in species and individuals level. The significance between FD and TD: significant at $p>0.05$, n=32 plots).

3.6. Effects of land-use change on functional diversity indices at species and individual level

We explored how land-use changes influenced the functional and taxonomic diversity in a particular ecological plant community. From the results of species (Fig. 21) and individual level (Fig. 22), forest had the highest species richness followed by jungle rubber and monoculture plantations at species level. But at individual level, jungle rubber had the highest individual functional richness and followed by forest and monoculture plantations with considerable fluctuations in diversity values. Functional evenness showed the highest value in species of oil palm plantations and followed by forest and jungle rubber but it had the least value in species of rubber plantations however, the functional evenness considerably increased from forest to oil palm plantations. The functional dispersion and RaoQ showed the similarity of value and their proportionate functional role in both species and individual level. Similarly, as at species level, the individual plant level also did not show the significant variations of functional dispersion and RaoQ indices. We observed that functional diversity value of different diversity indices vary with species and the number of individual plants found in the particular community. For instance, functional richness decreased substantially with reduced species richness over the area and then fluctuated the functional evenness as varied in species per land-use systems. Likewise, as the numbers of individuals increased, functional evenness also climbed up with increased numbers of individuals but other diversity indices such as functional dispersion and RaoQ remained similar between species level and individual level.

3.6.1. Functional diversity indices at species level

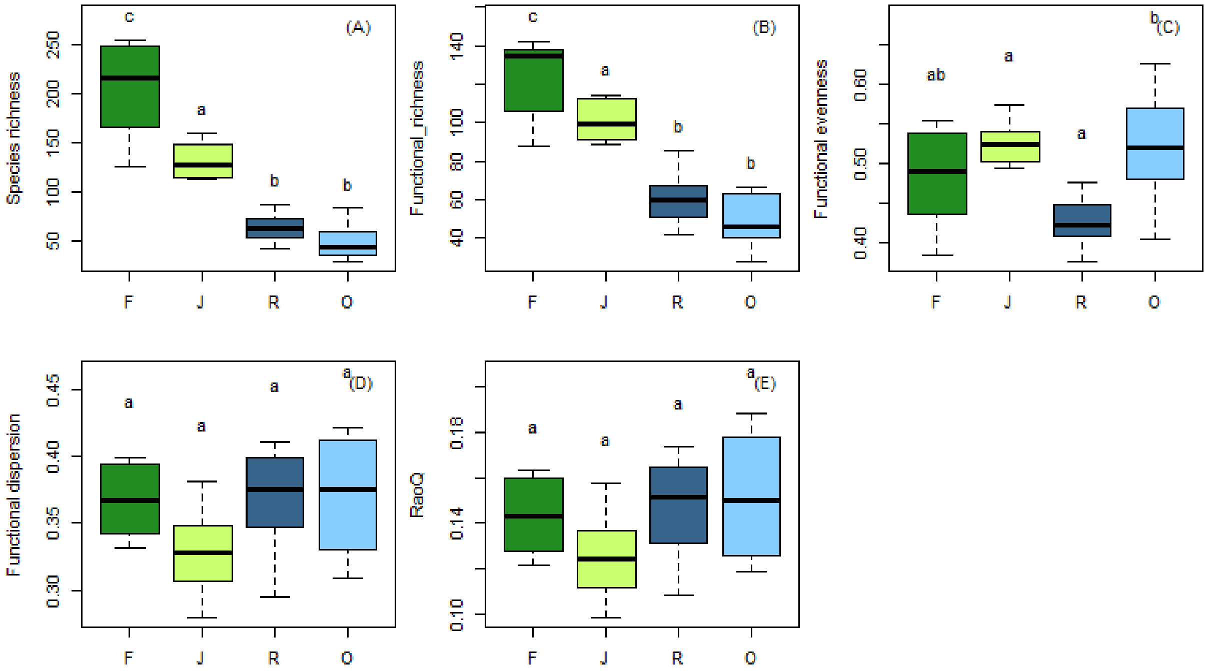


Figure 21: Functional diversity indices at species level (A), species richness (B), functional richness (C), functional evenness (D), functional dispersion and (E), quadratic entropy in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p=0.0001 (B), p>0.0001 (C), p>0.002 (D), p>0.037 and (E), p<0.006.

3.6.2. Functional diversity indices at individual level

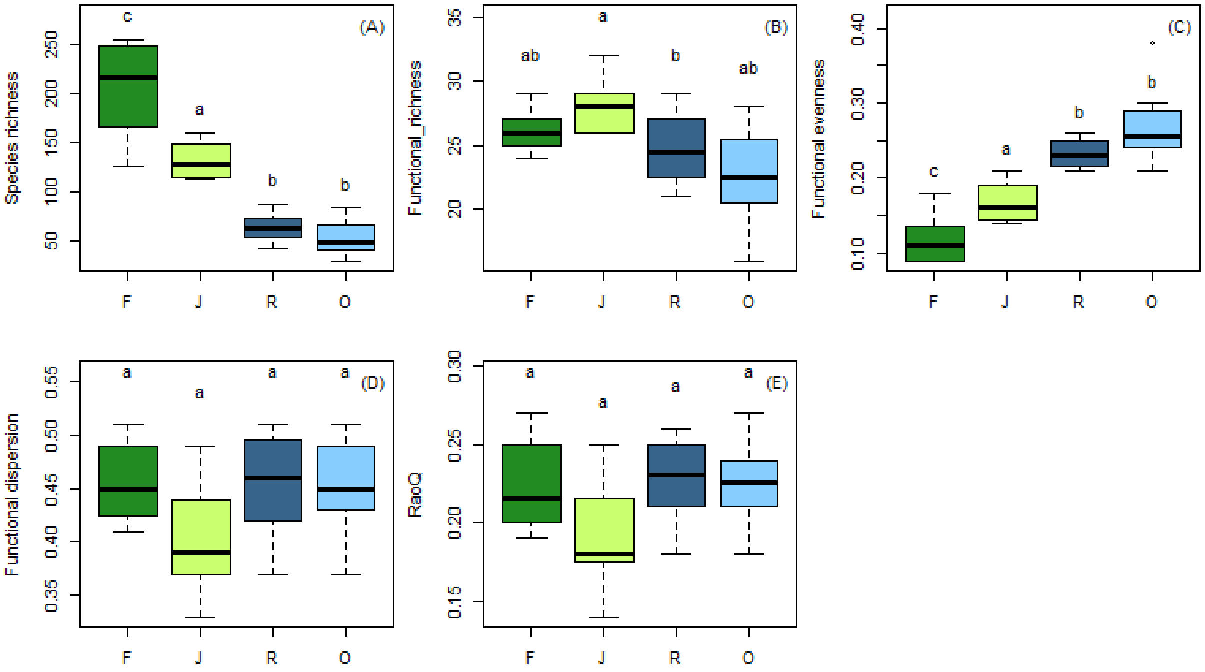


Figure 22: Functional diversity indices at individual level (A), species richness (B), functional richness (C), functional evenness (D), functional dispersion and (E), quadratic entropy in four different land-use systems (n= 8 plots per system). Kruskal-Wallis one-way analysis of variance showed significance level of differences (A), p=0.0001 (B), p>0.0002 (C), p>0.00197 (D), p>0.0745 and (E), p<0.106.

4. Discussion

4.1. Composition of ecological plant traits at species and individual level across land-use systems

The premise of our approach was to observe effects of land-use changes on functional traits and found the significantly different effects of land-use changes on them. The plant traits found across the land-use systems were differed significantly. The forest system stored more than two third proportions of woody traits in an average with the variability in their composition at both species and individual level and followed by the jungle rubber system. Similarly, looking at forest system, it comprised of the major proportions of woody vegetation particularly tree and shrub, phanerophyte and self-supporting plant traits as compared to other systems. This predicted the highest ecological roles in forest system which comprised of the highest species diversity and consequently, the highest functional diversity as predicted in results followed by other systems. So, the higher composition of woody vegetation lead to better ecological functions (Soliveres et al. 2014). And the proportions and compositions of traits significantly differed across land-use systems particularly woodiness, growth form, climber and life cycle of plant traits.

Besides this, the results of the trait sexual reproduction produced greater proportions and composition of monoecious and bisexual plants however, dioeciously reproduced plants found lower in all land-use systems. Generally, the insect-pollinated plants were profound in all land-use systems. The insects such as bee and beetle almost equally contributed for the pollinations of plants across the land-use systems however; bees had dominant effects and attracted by the larger number of plant individuals. The mechanisms related to the reproduction such as pollination and seed dispersal varied significantly over the land-use systems. The diversity of plant reproduction depends upon the attractions and preferences of pollinators and seed dispersers' span in the whole system such as floral attraction signals may have evolutionary consequences (Linhart 2015). Insect pollinated plants slightly varied at both individual level and species level. Insect adaptations in agro-forest based systems are attracted more as compared to the monoculture plantations and enhances the bees and other insect pollinators (Nicholls and Altieri 2013). The insect pollinators; fly and moth pollinations found the least effects in all land-use systems. Similarly, the bat pollinated plant species were more in diverse plant community such as in forest and jungle rubber as compared to monoculture plantations in contrast; wind pollinated plants were dominant in monoculture plantations and had large impact as compared to the other pollinations. The regeneration of plants and their recruitment largely depend upon the ecological behavior of insects and animals because they have indispensable roles for pollination and seed dispersion in a particular plant community. So, the major characteristics of these initial phase of plant regeneration usually depends upon the plant-animal interactions (Eike Lena et al. 2016; Quesada, Rosas, and Aguilar 2011). Bat contributed to pollinate more than two third proportions of plant individuals in all land-use systems except in rubber plantations. Bird pollination almost equally contributed in all systems at species level but large numbers of individual plants were visited in rubber plantations however, it was the least numbers of individuals pollinated by bird in oil palm plantations. The sexual reproduction was closely connected to the pollination and dispersal mechanisms and are crucial for ecological function (Winsa et al. 2017). At species level, wind pollination had higher impact in monoculture plantations and was similar role with bat pollination. At individual level, wind pollinated higher number of plant individuals in forest and rubber plantations than in jungle rubber and oil palm plantations. The pollination is significantly affected by the land use practices and it is the most vulnerable ecological processes in the life cycle of vegetation (Eike Lena et al. 2016). The abiotic pollinator such as wind has more pollen transformation roles in monoculture plantations comparing to the other land use systems as further supported by the findings. Since the insect pollinators are prevalent for the plant reproductions, insects are essential components of the ecological functioning.

As found in the dispersal syndrome, seed dispersal mechanisms were characterized by the presence of dispersal agents such as animals, water, wind and self-dispersal across four land-use systems. At both species and individual level, all land systems were dominated by animal-dispersed plants. Forest and jungle rubber species were highly dispersed by animals but it was lower in monoculture plantations. Similarly, the majority of plant individuals were dispersed by animals and followed by wind and water dispersal but self-dispersion was the least. Furthermore, monoculture plant individuals were almost equally dispersed by wind and followed by water dispersal. But self-dispersed plant individuals were less than one percentage at individual level and approximately 3% at species level. At species level, the seeds of rubber plants were almost equally dispersed by animals and wind. But the higher numbers of individual plants in forest and jungle rubber were dispersed by the dispersal agents such as animals, water and wind as compared to the species level. The dispersion of the higher number of individual plants was self-dispersed as compared to the species level.

4.2. Functional composition of plant traits across land-use system

The variations in functional composition of the plant traits related to the plant dynamics, structures and their plants-animals interactions differed significantly across four land-use systems. The functional compositions of plant traits has large impact on maintaining ecological function and productivity (Newbold et al. 2014). Forest and jungle rubber had larger composition of traits and consequently more functional roles. The functional composition of tree in trait growth form dominated in forest but herb dominated in monoculture plantations. Similarly, the proportion of shrub reached the highest in jungle rubber. It showed that woodiness greatly increased across four land-use system indicated rich ecological function. Forest species contained with more berry and drupe fruits than monoculture plantations however; monoculture plantations contained more capsule fruits than nut and pod fruits. Berry and drupe fruits are edible and more environments friendly and attracted for the animals for their foods and consequently promotes for seed dispersal. Bigger amount of edible and fleshy fruits attracts the higher animal seed dispersal and helps to maintain biodiversity and better interaction of plants and animals otherwise decrease the functional roles of traits (Eike Lena et al. 2016).

Having more insect-pollinated plant species and the number of individuals across land-use systems, bee and beetle had similar roles of pollination across land-use systems at species level. Monoculture plantations consists of high wind-pollinated plants however; bat pollinated plants were dominant in forest and jungle rubber followed by birds and wind-pollinated at species level. At individual level, bee and beetle pollination were dominant across all land-use systems. So, it could be mentioned that the insect has influential functional role across four land-use systems with higher prediction of species diversity. The visits of pollinators and seed dispersers depend upon the type and composition of ecological plants and their variability (Quesada, Rosas, and Aguilar 2011; Neuschulz et al. 2016). Similarly, the large numbers of individual's plants were pollinated by birds in rubber plantations which could have favored the environment for birds. Higher numbers of wind pollinated plants were in forest and monoculture plantations. Few species were pollinated by wind at species level whereas higher numbers of individual plants were pollinated by wind at individual level.

At species level, the seeds of more than two third plant species of forest and jungle rubber were dispersed by animals and followed by monoculture plantations which has crucial role for ecological functioning. The seeds dispersed by animals are profound benefits for plant regeneration and enrich the ecological function. So some plant regeneration is usually mutualistic plant-animal interactions for ecological functioning (Eike Lena et al. 2016). Wind and water dispersed plants species were higher in rubber but had similar dispersal roles in forest and jungle rubber. The monoculture plantations contained highly self-dispersed plant species than other systems.

At individual's plant level, the majority of the plants individuals found in the study area were animal-dispersed across land-use systems. Many plant species depend on animals for seed dispersal in lowland tropical forests that produce fruits are dispersed by animals, in particular by birds and mammals (Howe and Smallwood 1982). Water-dispersed plant individuals were high in oil palm plantations however; it was lower in forest, jungle rubber and rubber plantations. Likewise, larger numbers of individual plants in forest were wind-dispersed but were the least in jungle rubber and oil palm plantations. It was noticeable that higher number of individuals was self-dispersed plants in monoculture plantations.

It would be interesting to investigate the consequences of seed dispersion by different agents across land-use systems, a meta-analysis on the influence of different types of land-use practices on seed dispersion and predation mechanisms, plant recruitment and ecosystem functioning would be valuable.

4.3. Functional traits dissimilarity

The non-metric multidimensional scaling (NMDS) ordination based dissimilarity demonstrates the compositional variations of plant traits across four land-use systems. Forest and jungle rubber encompassed the majority of traits in closer distances however; monoculture plantations had highly scattered and were weakly distributed over the confidence area with larger distances. When the forest converted to monoculture plantations, it lead to alter traits composition as found in results. Furthermore, the polygon of monoculture plantations was almost overlapped. This caused the similar traits composition and similar pattern of traits distribution in monoculture plantations and this ultimately caused the functional evenness. These monoculture plantations combined to reveal the similarity of plants traits composition. They did not show significant differences and it showed the high degree of overlap and similarity in traits composition within confidence areas. Forest had diverse plant species though lower number of individuals and encompassed higher composition of traits which indicated the high species diversity and ultimately caused the rich functional richness and functional dispersion. The higher proximities between traits estimated the higher similarity of traits across land-use systems and followed by jungle rubber but monoculture plantations had lower species and higher number of individuals with lower composition of plant traits. So that, the visualization of high number of traits dimension achieve low stress values but frequently better closeness to each other (Zhu and Yu 2009) and the higher similarity of functional roles of traits. However, the effects of functional traits vary considerably (Aranzana et al. 2005).

4.4. Functional diversity across land-use system

The general view of functional diversity as a key component to perceive ecosystem and ecological functioning (Song et al. 2014) which reflects the plants and their functional traits with collective effect on ecological functioning by the interactions (Schöb, Butterfield, and Pugnaire 2012). As we analyzed the functional diversity across four land-use systems, forest confined the high species and functional richness as already recorded the high number of individuals and species. At species level, we detected a significant reduction of species and functional richness in jungle rubber and monoculture plantations but functional evenness observed similar proportions with noticeable decline in rubber plantations. It shows that lower species diversity leads to lower functional richness and ultimately causes the functional evenness. Functional dispersion and RaoQ were fluctuated over the land-use systems with non-significance differences in indices values. At individual level, species richness had similar trend of functional richness fluctuated across the land-use systems and appeared consistently low number of individuals and species. It indicates that conversion of forest to agroforests and monoculture could result in losses of functional groups and could lead to eventual losses of associated ecosystem functioning (Goswami et al. 2017; Midgley 2012). On the other hand, monoculture plantations have no significant effects on functional dispersion and Rao's entropy with greater value and showed significantly higher dispersion and Rao's quadratic entropy diversity indices. Here, the higher functional dispersion and functional evenness found in monoculture communities suggests that they are subjected to more diffuse ecological filtering (Mumme et al. 2015). The functional richness increased with higher species diversity and vice-versa in monoculture plantations at species level however; at individual level, some fluctuations was observed across land-use systems with non-significance functional richness in forest and oil palm plantations.

4.5. Relationships between functional diversity and taxonomic diversity

Since the findings showed the functional diversity and taxonomic diversity across four land-use systems, it is very interesting to compare the functional diversity and taxonomic diversity so we tried to illustrate the relationships between them. The relationships between these two components have paramount effect on ecological functioning as found in the results. The global biodiversity comprises not only the sum of taxonomic measurements such as individual species but also their ecological and functional diversity (Edie, Jablonski, and Valentine 2018; Grass et al. 2015). The ecosystem functioning of broad functional and taxonomic diversity generalizes the ecological relatedness among the various taxa and can thus calibrates the stability in macro-ecological and macro-evolutionary levels (Bush and Novack-Gottshall 2012; Novack-Gottshall 2007). As we calculated the correlation effects between the taxonomic diversity and functional diversity indices, we observed simply no correlation and fluctuated across the land-use systems. Functional diversity indices such as functional evenness, functional dispersion and Rao's quadratic entropy are highly scattered over the taxonomic scales which indicated the varied in functional diversity in a particular ecological system however; functional richness and taxonomic diversity propelled towards the correlation. We could interpret that the associations between functional diversity indices and taxonomic diversity are positive and independently of the land-use systems.

5. Conclusion

This study demonstrated the distribution pattern of functional traits of plants and their similarities and dissimilarities along with their functional roles in response across four land-use systems. The ecological and functional composition of plant traits fluctuated over the different land-use practices. Particularly, forest and jungle rubber had higher variations and dissimilarities in traits and their functional roles as compared to the monoculture plantations. So that, tropical land-use changes from forest to intensively managed agroforest plantations could alter the functional plant traits and their functional stability of diverse community by impacting their functional trait composition. Similarly, the functional composition of plant traits vary with in species and number of individuals of plants found in a particular vegetation community. In general, our results suggest that higher assemblages of functional plant traits containing in forest and jungle rubber tend to more variations in functional roles in ecological functions than more associated traits of monoculture plantations. Ultimately, these findings suggest that monoculture plantations are highly susceptible to losing entire ecological functions such as lower species richness and higher functional evenness and functional dispersion in monoculture plantations observed at species level. Similarly, at individual level; it presented the highest species richness and functional richness but lower functional evenness with increased species richness. It concluded that the higher species diversity lowered the functional evenness at individual level however; it increased the functional evenness at species level. There is very high impact and variations of insects (i.e. bee, beetle, fly and moth) and other pollinators i.e. bat, bird and wind. The seed dispersers were concentrated in more diverse systems than in monocultures plantations in most cases. However; wind pollination had greater impact in monoculture plantations than in diverse land-use systems that are important for reproduction and recruitment of plants in a particular ecological community. Despite these concerning results, our study also provides insight into the potentially higher level of taxonomic diversity, functional diversity in forest and jungle rubber system following monoculture plantations and associated to the prosperous ecological functions. We tried to cover the ecologically important plant traits and their functional roles across four land-use systems. And it also provided the plant-animal interactions based on pollination, reproduction and dispersion mechanisms and their relationships in response to the land-use systems for ecological function. Finally, the future studies focused on land-use change effects on ecological plant traits will undoubtedly improve our knowledge on the generality of the ecological plant trait patterns found in our study.

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7. Appendices

a) Appendix A

Table A.1: Functional composition of ecological plant traits at species level

system	non_woody	woody	herb	shrub	tree	obligatory	self_supporting	annual	biennial	perennial	chamaephyte	cryptophyte	hemicryptophyte	phanerophyte
F	0.586098	0.413902	0.52396	0.219063	0.256977	0.121116	0.878884	0.293839	0.160611	0.54555	0.319115	0.090047	0.082148	0.508689
F	0.614987	0.385013	0.616095	0.070506	0.3134	0.059062	0.940938	0.430048	0.190107	0.379845	0.448136	0.134367	0.040605	0.376892
F	0.06953	0.93047	0.06544	0.388548	0.546012	0.393661	0.60634	0.003067	0.046012	0.95092	0.011247	0	0.035787	0.952965
F	0.068644	0.931356	0.078814	0.069492	0.851695	0.261864	0.738136	0.001695	0.035593	0.962712	0.011864	0	0.028814	0.959322
F	0.035579	0.964421	0.042392	0.280848	0.67676	0.283876	0.716124	0.002271	0.028009	0.96972	0.003028	0.009084	0.02271	0.965178
F	0.049846	0.950154	0.049846	0.326154	0.624	0.294769	0.705231	0.004923	0.036923	0.958154	0.006154	0.031385	0.002462	0.96
F	0.231019	0.768981	0.234259	0.241204	0.524537	0.298611	0.701389	0.181481	0.014815	0.803704	0.1875	0.013426	0.004167	0.794907
F	0.41205	0.58795	0.412907	0.230725	0.356368	0.221873	0.778127	0.393775	0.005997	0.600228	0.396916	0.003427	0.002284	0.597373
J	0.347478	0.652522	0.446757	0.154524	0.398719	0.100881	0.899119	0.095276	0.106485	0.798239	0.11209	0.13771	0.027222	0.722978
J	0.322085	0.677915	0.343176	0.480566	0.176258	0.110877	0.889123	0.0464	0.052124	0.901476	0.052425	0.069298	0.163001	0.715276
J	0.224205	0.775795	0.220326	0.297905	0.481769	0.133437	0.866563	0.005431	0.02405	0.97052	0.017067	0.171451	0.006982	0.8045
J	0.201655	0.798345	0.239547	0.52439	0.236063	0.083188	0.916812	0.021341	0.066638	0.912021	0.038763	0.073171	0.044425	0.843641
J	0.203642	0.796358	0.203974	0.625828	0.170199	0.105298	0.894702	0.012252	0.18245	0.805298	0.009934	0.064901	0.134768	0.790397
J	0.236217	0.763783	0.244285	0.487225	0.268489	0.246078	0.753922	0.011654	0.045271	0.943075	0.009413	0.080233	0.118333	0.792022
J	0.16447	0.83553	0.165447	0.443143	0.39141	0.057589	0.942411	0.013665	0.055149	0.931186	0.0449	0.088336	0.014641	0.852123
J	0.155482	0.844518	0.233223	0.266445	0.500332	0.207973	0.792027	0.013953	0.085714	0.900332	0.017276	0.093688	0.016611	0.872425
R	0.69148	0.30852	0.684727	0.308755	0.006517	0.021594	0.978406	0.03298	0.147782	0.819238	0.135925	0.027091	0.508284	0.3287
R	0.97875	0.02125	0.959064	0.03204	0.008895	0.006836	0.993164	0.150152	0.415369	0.434478	0.673832	0.086978	0.175192	0.063998
R	0.391985	0.608015	0.393056	0.577154	0.02979	0.138448	0.861552	0.018217	0.187741	0.794042	0.048435	0.1033	0.132876	0.715388
R	0.832295	0.167705	0.832513	0.153165	0.014322	0.012791	0.987209	0.16213	0.471302	0.366568	0.639117	0.052258	0.129113	0.179512
R	0.60789	0.39211	0.590175	0.380175	0.02965	0.009611	0.990389	0.223004	0.204473	0.572523	0.386771	0.07155	0.124066	0.417614

R	0.740886	0.259114	0.745373	0.178351	0.076276	0.034212	0.965788	0.226584	0.200785	0.57263	0.412227	0.180034	0.103758	0.303982
R	0.85221	0.14779	0.851804	0.138528	0.009669	0.001706	0.998294	0.218963	0.252112	0.528924	0.456451	0.015681	0.375203	0.152665
R	0.81451	0.18549	0.809873	0.148542	0.041586	0.019147	0.980853	0.190202	0.285714	0.524084	0.355049	0.19095	0.245774	0.208227
O	0.361026	0.638974	0.362821	0.55105	0.08613	0.019917	0.980083	0.077158	0.194689	0.728154	0.078055	0.244213	0.027454	0.650278
O	0.774038	0.225962	0.665522	0.195055	0.139423	0.021291	0.978709	0.245879	0.501374	0.252747	0.126374	0.071429	0.445742	0.356456
O	0.318008	0.681992	0.287356	0.149425	0.563218	0.034483	0.965517	0.091954	0.183908	0.724138	0	0.08046	0.206897	0.712644
O	0.731563	0.268437	0.761062	0.099705	0.139233	0.037168	0.962832	0.095575	0.289086	0.615339	0.077876	0.309735	0.379941	0.232448
O	0.843349	0.156651	0.83922	0.124039	0.036742	0.023213	0.976787	0.260325	0.176873	0.562803	0.655511	0.033609	0.143122	0.167758
O	0.557849	0.442151	0.558529	0.330615	0.110856	0.020048	0.979952	0.047995	0.339195	0.61281	0.214237	0.138974	0.203109	0.44368
O	0.95362	0.04638	0.95362	0.025515	0.020865	0.00553	0.99447	0.264706	0.521619	0.213675	0.551785	0.038084	0.329814	0.080317
O	0.473412	0.526588	0.473412	0.367403	0.159185	0.058356	0.941644	0.089088	0.357044	0.553867	0.085981	0.296271	0.062845	0.554903

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Table A.2: Functional composition of ecological plant traits at species level

system	asexual	bisexual	dioecious	monoecious	bat	bee	beetle	bird	fly	moth	wind	berry	capsule	drupe	follicle	nut	pod
F	0.005266	0.352291	0.037388	0.605055	0.174829	0.170616	0.4792	0.063191	0.041074	0.046867	0.024223	0.273828	0.399684	0.21643	0.050553	0.010005	0.0495
F	0.000738	0.119601	0.070875	0.808786	0.05168	0.234404	0.527501	0.122554	0.018826	0.032853	0.012182	0.219638	0.608343	0.081949	0.036914	0.034699	0.018457
F	0.001022	0.396728	0.232106	0.370143	0.050102	0.543967	0.127812	0.035787	0.116564	0.109407	0.01636	0.138037	0.351738	0.342536	0.046012	0.01636	0.105317
F	0.004237	0.128814	0.068644	0.798305	0.069492	0.345763	0.091525	0.048305	0.05339	0.363559	0.027966	0.089831	0.092373	0.201695	0.032203	0.012712	0.571186
F	0.004542	0.304315	0.240727	0.450416	0.12112	0.344436	0.155185	0.177896	0.029523	0.141559	0.03028	0.173354	0.218774	0.341408	0.150643	0.029523	0.086298
F	0.001231	0.364308	0.297231	0.308923	0.085538	0.352615	0.186462	0.156308	0.074462	0.046769	0.097846	0.123692	0.278154	0.324308	0.149538	0.033846	0.090462
F	0.001389	0.262037	0.153704	0.58287	0.070833	0.289815	0.326389	0.156019	0.032407	0.078704	0.045833	0.124537	0.390741	0.183333	0.113426	0.021296	0.166667
F	0.001428	0.214449	0.140491	0.643347	0.071388	0.221302	0.521416	0.093661	0.029983	0.042547	0.019703	0.09052	0.549971	0.146773	0.094232	0.016276	0.102227
J	0.053643	0.168135	0.340272	0.43795	0.055244	0.22498	0.089672	0.040833	0.052842	0.142514	0.393915	0.181745	0.394716	0.183347	0.08807	0.040833	0.111289
J	0.044592	0.570955	0.175655	0.208798	0.097921	0.10696	0.080446	0.019283	0.42332	0.163603	0.108466	0.472431	0.19072	0.18379	0.050919	0.035553	0.066586
J	0.157486	0.323507	0.241272	0.277735	0.076804	0.150504	0.069046	0.067494	0.222653	0.272304	0.141195	0.342901	0.206362	0.128782	0.110163	0.149728	0.062064
J	0.047038	0.621951	0.124564	0.204268	0.040505	0.179007	0.086237	0.041376	0.439895	0.108449	0.10453	0.484321	0.203397	0.154181	0.07622	0.043554	0.038328
J	0.016225	0.648676	0.156623	0.178477	0.010927	0.234768	0.050331	0.031788	0.513907	0.016225	0.142053	0.529139	0.29404	0.064238	0.03245	0	0.080132
J	0.03048	0.529359	0.265352	0.17481	0.034514	0.389511	0.066786	0.028238	0.267593	0.087853	0.125504	0.363962	0.469745	0.064993	0.051546	0.030031	0.019722

J	0.051733	0.502196	0.143973	0.302099	0.021962	0.083943	0.051245	0.059541	0.392387	0.175695	0.215227	0.526598	0.212787	0.061005	0.121035	0.047828	0.030747
J	0.024585	0.502326	0.098339	0.374751	0.1701	0.187375	0.162791	0.097674	0.088372	0.134219	0.159468	0.151495	0.24186	0.299003	0.238538	0.021927	0.047176
R	0.019238	0.528308	0.422458	0.029996	0.026541	0.178956	0.434079	0.002356	0.292187	0.011072	0.05481	0.304594	0.189713	0.449391	0.017354	0.015469	0.023479
R	0.023392	0.617247	0.179475	0.179886	0.06128	0.357466	0.170826	0.180545	0.006013	0.002059	0.22181	0.195124	0.486698	0.217033	0.001235	0.023309	0.0766
R	0.061937	0.729104	0.0988	0.110159	0.02679	0.141234	0.174668	0.071367	0.520574	0.007715	0.057651	0.623232	0.155165	0.097728	0.109087	0.002143	0.012645
R	0.018476	0.733027	0.047557	0.20094	0.069968	0.208812	0.054335	0.299989	0.13775	0.005466	0.22368	0.471739	0.242156	0.109435	0.010495	0.004373	0.161802
R	0.016396	0.620642	0.063195	0.299768	0.029399	0.274578	0.055845	0.034047	0.34173	0.005151	0.25925	0.384698	0.206546	0.133865	0.041397	0.01985	0.213644
R	0.130118	0.441952	0.155917	0.272013	0.077958	0.266966	0.127874	0.031969	0.169377	0.052159	0.273696	0.235558	0.287156	0.159282	0.060011	0.042064	0.215928
R	0.017225	0.435002	0.367241	0.180533	0.145028	0.090104	0.369516	0.038593	0.125366	0.006094	0.225301	0.165015	0.233263	0.439064	0.007556	0.000731	0.154371
R	0.043306	0.461257	0.266941	0.228497	0.034555	0.157891	0.402767	0.110247	0.088332	0.016156	0.190052	0.204338	0.158639	0.449813	0.026328	0.010396	0.150486
O	0.081644	0.527185	0.216759	0.174412	0.013458	0.039476	0.020097	0.045936	0.494886	0.075543	0.310605	0.553562	0.233447	0.059394	0.005204	0.070519	0.077875
O	0.018544	0.510302	0.262363	0.208791	0.019918	0.055632	0.018544	0.017857	0.052885	0.054945	0.78022	0.081044	0.221841	0.440934	0.002747	0.123626	0.129808
O	0.015326	0.233717	0.597701	0.153257	0.030651	0.141762	0.015326	0.05364	0	0.003831	0.754789	0.153257	0.544061	0.206897	0	0.091954	0.003831
O	0.305015	0.365782	0.105605	0.223599	0.054867	0.146313	0.041298	0.041298	0.043658	0.362242	0.310324	0.100295	0.377581	0.166372	0.00236	0.267257	0.086136
O	0.001567	0.651666	0.044432	0.302336	0.012674	0.478354	0.016377	0.010396	0.113928	0.008117	0.360154	0.129735	0.463828	0.140701	0.006266	0.000142	0.259328
O	0.002888	0.730292	0.18527	0.081549	0.003908	0.366718	0.065155	0.014271	0.302752	0.005946	0.24125	0.31422	0.554621	0.074584	0.009429	0	0.047146
O	0.012695	0.448969	0.207516	0.33082	0.276144	0.112117	0.171694	0.004525	0.019608	0.000503	0.41541	0.02363	0.362996	0.341629	0.003519	0.003519	0.264706
O	0.027279	0.441298	0.374309	0.157113	0.031423	0.071478	0.037638	0.025898	0.316989	0.01761	0.498964	0.339088	0.439572	0.087707	0.040401	0.002072	0.09116

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Table A.3: Functional composition of ecological plant traits at species level

system	dehiscent	indehiscent	dry	fleshy	anemochorous	autochorous	hydrochorous	zoochorous
F	0.532386	0.467615	0.059505	0.940495	0.352291	0.02159	0.183254	0.442865
F	0.517534	0.482466	0.053156	0.946844	0.443706	0.033223	0.159468	0.363603
F	0.478528	0.521472	0.121677	0.878323	0.087935	0.002045	0.366053	0.543967
F	0.661017	0.338983	0.583898	0.416102	0.218644	0.002542	0.147458	0.631356
F	0.305829	0.694171	0.115821	0.884179	0.183952	0.005299	0.184709	0.626041
F	0.380308	0.619692	0.124308	0.875692	0.243077	0.004308	0.169231	0.583385
F	0.553704	0.446296	0.187963	0.812037	0.397685	0.000926	0.161111	0.440278
F	0.642776	0.357224	0.118504	0.881496	0.555397	0.001713	0.127356	0.315534
J	0.382706	0.617294	0.152122	0.847878	0.113691	0.006405	0.291433	0.588471
J	0.650798	0.349202	0.102139	0.897861	0.048509	0.010244	0.135583	0.805664
J	0.586501	0.413499	0.211792	0.788208	0.03879	0	0.214895	0.746315
J	0.727788	0.272213	0.081882	0.918119	0.060105	0.004791	0.178136	0.756969
J	0.716887	0.283113	0.080132	0.919868	0.074834	0.012914	0.279139	0.633113
J	0.61766	0.38234	0.049753	0.950247	0.02017	0.017033	0.186912	0.775885
J	0.741337	0.258663	0.078575	0.921425	0.017082	0.003416	0.148365	0.831137
J	0.466445	0.533555	0.069103	0.930897	0.100332	0.003322	0.249169	0.647176
R	0.921476	0.078524	0.038948	0.961052	0.002591	0.097291	0.452532	0.447585
R	0.66329	0.33671	0.099909	0.900091	0.102545	0.329709	0.213491	0.354254
R	0.794471	0.205529	0.014788	0.985212	0.016074	0.012859	0.239606	0.731462
R	0.553187	0.446813	0.166175	0.833825	0.020444	0.184213	0.090959	0.704384
R	0.821534	0.178466	0.233495	0.766505	0.018531	0.143351	0.099001	0.739117
R	0.724061	0.275939	0.257992	0.742008	0.017947	0.169938	0.180595	0.63152
R	0.792655	0.207345	0.155102	0.844898	0.005606	0.173952	0.343273	0.477169
R	0.784892	0.215108	0.160883	0.839117	0.009274	0.172775	0.37816	0.439791
O	0.838866	0.161134	0.148394	0.851606	0.008254	0.020635	0.241163	0.729948
O	0.699176	0.300824	0.253434	0.746566	0.01511	0.390797	0.307005	0.287088

O	0.149425	0.850575	0.095785	0.904215	0.091954	0.111111	0.643678	0.153257
O	0.745133	0.254867	0.353392	0.646608	0.068437	0.122124	0.141593	0.667847
O	0.875107	0.124893	0.25947	0.74053	0.026488	0.439049	0.083879	0.450584
O	0.864339	0.135661	0.047146	0.952854	0.00756	0.182382	0.241081	0.568977
O	0.581574	0.418426	0.268225	0.731775	0.035194	0.080568	0.295123	0.589115
O	0.804213	0.195787	0.093232	0.906768	0.007597	0.055939	0.412293	0.524171

Note: F-Forest, J-Jungle rubber, R-Rubber plantations, O-Oil palm plantations. All these values were derived from ‘Functcomp’ function of FD package in R version 3.4.1.

b) Appendix B

Table B: Functional composition of ecological plant traits at individual level

system	non woody	woody	bat	bee	beetle	bird	fly	moth	wind	anemochorous	autochorous	hydrochorous	zoochorous
F	0.586098	0.413902	0.129015	0.17009	0.508162	0.029489	0.131648	0.014745	0.016851	0.352291	0.02159	0.183254	0.442865
F	0.614987	0.385013	0.153562	0.222961	0.501661	0.014396	0.024732	0.065338	0.01735	0.443706	0.033223	0.159468	0.363603
F	0.06953	0.93047	0.06544	0.380368	0.201431	0.026585	0.252556	0.05726	0.01636	0.087935	0.002045	0.366053	0.543967
F	0.068644	0.931356	0.062712	0.180508	0.45678	0.024576	0.037288	0.201695	0.036441	0.218644	0.002542	0.147458	0.631356
F	0.035579	0.964421	0.149886	0.301287	0.286904	0.041635	0.031794	0.137774	0.050719	0.183952	0.005299	0.184709	0.626041
F	0.049846	0.950154	0.118154	0.304615	0.310154	0.021538	0.012923	0.132308	0.100308	0.243077	0.004308	0.169231	0.583385
F	0.231019	0.768981	0.092593	0.266204	0.389352	0.017593	0.030556	0.112037	0.091667	0.397685	0.000926	0.161111	0.440278
F	0.41205	0.58795	0.081382	0.214449	0.575385	0.017419	0.015991	0.047401	0.047973	0.555397	0.001713	0.127356	0.315534
J	0.347478	0.652522	0.105685	0.176942	0.127302	0.116894	0.113691	0.103283	0.256205	0.113691	0.006405	0.291433	0.588471
J	0.322085	0.677915	0.525158	0.102139	0.108466	0.064779	0.003013	0.03013	0.166315	0.048509	0.010244	0.135583	0.805664
J	0.224205	0.775795	0.347556	0.137316	0.268425	0.043445	0.01474	0.049651	0.138867	0.03879	0	0.214895	0.746315
J	0.201655	0.798345	0.506533	0.163328	0.119338	0.043554	0.00392	0.045732	0.117596	0.060105	0.004791	0.178136	0.756969

J	0.203642	0.796358	0.521192	0.225828	0.056954	0.037417	0.009934	0.012252	0.136424	0.074834	0.012914	0.279139	0.633113
J	0.236217	0.763783	0.336172	0.203496	0.091439	0.005379	0.199462	0.0381	0.125952	0.02017	0.017033	0.186912	0.775885
J	0.16447	0.83553	0.494388	0.10981	0.110786	0.062958	0.001464	0.018546	0.20205	0.017082	0.003416	0.148365	0.831137
J	0.155482	0.844518	0.336213	0.15814	0.214618	0.062458	0.053821	0.018605	0.156146	0.100332	0.003322	0.249169	0.647176
R	0.69148	0.30852	0.318806	0.111425	0.438634	0.088732	0.00958	0.001413	0.03141	0.002591	0.097291	0.452532	0.447585
R	0.97875	0.02125	0.066963	0.516267	0.171815	0.096121	0.078494	0.002224	0.068116	0.102545	0.329709	0.213491	0.354254
R	0.391985	0.608015	0.546507	0.13652	0.176597	0.039006	0.012216	0.049507	0.039649	0.016074	0.012859	0.239606	0.731462
R	0.832295	0.167705	0.207828	0.488575	0.06483	0.163879	0.006997	0.011807	0.056084	0.020444	0.184213	0.090959	0.704384
R	0.60789	0.39211	0.363842	0.243231	0.080156	0.240907	0.006407	0.023996	0.04146	0.018531	0.143351	0.099001	0.739117
R	0.740886	0.259114	0.247897	0.275379	0.17106	0.218172	0.000561	0.031969	0.054964	0.017947	0.169938	0.180595	0.63152
R	0.85221	0.14779	0.270068	0.120328	0.370085	0.15429	0.000569	0.013243	0.071417	0.005606	0.173952	0.343273	0.477169
R	0.81451	0.18549	0.121915	0.205909	0.41279	0.155423	0.000299	0.059461	0.044203	0.009274	0.172775	0.37816	0.439791
O	0.361026	0.638974	0.511574	0.032478	0.084694	0.077875	0.001256	0.05724	0.234882	0.008254	0.020635	0.241163	0.729948
O	0.774038	0.225962	0.070055	0.095467	0.033654	0.12706	0	0.01511	0.658654	0.01511	0.390797	0.307005	0.287088
O	0.318008	0.681992	0.02682	0.1341	0.019157	0.007663	0.015326	0.038314	0.758621	0.091954	0.111111	0.643678	0.153257
O	0.731563	0.268437	0.096755	0.235988	0.323304	0.096755	0.0059	0.00354	0.237758	0.068437	0.122124	0.141593	0.667847
O	0.843349	0.156651	0.125178	0.444033	0.018513	0.285246	0.000997	0.013956	0.112076	0.026488	0.439049	0.083879	0.450584
O	0.557849	0.442151	0.303942	0.186035	0.059293	0.238532	0.004077	0.016395	0.191726	0.00756	0.182382	0.241081	0.568977
O	0.95362	0.04638	0.294997	0.111237	0.17182	0.263072	0	0.006033	0.152841	0.035194	0.080568	0.295123	0.589115
O	0.473412	0.526588	0.355318	0.059392	0.034876	0.097376	0.015193	0.02279	0.415055	0.007597	0.055939	0.412293	0.524171

Note: F-Forest, J-Jungle rubber, R-Rubber plantations, O-Oil palm plantations. All these values were derived from ‘Functcomp’ function of FD package in R.

c) Appendix C

Table C: Functional diversity indices and their values at species level

System	Species richness	Functional richness	Functional evenness	Functional dispersion	Rap’s quadratic entropy
F	206	146	0.5371451	0.3849064	0.15287623
F	192	142	0.5625558	0.3376171	0.12932253
F	126	95	0.5349608	0.300539	0.10006839
F	142	102	0.5467081	0.2659322	0.08512682
F	250	156	0.497747	0.3323438	0.11728137
F	248	155	0.5114298	0.3563825	0.13455986
F	255	155	0.4906792	0.3784594	0.15024825
F	225	144	0.4755864	0.3871006	0.15798486
J	147	119	0.5558692	0.372901	0.14222249
J	149	123	0.5331082	0.2967703	0.10743803
J	136	100	0.5059541	0.3375015	0.11953806
J	118	98	0.5393751	0.2919725	0.10523037
J	115	97	0.5352085	0.3127264	0.12435683
J	116	90	0.5154029	0.3091516	0.1086128
J	113	97	0.5958707	0.3256751	0.11948443
J	159	110	0.5008315	0.3564966	0.13232541
O	56	54	0.4075811	0.3031754	0.10388454
O	60	57	0.4645595	0.3706367	0.14743963
O	65	62	0.4541533	0.2345572	0.07679932
O	65	63	0.4762077	0.3891648	0.15624287
O	88	84	0.4184637	0.3812652	0.15114089
O	43	42	0.4570907	0.383295	0.15076322
O	52	50	0.4070422	0.3370158	0.12785443
O	80	71	0.415407	0.3712739	0.144306
R	52	49	0.4829549	0.3110769	0.11227138
R	43	40	0.5390101	0.3434655	0.13141344
R	30	29	0.6408297	0.3069329	0.10941459
R	45	43	0.4536686	0.3599258	0.13522149
R	69	64	0.4731086	0.3665654	0.14412774
R	64	60	0.4759241	0.3632689	0.1337812
R	38	37	0.4191861	0.367426	0.14647968
R	84	68	0.482498	0.3498477	0.12870261

Note: F-Forest, J-Jungle rubber, R-Rubber plantations, O-Oil palm plantations. All these indices values were derived from ‘dbFD’ function of FD package in R version 3.4.1.

d) Appendix D

Table D: Functional diversity indices values at individual level

System	Species richness	Functional richness	Functional evenness	Functional dispersion	Rao’s Quadratic entropy
F	206	29	0.11	0.5	0.26
F	192	26	0.12	0.51	0.27
F	126	25	0.18	0.44	0.2
F	142	24	0.15	0.42	0.2
F	250	26	0.09	0.41	0.19
F	248	25	0.09	0.43	0.2
F	255	27	0.09	0.48	0.24
F	225	27	0.11	0.46	0.23
J	147	32	0.15	0.49	0.25
J	149	29	0.14	0.36	0.17
J	136	26	0.15	0.39	0.18
J	118	26	0.17	0.38	0.18
J	115	28	0.21	0.44	0.22
J	116	26	0.19	0.39	0.18
J	113	29	0.19	0.33	0.14
J	159	28	0.14	0.44	0.21
R	56	23	0.26	0.51	0.26
R	60	26	0.23	0.46	0.23
R	65	22	0.21	0.42	0.21
R	65	25	0.24	0.37	0.18
R	88	29	0.23	0.42	0.21
R	43	21	0.22	0.46	0.23
R	52	24	0.26	0.49	0.25
R	80	28	0.21	0.5	0.25
O	52	23	0.24	0.42	0.21
O	43	20	0.3	0.46	0.23
O	30	16	0.38	0.37	0.18
O	45	22	0.25	0.44	0.22
O	69	28	0.26	0.48	0.23
O	64	26	0.24	0.51	0.27
O	38	21	0.28	0.44	0.21
O	84	25	0.21	0.5	0.25

Note: F-Forest, J-Jungle rubber, R-Rubber plantations, O-Oil palm plantations. All these indices values were derived from ‘dbFD’ function of FD package in R version 3.4.1.