Recognising biodiversity in rubber plantations

"Toward a biodiverse rubber estate: Quick biodiversity survey of Bridgestone Sumatra Rubber Estate, North Sumatra"

Project Report

World Agroforestry Centre

Recognising biodiversity in rubber plantations

Report prepared by

Hesti Lestari Tata (editor)

Elok Mulyoutami and Janudianto (chapter 2)

Zuraidah Said, Andree Ekadinata and Atiek Widayati (chapter 3)

Harti Ningsih, Subekti Rahayu and Hesti L. Tata (chapter 4)

Asep Ayat (chapter 5)

Pandam Nugroho, Sephy Noerfahmy, Insan Taufik and Hesti L. Tata (chapter 6)

BRIDGESTONE PROJECT

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World Agroforestry Centre (ICRAF)
Southeast Asia Regional Program
Jl. CIFOR, Situ Gede, Sindang Barang, Bogor 16115
[PO BOX 161, Bogor 16001]
Indonesia
Tel: +62 251 8625415; Fax: +62 251 8625416
Email: icraf-indonesia@cgiar.org
Website: www.worldagroforestrycentre.org/sea

Cover photos: Asep Ayat

Executive summary

Biological diversity (biodiversity) is a description of the number, variety and variability of living organisms, which can be described in term of genes, species and ecosystems. As an ecosystem, tropical rainforest is characterised by high diversity and species richness. In Indonesia, owing to high deforestation, many forest areas, particularly in Sumatra, are declining rapidly. Large forest areas were lost due to interactions between the granting of logging concessions, overcapacity in the pulp and paper industry, increased accessibility to formerly remote areas, spontaneous and state-sponsored migration and profitable opportunities for tree-crop plantations, such as rubber and oil palm. In North Sumatra alone, rubber and oil palm were introduced during the colonial era in the early 1990s. Rubber plantation estates in Dolok Merangir have a long history with the first one being established in 1916 as the site of Goodyear's first rubber plantation. In 2005, the Dolok Merangir and Aek Tarum rubber plantations were sold to Bridgestone, a tire company based in Japan.

Deforestation and transformation of forest cover to other land uses results in a decline in biodiversity. Our study focused on a biodiversity survey on land-cover change in the Dolok Merangir and Aek Tarum rubber plantation areas over the period 1970 to 2010, and the diversity and species composition of vegetation in the rubber plantations compared with rubber smallholder and forest areas surrounding the plantations. Animal diversity studies of birds and bats that play important roles in the ecosystem as pollinators, seed dispersal agents and biological controllers were also undertaken in those three habitats at two sites.

Furthermore, humans as an integral component in the ecosystems play the most important role with a direct influence over land-cover change. The perceptions of local people and their understanding of local activities and their effects on biodiversity were also studied in the research. The overall objective of the research was to assess biodiversity data from the study sites and to make recommendations on how to improve biodiversity in the plantations on the Bridgestone Sumatra Rubber Estate (PT BSRE).

Summary of findings

- Local perceptions of land-use functions and values as well as local preferences for land-use systems were assessed to take into account human and environmental aspects of biodiversity conservation. Six villages of rubber-latex producers were selected within the two study sites and cluster-based sampling was undertaken based on the distance to the forest. All farmers perceived that rubber agroforest was the most important land use as it could provide sources of income, food and environmental values. The second most important land use was smallholder oil palm, followed by smallholder rubber monoculture, as the main sources of cash incomes for households. The rubber or oil palm plantations were used for grazing, in particular for cows and goats, which could cause some problems for the main commodity production of the estate company. A solution to overcome the problem needs to be a priority, such as improving the awareness of villagers about livestock management techniques through extension services and community development.
- The people's understanding of biodiversity was closely associated with livelihoods' patterns and social practices, as biodiversity contributed to their daily needs and was related to specific knowledge. Forests had the highest value for biodiversity, being

important for wild animal habitat and erosion control. Rubber agroforest and rubber monoculture provided better erosion control than oil palm plantation. Villagers recognised some tree species for erosion control, such as bamboo, rattan, betel nut, mahogany, *Hibiscus macrophyllus, Eryhtrina* sp. and *Cyperus rotundus* (a grass of the family Cyperaceae). Even though they were aware of the biodiversity function of rubber agroforests and native forests, the boom in oil palm production and its high prices had influenced farmers' decisions.

- Analysis of land-use and land-cover changes and trajectories of the rubber plantations of Dolok Merangir and Aek Tarum, using the quick biodiversity survey method, was conducted to understand the dynamics of the natural habitat as a result of changes to landscape composition and configuration. From the land-cover change analysis in the Aek Tarum area, we noted that the forest area (undisturbed forest and logged-over forest) decreased from 45 018 ha (56.3%) in 1970 to 10 220 ha (12.8%) in 2010. The biggest rate of forest loss during the study period at Aek Tarum occurred in the 1970–1990 period (1250 ha y^{-1}); while the forest loss rate during 1970–2010 was only 870 ha y^{-1} on average. This forest loss was followed by an increase in tree-based systems, such as rubber monoculture and oil palm. In the Dolok Merangir estate, forest cover in 1970 was 8.3% of the total area (139 353.9 ha) and decreased steadily to only 1.6% in 2010. Smallholder rubber areas decreased from 26.8% in 1970 to 11.2% in 2010, while oil palm plantations rose dramatically from 11% in 1970 to 35.8% in 2010. Early conversion of the forest at Dolok Merangir implies relatively stable non-forest land-use systems for a longer period of time and, by now, the rubber plantations have already developed into a mature system. The old rubber systems provide a more stable habitat for the different biodiversity components in this plantation area and this might benefit biodiversity conservation.

- Vegetation analysis was conducted in the three habitats of rubber plantation, rubber smallholder and forest. All stages of vegetation (seedling, sapling and tree) in the forest were more diverse than in the smallholder rubber (SH_AT, SH_DM) and rubber plantation (P_AT, P_DM) sample areas. Rubber plantation has the lowest vegetation diversity due to the intensive management practices to increase latex productivity, such as weeding, fertilization and slashing of all non-rubber trees. On the other hand, traditional farmers generally planted useful species in their agroforestry systems with selection by protecting seedlings that would maintain plant diversity at all stages. The species composition of the tree stage was completely different. While rubber trees dominated the plantation, other tree species dominated the smallholder rubber site at Dolok Merangir, for example, bamboo (*Phyllostachys bambusoides),* rubber *(Hevea brasiliensis)* and durian *(Durio zibethinus*), and the trees at the smallholder rubber site at Aek Tarum were dominated by rubber (*Hevea brasiliensis*), *jengkol* (*Archidendron pauciflorum)* and oil palm *(Elaeis guineensis).* Others species that we found on the smallholder sites were *Swietenia mahagoni, Arenga pinnata* and *Cocos nucifera*, which all have market values that farmers depended on for their livelihoods. In the forest, the tree stage was dominated by *Platea excelsa* (suitable for construction wood, from the family Icacinaceae), *Myrica esculenta* (family Myriceae, known as box myrtle, can be used as a medicine for skin disease) and *Altingia excelsa* (family Hamamelidaceae, known as *rasamala*, a valuable timber). The sapling and pole stages on the plantation and rubber smallholder sites were dominated by rubber trees as this is the productive stage for latex and hence the farmers maintained the rubber trees and minimised competition from other trees.

- Carbon and nitrogen are two important elements in soil organic matter, particularly with regard to their relationship to each other that is known as the carbon-nitrogen ratio. Soil analysis at the rubber plantation and smallholder rubber sites indicated that the carbon-nitrogen ratio was relatively constant across all soil depths with a value in the range 9–11, but this was slightly lower than in forest soil where the value ranged from 13 to 14. This implies that the nitrogen content on the rubber plantation and smallholder sites was higher than in the forest soil. Fertiliser application may have affected the nitrogen content on the plantation and smallholder rubber sites. In addition, the soil fertility on the smallholder and rubber plantation sites was lower compared to the forest soil, as indicated by the low value of the ratio of carbon reference (C_{ref}) to the carbon organic content (C_{org}).

- Bird diversity was analysed in four habitats (forest, rubber smallholder, rubber plantation and emplacement) in the Dolok Merangir and Aek Tarum areas and 728 individual birds were recorded consisting of 142 species of birds from 42 families. The number of bird species recorded decreased from 122 species at the forest sites to 46 species on the smallholder and 39 species on the emplacement sites, with the lowest number of 30 species recorded in the rubber plantations. The types of bird by their feeding habit (guild type) decreased with vegetation type. Forest was the most diverse for bird species with 17 guild types. We found 14 and 11 guild types at the rubber smallholder and rubber plantation sites, respectively. The emplacement site in a garden in the Bridgestone housing area contained 15 guild types of bird. Eleven guild types of bird or two feeding groups were not present in the rubber plantation, namely, the nectivores and nectivores-insectivores-frugivores (these can be grouped as nectivores) and the terrestrial insectivores-frugivores and arboreal frugivore predators (these can be grouped as omnivores). This implies that the rubber plantation sites did not provide a suitable environment for some birds with specific roles. Insectivorous groups contributed a large percentage to the sightings in plantations and included the Yellow-vented Bulbul (*Pycnonotus goiavier*), the Common Tailorbird (*Orthotomus sutorius*), the Ashy Tailorbird (*Orthotomus ruficeps*) and the Yellow-browed Warbler (*Phylloscopus inornatus*). They play a role in controlling insect populations, which are commonly found as pests in tree crop plantations. The differences in the tree composition of the three habitats in the PT BSRE area and its surroundings (see chapter 4) influenced bird species richness, diversity and species composition. There was a positive correlation between tree diversity and bird diversity.

- Additionally, a large number of raptor bird species were also found in the PT BSRE area, such as the Brahminy Kite *(Haliastur indus)*, the White-bellied Sea Eagle *(Haliaeetus leucogaster)*, the Black Eagle *(Ictinaetus malayensis)*, the Crested Hawk-eagle *(Spizaetus cirrhatus)*, Blyth's Hawk-eagle *(Spizaetus alboniger)* and the Crested Serpent Eagle *(Spilornis cheela)*. All these raptors are protected under Indonesian laws and regulations. Moreover, the high number of raptors in this area implied that this area was important as part of their home range. The availability of food in the PT BSRE area and its surroundings was important in supporting the population.

- Based on the bird protection status published by the International Union for Conservation of Nature and Natural Resources (IUCN) within the four habitats, we recorded twelve species that were categorised as 'near-threatened' (NT), while two species were categorised as 'vulnerable' (VU), being *Padda oryzivora (*Java Sparrow) and *Treron capellei (*Large Green Pigeon), found in forest habitat. In addition, one bird species listed in the CITES Appendix I—*Rhinoplax vigil* (Helmeted Hornbill)—was encountered in forest habitat. Efforts at biodiversity conservation are needed to maintain the equilibrium of functions in the ecosystem.

- Bat diversity in the tree habitats was studied to identify the level of bat species richness and their role and function in the habitat. We live-trapped 234 individual bats from three families consisting of 11 species, with eight of the species in the suborder Megachiroptera (fruit eaters) while the rest were Microchiroptera (insect eaters). *Cynopterus sphinx* (Greater Short-nosed Fruit Bat) was the most common bat species found in the area from a total of 1765.8 metres effort per night. *Cynopterus* spp. were the most common types found in rubber plantations, which is an indicator of forest disturbance. There were three species, namely, *Chironax melanocephalus* (Black-capped Fruit Bat), *Rhinolophus pusillus* (Least Horseshoe Bat) and *R. affinis* (Intermediate Horseshoe Bat) found in the forest only. Of the total bat species (27 species), 73% came from the family Pteropodidae (Megachiroptera) and the remaining 27% consisted of the families Rhinolophidae and Hipposideridae (Microchiroptera). Insect-eating bats play an important role as predators of mosquitoes and other plant pests, while the Megachiroptera are pollinators and seed dispersal agents. According to the IUCN status lists, all the bat species encountered in the study area were categorised as 'least concern'.

- The highest bat species richness was found in the forest habitat at Aek Tarum (Margalef's index, d=4.61), followed by young rubber plantation at Aek Tarum (d=2.12) and forest at Aek Nauli (d=1.91). Very low bat species richness was found in the rubber plantations (young and old) at Dolok Merangir and the old rubber plantation at Aek Tarum. The low value of bat diversity along each transect illustrates that the rubber plantations were in an alarming condition due to the imbalance in the number of individuals of each species within the community. Hence, it is necessary to establish a 'buffer zone' or conservation area in the bordering plantation area.

Recommendations

- Buffer zones, such as rubber smallholder and rubber plantation areas, play a role as stepping stone corridors for animals to reach forest areas. Vegetation in rubber agroforest areas provided carrying capacity to support bird and bat diversity. To improve biodiversity in the PT BSRE area, it is recommended to preserve intermediary regions, such as riparian areas, along the main roads and asphalt road in the plantation and on steep slopes.

- As an intermediary region could be a corridor or a bridge between one region and another on the border of a plantation, it is recommended to not only plant rubber trees but also a mix of other trees to provide food and places for nesting and resting for birds and bats, subject to the fruit not being preferred by humans, so that it is left for the animals. Trees with a narrow canopy would minimise light competition with the rubber trees that make up the main commercial crop in the plantation. Several suitable species for planting are *Ficus* sp., *Canarium indicum* (canarium nut) and *Syzigium polyanthum* (*salam*). Bamboo can be planted along the river banks to support birds and bats by providing places for nesting. In addition, other tree species, such as *Inga* sp. (Euphorbiaceae), *Sonneratia* sp. (Lythraceae) and Palmae can also support bats.

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1. Project overview

Hesti L. Tata

1.1 Introduction

Sumatra is the world's fifth largest island and part of the biogegraphical 'Sundaland' domain that is widely known for its biodiversity. The lowland forest of Sumatra is characterised by the conspicuous presence of thick climbers, large buttressed trees and the prevalence of trees with tall and smooth-barked trunks. Occasionally, the canopy may be dominated by Leguminosae species, such as *Koompasia excelsa* (locally known as *kayu raja*) and *Koompasia malaccensis*, and by many Dipterocarpaceae species as emergent trees. In the lower canopy, Burseraceae, Sapotaceae, Euphorbiaceae, Lauracaeae, Myristicaceae and Rubiaceae are common families (Whitten et al. 2000). The structure of the vegetation in natural forest consists of many canopy layers composed of many vegetation species. Numerous studies have shown that natural tropical forest is more diverse than other ecosystems (Whitmore 1984, Whitten et al. 2000, Rennols and Laumonier 2006).

Since the nineteenth century, forest cover in Sumatra has declined drastically, mainly owing to human activities. The natural vegetation in forested areas has changed to man-made ecosystems, such as agroforest, tree plantation and agriculture. For centuries, Sumatran smallholder farmers practised traditional systems of mixed agriculture involving annual crops and perennial trees—such as food, fruit trees and resin—to form a typical forest-like structure; hence its designation as an agroforestry system. The entire system of agriculture in Indonesia has been built around natural forest (Laumonier 1997). Some forest-derived land-cover types still maintain substantial subsets of the original forest vegetation and approach the structure of secondary forest (Murdiyarso et al. 2002). Loss of forest biodiversity depends on the type of land cover to which the natural forest was converted (Gillison and Liswanti, 2004).

Figure 1. *Koompasia excelsa* (kayu raja)

The species is well known as a honey-bee tree and has been kept in the PT Bridgestone Sumatra Rubber Estate, Dolok Merangir

Rubber (*Hevea brasiliensis*) has a long history of establishment in Indonesia. The first rubber tree was introduced by Hofland and planted in the Bogor Botanical Gardens in 1864 as part of a collection[1]. The development of rubber plantations in North Sumatra in 1920[2] was driven by the increase in the demand for rubber in Western countries in that era. The newly introduced crop adapted to the environment of North Sumatra and expanded rapidly as it contributed to economic development. At first, in Sumatra, the

1 http://balitgetas.wordpress.com/2009/07/21/sejarah-dan-prospek-pengembangan-karet/

2 http://www.archive.org/details/Islandof1920?start=149.5

local people were not allowed by the colonial government to plant rubber. However, people collected the fallen rubber seeds clandestinely and planted them in their gardens mixed with other trees, such as pepper, coffee and benzoin (*Styrax* spp.). Since then until the present, rubber smallholders have maintained both agroforestry and monocultural systems in Sumatra. These man-made ecosystems should be taken into account in the overall landscape of Sumatra.

Disturbed and agricultural areas have biological components that interact, change in abundance, adapt to physical constraints and impose themselves upon human life. In terms of tree composition and structure, the complex rubber agroforestry system has a comparable ecology with a forest (Laumonier 1997, Beukema et al. 2007, Rasnovi 2008). There are also economic aspects, with the rubber agroforest system in Batang Toru, North Sumatra providing IDR 35 000 as benefits for the labourers (Tata and van Noordwijk 2010).

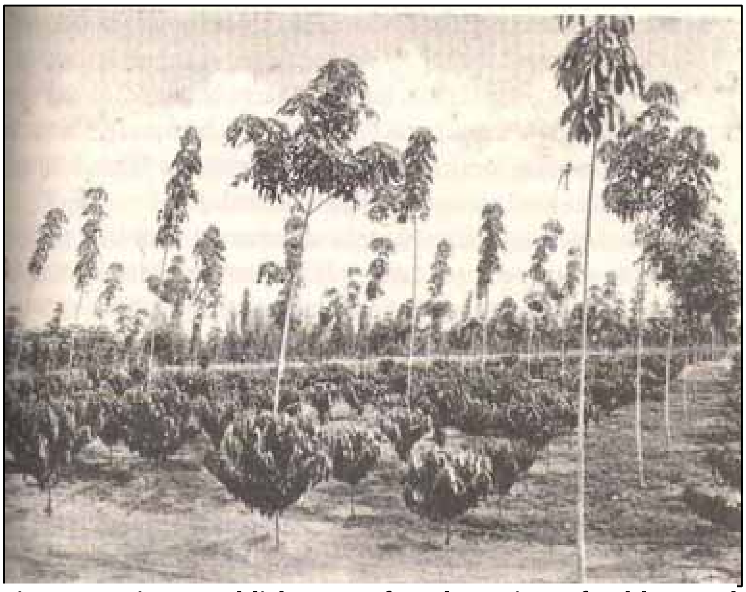


Figure 2. First establishment of a plantation of rubber and coffee, East Sumatra

Source: *Indonesia: 500 early postcards* (Reid 2010)

Undoubtedly, animals play an important part in natural and man-made ecosystems. Like the stratification of plants in a natural ecosystem, there is also a stratification of the animal population. Different groups of animals according to their range of foodstuffs occupy different layers of the canopy (Whitmore and Burnham 1984). Forest provides more than habitat for the animals that live within it; animals closely interact with plants in the ecosystem. Animals play a role in the stability of the food chain in all niches of ecosystems, for example, frugivores (fruit-eaters) as primary consumers and insectivores and carnivores as secondary consumers. Groups of birds and bats play roles as pollinators, seed dispersal agents and as pests for plants. Other groups of animals are responsible for biological control as predators.

Biodiversity conservation aims to protect the diversity of life through limiting losses of species and ecosystems owing to excessive rates of extinction. Van Noordwijk (2005) mentioned that it is important to maintain what species are still left but there should also be research to determine which plants and animals used to occupy the main categories. Conservationists tend to use extinction status to manage the diversity of organisms; on the other hand, local people and farmers recognise the species which have benefits and value to them, such as through use in daily life and for their economic and cultural values. Until recently, the opportunities for conservation within 'agroforestry' landscapes had only been explored by mainstream conservation agencies (Schroth et al. 2004, Roshetko et al. 2007, Tata and van Noordwijk 2010).

1.2 Objectives of the study

The study aimed to assess the overall biodiversity of plants, birds and bats within a landscape continuum, identifying areas of higher and lower biodiversity and the links between them, as well as providing a detailed picture of the overall biodiversity health of the study sites. Perceptions of the local people with regard to local practices and the use of resources as well as perceptions of biodiversity were analysed.

1.3 Study sites

The study was conducted in an area of the Bridgestone Sumatra Rubber Estate company(PT BSRE) in the Dolok Merangir and Aek Tarum plantations, located in North Sumatra province, Indonesia (Figure 3). Forest plots were laid out on 'Bartong' forest in Asahan district and in a forest research area of Aek Nauli. Vegetation types in forest, smallholder rubber and rubber plantation is shown in Figure 4. The size of the study area at Aek Tarum was 79 944.5 ha, and the size of the Dolok Merangir study area was 139 353.93 ha. Each study site included PT BSRE company land surrounded by a 12 km buffer.

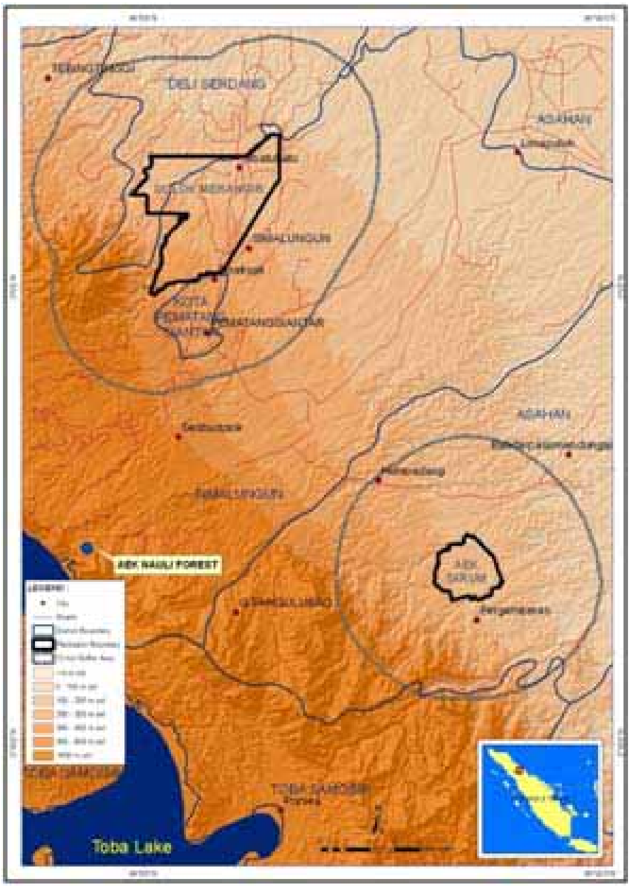


Figure 3. Study sites in PT BSRE's Dolok Merangir and Aek Tarum plantations, North Sumatra

Figure 4. General characteristics of habitat types
Legend: (a) Aek Nauli forest; (b) *Bartong* forest; (c) rubber plantation; (d) smallholder rubber plantation

1.4 General methods and analysis

The biodiversity survey included plants (all stages of growth: understory, seedling, sapling and tree), birds and bats according to the Quick Biodiversity Survey (QBS) method developed by the World Agroforestry Centre (Nurhariyanto et al. 2008). We also analysed local people's perspectives of their surrounding landscape. Information was collected through multidisciplinary and collaborative methods (Sheil et al. 2002). Current land-use and land-use changes in the study areas were analysed using available maps and GIS datasets (Dewi and Ekadinata 2010). The overall data and analyses were then used to formulate recommendations on improving biodiversity within PT BSRE and its patchy natural reserves.

2. Understanding local use of resources and local perceptions of biodiversity

Elok Mulyoutami and Janudianto

2.1 Background

The variability of living organisms in all ecosystems serves to maintain the balance of nature. The various types of animal and plant health and abundance in natural environments provides separate functions for physical environmental conditions, human life in surrounding environments and the interrelationships between living organisms. People are always regarded as the major threat to biodiversity. Deforestation owing to over-exploitation, over-population and changing forests to more intensive land-use systems has caused habitat loss for animals and many other living organisms. However, humans are not always the main culprit; natural disturbance can also destroy a habitat. Through knowledge, people can organise their environment and attempt to resolve conflicts with it, to live together with the animals and plants.

It is important to take into account human and environmental aspects in biodiversity conservation: the anthropocentric and non-utilitarian points of view. The value of land-use systems in a landscape is not only captured by their physical aspects but also the cultural and social aspects. This also reflects on how to measure biodiversity, that is, it need not always be based on a natural science approach, such as analysis of flora and fauna (see chapters 4, 5 and 6). The relative importance of biodiversity to humans can be assessed through understanding the socio-cultural aspects of local communities. Natural scientific methods define the 'level of biodiversity', making it possible to compare sites or to provide data that can be used for comparisons (Sutherland 2000). On the other hand, the socio-cultural approach reveals how local people measure biodiversity and the importance of maintaining it for the sustainability of their livelihoods. This is particularly important when biodiversity conservation is linked to poverty alleviation (Huq 2000, Solis-Rivera 2000) through environmental services rewards schemes. Judging the value of what is important for local communities helps them to capitalise on opportunities for biodiversity conservation.

The survey in the area of PT BSRE had the objective of assessing the biodiversity of trees and specific animals in the estate plantation and surrounding smallholder plantations. The results were expected to be useful in showing the biodiversity health of the site based on science. Information and advice on how to improve the biodiversity and environmental values of each land use were expected to be outcomes of the project, therefore, it was also important to analyse local practices and use of resources as well as perceptions of biodiversity. This study focused on local perceptions of land-use functions and values as well as local preferences for land-use systems.

2.2 Objectives and methods

Multidisciplinary Landscape Analysis[3] (MLA) is an approach used to understand local people's perspectives of their surrounding landscape. Information is collected through multidisciplinary

[3] This method was developed by the Center for International Forestry Research.

and collaborative methods, primarily related to environmental impact and local people's perspectives (Sheil et al. 2002). We adapted the MLA to highlight the values and preferences of local people in the context of biodiversity and its utilisation. Whilst MLA was designed to explore forest values as a core of assessment and other land uses as complementary, we treated landscape as a continuum and positioned community in the centre of the system.

A series of focus groups in some villages were held, with an emphasis on gender balance. The questions in the discussions were based on two main research questions.

1. What are the local perceptions of land-use systems and their functions; how will they be reflected in their perceptions of the value of monoculture compared with agroforestry systems; and which is their preferred system?

2. What are the most valuable plants and animals in each land use and how does this indicate the importance of biodiversity for their livelihoods?

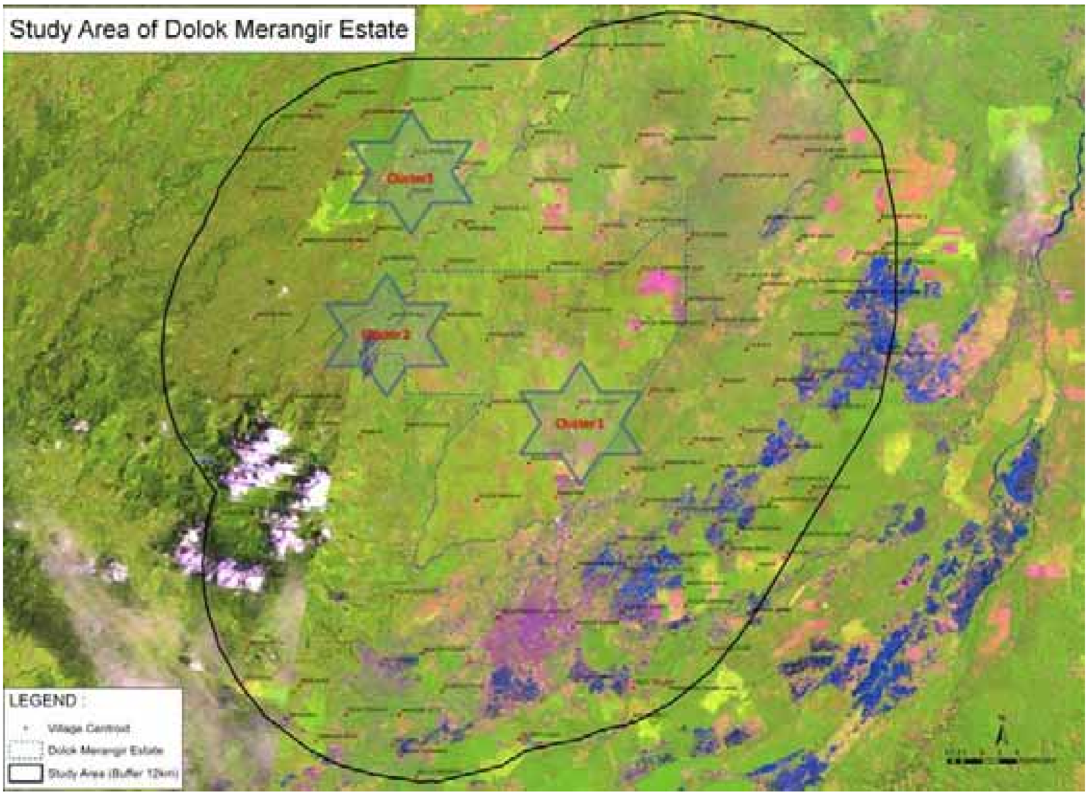
Weight ranking or pebble distribution methods were employed as practical methods to assess the importance of biodiversity for the people in each village. While doing the ranking, discussions with participants were also captured, in particular, to obtain more information about valuable plants and animals.

2.2.1 Location and village selection

The study was focused on villages in surroundings PT BSRE's estate in Simalungun, Serdang Berdagai and Asahan district. Villages were selected purposively within some sub-districts that were statistically well known as producers of high quality and quantities of rubber latex. Six villages were selected surrounding the plantation, taking into consideration the village's position (inside or outside the plantation area), distance to the forest and rubber as one of the main sources of livelihood. Selected villages are presented in Table 1 with more detailed information and spatial rendering in Figure 5.

Based on local consultations and field observations, we grouped the sample villages into three clusters:

- Cluster 1, villages inside the area of BSRE, represented by Batu Silangit.
- Cluster 2, the villages far from the forest, represented by Naga Raja and Aek Bamban.
- Cluster 3, villages surrounding the plantation but close to the forest: Huta Rao, Silau Padang and Merjanji Aceh.



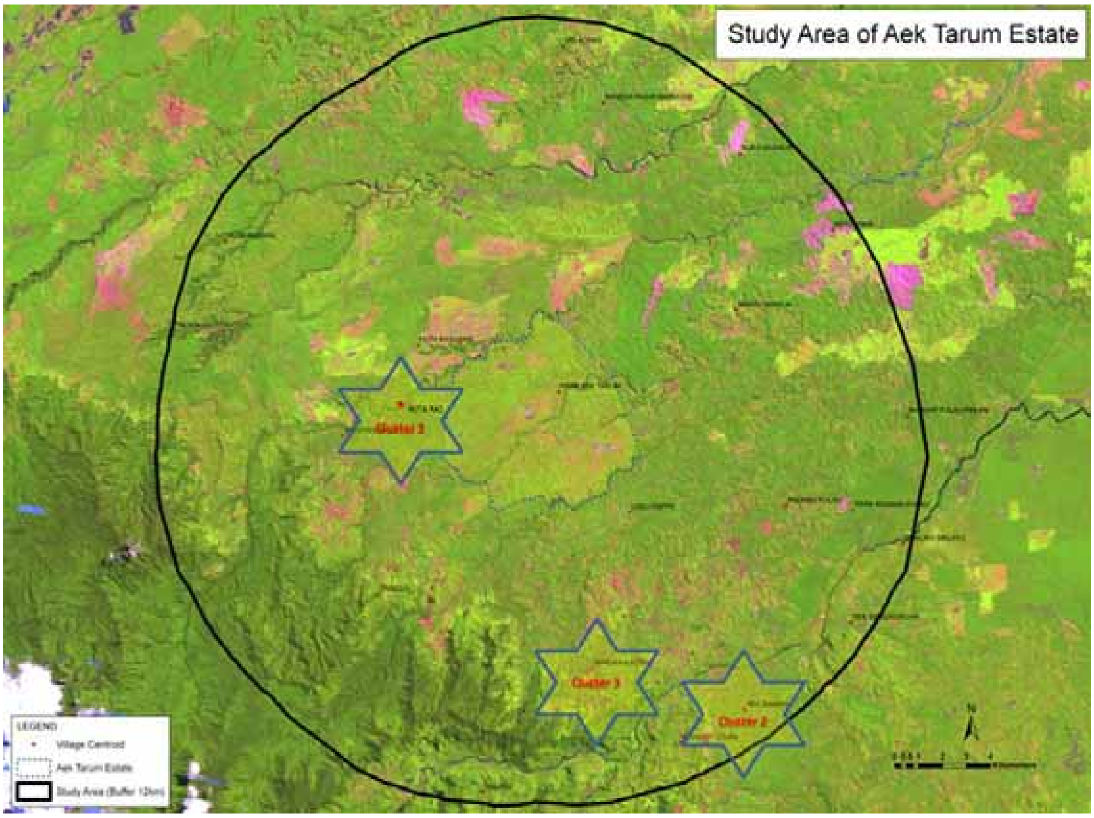


Figure 5. Location of selected villages
Legend: Dolok Merangir (above) and Aek Tarum (below) (marked with a) ☆

Table 1. Village or location characteristics and clustering based on distance to forest

Village	Administrative location	Main livelihood source	Distance to forest	Distance to rubber plantation	Cluster
Batu Silangit	Kecamatan Tapian Dolok Kabupaten Simalungun	Rubber	Very far	Enclave	Cluster 1
Naga Raja	Kecamatan Sipispis, Kabupaten Serdang Berdagai	Oil palm Rubber	Moderate	Bordering	Cluster 2
Silau Padang		Rubber	Close	Far	Cluster 3
Huta Rao	Kecamatan Bandar Pulau Kabupaten Asahan	Oil palm Rubber	Close	Bordering	Cluster 3
Aek Bamban	Kecamatan Aek Songsongan, Kabupaten Asahan	Rubber	Moderate	Far	Cluster 2
Merjanji Aceh		Oil palm Rubber	Close	Far	Cluster 3

2.3 Local classification and land-use values

During discussions with farmers, questions about land-use values referred to the use and importance of the land in people's lives, while questions on biodiversity values referred to the importance of a high variety species in each land-use system. Knowing the value or the importance of land use and biodiversity was important for understanding people's preferences and priorities (Sheil et al. 2002).

Land-use classification in this study was defined based on local people's perspectives. People were asked for the main land-use system in their village and surrounding areas. The classification and availability of each land use in each village are illustrated in Table 2. The majority mentioned the productive and economically important land uses, while fallow and shrub land were not mentioned, since the land was not high value and was considered unused.

Smallholder rubber and oil palm were the main sources of livelihoods in almost every village, since the two systems were important as cash income sources. Smallholder rubber plots appeared in the form of monoculture plantations as well as agroforestry systems that included some important timber or fruit trees and shrubs.

Smallholder rubber agroforests and home gardens existed in each village. Home gardens were perceived as the plot surrounding the house and were used for basic needs. The gardens consisted of some fruit trees, light timber trees, flowers and sometimes rubber trees. Smallholder rubber agroforests were usually somewhat further from the house and consisted of some economically important trees such as rubber combined with fruit trees. Rubber monoculture plots were also common within the surveyed villages: they occurred surrounding houses and also far from settlements. Forest was defined as dense vegetation that grew naturally, was multi-strata, of different ages, with a multilayer canopy. It often occured beside rivers, formally called riparian forest.

Table 2. Land uses and availability in each cluster

Land-use types	Cluster 1	Cluster 2	Cluster 3
Dry field	√	√	√
Rice field		√	
Home garden	√	√	√
Rubber agroforest	√	√	√
Smallholder rubber monoculture		√	√
Rubber monoculture estate	√	√	√
Smallholder oil palm		√	√
Oil palm estate		√	
Forest			√

All farmers perceived that rubber agroforest was the most important land use, as it could provide sources of income, food and held environmental value (Figure 6). The second important land use was smallholder oil palm, followed by smallholder rubber monoculture, as the main cash incomes for households.

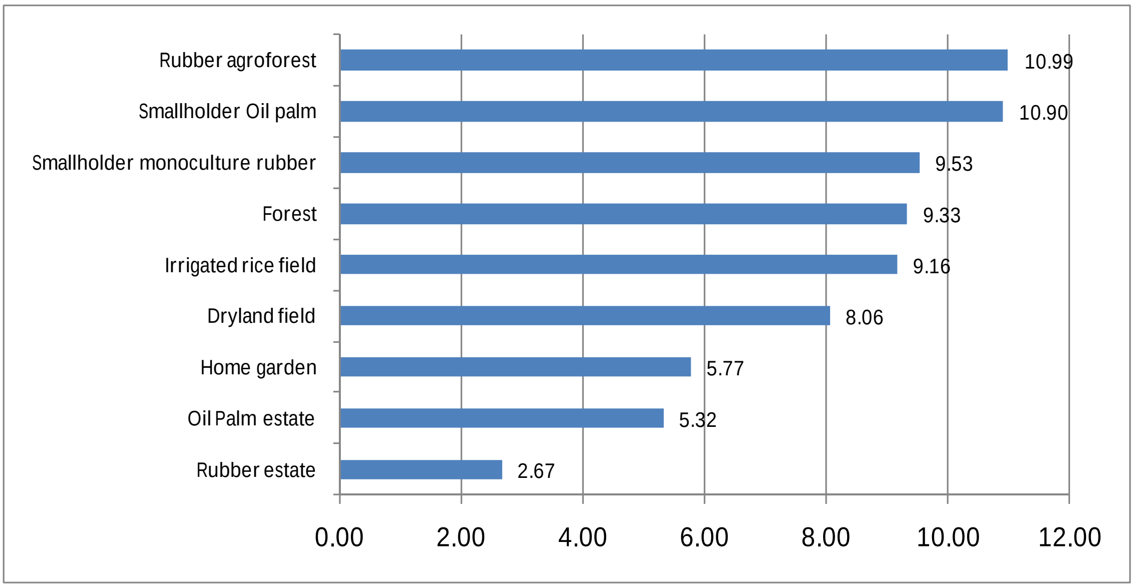


Figure 6. Farmers' descriptions of land-use values

Figure 5 shows the land-use values in each cluster. The value of rubber agroforest in Batu Silangit (Cluster 1) village was very high, since they cultivated rubber within their systems. Batu Silangit was an enclave village and most people who lived there had a close relationship with PT BSRE, however, interestingly, they preferred to cultivate rubber trees in mixed systems. The main reason for this was limited land ownership: on average, farmers had 0.5–2 ha. Therefore, they had to optimise the use of their plots, not only for income but also for subsistence needs, by planting food and fruit trees and other useful trees.

In Cluster 2, which consisted of Naga Raja and Aek Bamban villages, the highest value land use was smallholder oil palm followed by irrigated paddy field. Previously, in Aek Bamban village, cultivation of irrigated paddy rice and rubber played a leading role in the village's livelihoods. At the time of study, however, paddy rice farming was slowly vanishing owing to erratic water supply for irrigation. Most of the irrigated paddy lands have been converted to oil palm plantations, such as the two big oil palm plantations owned by private companies that lie close to Aek Bamban village. Naga Raja village is located close to PT BSRE, but river water flow in the area is influenced by a private oil palm plantation in Sipispis sub-district.

Rubber and oil palm plots in Cluster 3 had the highest value, followed by smallholder oil palm plots and rubber agroforestry systems. Rubber had higher value than oil palm, but the difference was not significant.

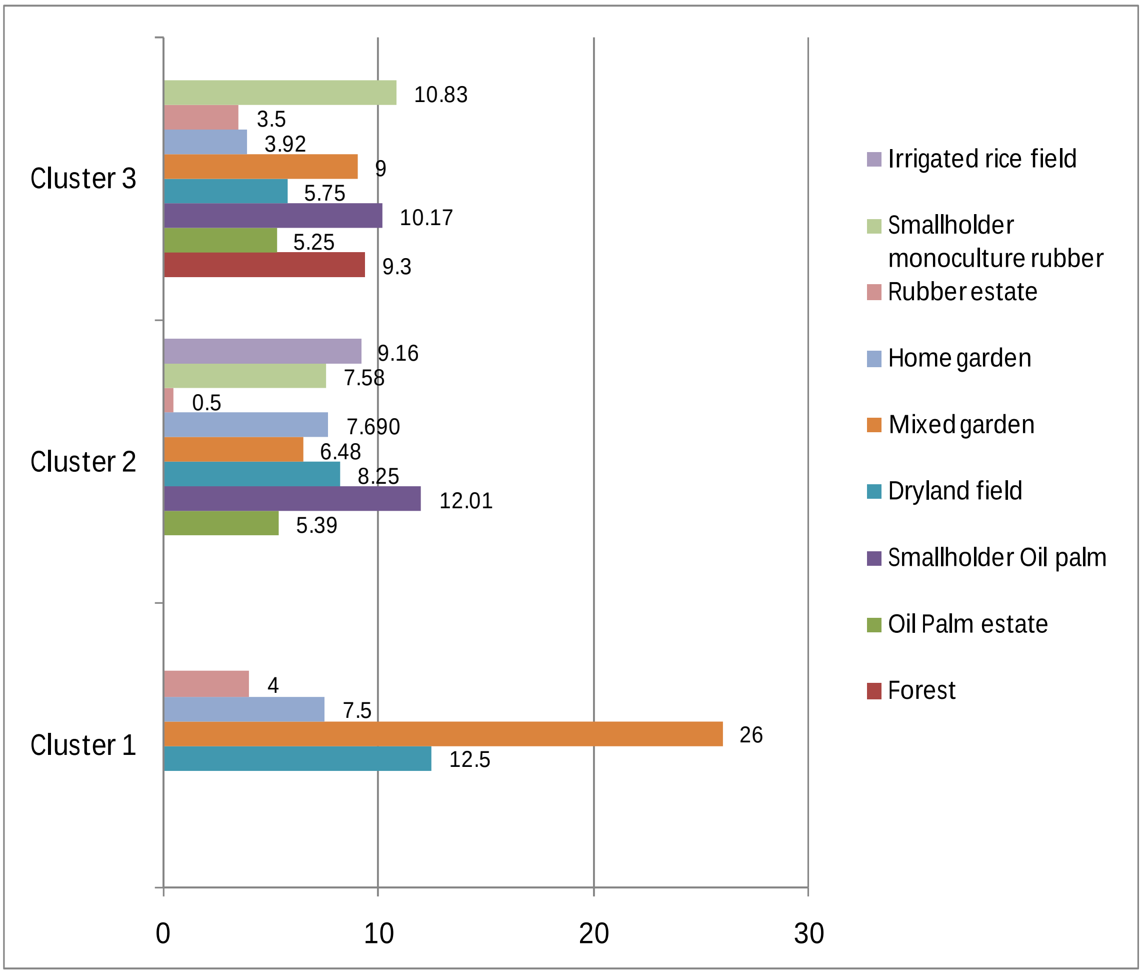


Figure 7. Farmers' descriptions of land-use value per cluster

2.4 Biodiversity functions

Rural communities that have direct dependence on diverse local natural resources have different perceptions of the value of biodiversity.

People's understanding of biodiversity was closely associated with livelihoods patterns and social life, as biodiversity contributed to their daily needs, and related to specific knowledge. Perceptions of different user groups (for example, farmers, hunters) varied and there was a noted difference depending on distance to natural resources, access to markets etc.

Table 3. Function of each land-use system relative to biodiversity

	Forest	Home garden	Rubber agroforest	Rubber estate	Smallholder monoculture rubber	Oil palm estate	Smallholder oil palm	Irrigated rice field	Dryland field
A. Direct functions									
Source of income	High	High	High	Medium	High	Medium	High	High	High
Source of food	Medium	High	Low	No	Low	No	Low	High	High
Source of fuel wood	Low	Low	Low	High	Medium	Low	Low	No	Low
Raw material for house building	High	Low	Low	No	Low	Low	Low	No	Low
Material for handicraft	Medium	Low	Low	No	Low	Medium	Low	Low	Low
Medicinal plants	Medium	High	Low	No	Low	No	Low	Low	Medium
Raw material for tools	Low	No	Low	No	Low	No	Low	No	Low
B. Indirect function									
Grazing land or source of fodder	Low	Low	Low	High	Low	High	Low	Medium	Low
Animal habitat	High	No	Low	No	Low	No	Low	No	No
Erosion prevention	High	Low	Low	Low	Low	Low	Low	Low	Low

Table 3 shows the relational function of biodiversity in the different land-use systems. Forests were perceived as an important habitat for wild animals, such as monkey, snake, wild boar, bat, squirrel, civet cat, *trenggiling* (scaly anteater), reptiles, bear, peacock, deer, *kancil* (mouse deer), tiger, gibbon, hornbill, crow, magpie and parrot. Rubber agroforestry systems have medium-to-low value in terms of wild animal habitat, even though the systems are not significantly different from smallholder monoculture rubber and smallholder oil palm. The participants mentioned that wild boar, snake and bat were often found in the systems. Although local people during the scoring exercise consistently said other land uses were not important as animal habitat they mentioned that they still found some bird, bat, rat and snake species.

People also understood that forest had the highest function for erosion control as these area are prone to soil erosion owing to topography. Most villagers in each area mentioned this. All rubber plots under mixed and monoculture systems were perceived as having a good value in preventing erosion, while oil palm plots were of relatively low value. Interestingly, in Cluster 3, in particular in Huta Rao village, farmers agreed that the use of the rubber estate for erosion control was good, as the village was in a mountainous area. They mentioned that rubber monoculture functioned as erosion control better than that of oil palm plantation. Oil palm expansion in this area was relatively high. The villagers mentioned some species as erosion control, such as bamboo, rattan, betel, mahogany, *Erythrina*, lemon grass, *Hibiscus* tree (*waru*), *glagah* (a family of Cyperaceae) and *jati putih* (*Gmelina*). *Waru*, bamboo and *Gmelina* were good in preventing landslides and erosion in riparian areas.

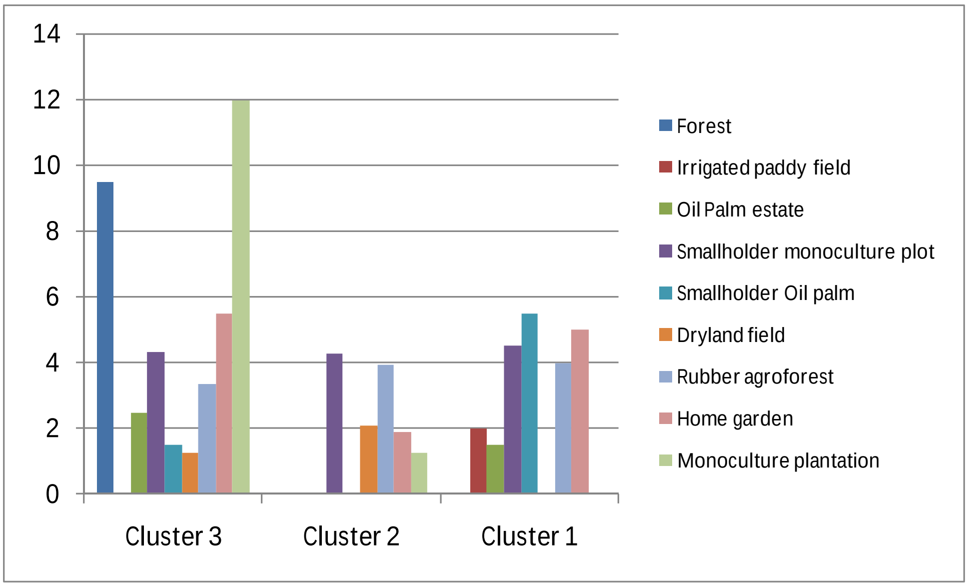


Figure 8. People's perception of erosion functions of each land-use system

People usually used the rubber or oil palm plantations for grazing. *Rumput paitan* (*Paspalum conjugatum*), *rumput babi* (*Leptaspis urceolata*) and *rumput putihan* (*Clibadium surinamense)*, that grew wild in the plots, were used as fodder, in particular, for cows and goats. Villagers also mentioned *rumput gajah* (*Panicum maximum*). Actually, grazing was not allowed inside the plantation but because people didn't have other alternatives they still used the area since animal husbandry had become an important livelihood source. There was no alternative pasture nearby.

Rubber agroforests provided sources of raw materials for handicrafts and farming equipment for three groups of villages. Oil palm plots remained important for handicrafts as they could provide palm midribs for brooms, in particular, in Aek Bamban village. Old trunks of oil palm can be used as handles for machete and plaited leaves can be used as house walls. Irrigated and dry paddy areas were important for grass that could be used for floor mats. Villagers also used leaves of palm sugar (*Arenga pinnata*) for brooms and raw material for roofs.

Home gardens, dryland fields and rubber agroforests were three important land-use systems for medicinal plants. Naga Raja village was one step ahead of other villages as there was a demonstration plot at the village office for many kinds of medicinal plants. The main species that were used as medicine were ginger (*Zingiber officinale* Rosc.), turmeric (*kunyit*; *Curcuma domestica* Val.), Java turmeric (*temulawak*; *Curcuma xanthorriza* Roxb.), *lempuyang* (*Zingiber* spp.), *laos* (galangal; *Alpinia galangal*), *bengle* (*Zingiber cassumunar*), sand ginger (*kencur*; *Kaemferia galangal*), *jeringo*, *payang* (*Mangifera payang)***,** betel nut (*pinang*; *Areca catechu*), *andi lotung*, sugar palm (*aren*; *Arenga pinnata*), *pasak bumi* (*Eurycoma longifolia*), *kulit kayu maibung* (*Millettia atropurpurea*), *jarak* leaves (*Ricinus communis* Linn.), *bunga raya* (*Hibiscus rosa sinensis*), *setawar* leaves (*Costus speciosus)*, *kelundang* root, *kulit manis* (*Cinnamomum* sp.) and *sambiloto* (*Andrographis paniculata*).

Raw materials for housing and construction, such as timber, mainly came from the forest. However, poor families used palm midribs and leaves as house walls. Therefore, oil palm plots have become an important source of building materials. Home gardens and rubber agroforests were also important land uses as sources of raw materials for building in every cluster of villages. The main species for construction were meranti (*Shorea* sp.), durian (*Durio zibhetinus*), coconut (*kelapa*; *Cocos nucifera*), white teak (*jati*; *Gmelina arborea*), *rambai* (*Baccaurea motleyana*), mangosteen (*manggis*; *Garcinia mangostana*), stinky bean (*jengkol*; *Archidendron jiringa*), Indian devil tree (*pulai*; *Alstonia scholaris*), paraserianthes (*sengon*; *Paraserienthes falcataria*), candle nut (*kemiri*; *Aleuritus moluccana*), jackfruit (*nangka*; *Artocarpus integra*), *kayu losa*, mahogany (*mahoni*; *Swietenia macrophylla*), *dadap* (*Erythrina variegate*), *kayu raja* (*Endospermum* spp.), *kayu laban* (*Vitex* spp.), *kayu johar* (*Senna* spp.), *cempedak* (*Artocarpus champedan*).

Irrigated paddy and croplands were very important land uses for food production. Home gardens, followed by rubber agroforests, were tree-based land-use systems that were also important for food production. In some villages, smallholder oil palm was important as a food source because some villagers occasionally consumed oil palm tubers and shoots (edible topmost frond). The main species known as important food sources were durian (*D. zibhetinus*), champedan (*cempedak*; *Artocarpus integer*), *bedaro* (*Canarium littorale*), *duku* (*Lansium domesticum*), *petai* (*Parkia speciosa*), stinky bean (*jengkol*; *A. jiringa*), *kabau* (*Pithecelobium lobatum*), rambutan (*Nephelium lappaceum*), *rambai* (*B. motleyana*), *langsat* (*Lansium* sp.). Most of the plants were not deliberately planted and were not maintained with fertiliser or insecticide applications.

People in the surveyed villages mostly used wood for cooking (70–80% of participants). Rubber wood was the main source of fuel wood since it can be easily found in local rubber plots as well as in rubber plantations nearby. The villagers collected fallen branches or dead trees. In the villages near to rubber plantations, residents preferred to collect fuel wood from the plantations. Rubber agroforests were also important as sources of fuel wood because they contained some important fuel wood species such as *petai (P. speciosa)*, *jengkol (A. jiringa)*, candle nut (*kemiri; A. moluccana)*, rambutan *(N. lappaceum)*, cocoa *(Theobroma cacao)* and guava *(Syzigium* sp.).

Most of the land uses functioned as sources of income; some tree species grown in the plots produced marketable products, which could be sold for cash. Table 3 shows that the estate plantation plots provided little value as income sources because villagers had no access for profit-making ventures. The most important source of income was from smallholder oil palm plots followed by smallholder rubber monoculture. Smallholder oil palm and monoculture rubber provided the highest values as sources of income, contributing the highest proportions of household incomes. Other important saleable products came from dryland fields, rubber agroforests and home gardens, derived from durian, *jengkol*, *petai*, banana and cocoa. Forest also ranked high in terms of income sources, as it could provide woods for household consumption. Some people planted mahogani and teak mixed with other trees in their land. Table 4 shows a list of valuable plants and animals.

Table 4. List of valuable plants and animals

	Smallholder oil palm	Rubber agroforest	Irrigated paddy field	Dryland field	Homegarden	Rubber monoculture
Animal	Bat, snake *perkutut/* turtledove *(Geopelia* sp.*)* quail *(puyuh/ gemek)*, squirrel	Bat, *perkutut*/turtledove *(Geopelia* sp.*)* squirrel monkey, wild boar, snake	*Keong (Pomacea canaliculata)*, rat *(Rattus argentiventer), jangkrik* (cricket; *Gryllus* sp.), *wereng (Nilaparvata lugens), kepinding (Scotinophora coarctata), walang sangit (Leptocorisa acuta)*	Wild boar *(Sus scrofa)*, monkey snake, squirrel	Rat, *jangkrik* (cricket; *Gryllus* sp.) centipede *(kelabang)* scorpion, chicken duck,	Bat, wild boar, snake squirrel
Food		*Petai (Parkia speciosa)* *jengkol (Archidendron pauciflorum), durian (Durio zibhetinus)* Candle nut *(Aleuritus moluccana)*	*Paddy, soy bean*	*Maize, eggplant, cassava, banana, long bean*, petai (Parkia speciosa)*, jengkol* (Archidendron pauciflorum)*, chilli, candle nut* (*Aleuritus moluccana), sweet potato, taro (Caladium* sp.)	*Banana, rubber, rambutan (*Nephelium *sp.)* jambu air *(*Eugenia aquea *Burm)*, jambu klutuk *(Syzigium sp.), papaya*	
Fuel wood	*Oil palm fruit*	Rubber *(Hevea brasiliensis)* *jengkol (Archidendron pauciflorum)* petai *(Parkia speciosa)*	-	Petai *(Parkia speciosa)* *jengkol (Archidendron pauciflorum)* *candle nut (Aleuritus moluccana)*	*Rambutan (Nephelium lappaceum)* Cocoa *(Theobroma cacao)* Jambu *(Syzigium sp)*	Rubber *(Hevea brasiliensis)*
Source of income		Rubber *(Hevea brasiliensis): sap and wood, durian: fruit and wood, jengkol: fruit and wood*, petai, *candle nut*	*Paddy, soy bean*	*Durian, jengkol*, petai	*Cocoa*, jambu air, *rambutan*, jambu klutuk	*Rubber: latex, wood and fruit for seed*
Construction	*Palm midrib for traditional house walls*	*Durian*, petai *(Parkia speciosa), jengkol (Archidendron pauciflorum)* *mahogany, teak*	-	*Jengkol (Archidendron pauciflorum)* *Candle nut (Aleuritus moluccana) Durian*	Rumput paitan	Rumput paitan, rumput gajah
Medicinal plants	-	Sirih, candle nut *(Aleuritus moluccana), Rumput artisan (scientific name not known)* Suwawa (rumput tai babi*)(scientific name not known)*	Daun ekor, ekor anjung *(scientific name not known)* *Tapu arang (scientific name not known)*	*Andi lotung (white flower) (scientific name not known)* jeruk purut *(Citrus aurantifolia)*	*Ginger*, kencur, kunyit, lengkuas, bengle, jeringo sirih *(Piper betle L)*, sereh *(Cymbopogon winterianus jowwit), kembang sepatu/daun bunga raya (Hibiscus rosa sinensis),pinang (Areca catechu)*	*Sirih, sambiloto (Andrographis paniculata), ciplukan (Physallisa angulata L)*
Fodder	*Gelagah (Sacharum spontaneum)*	*Gelagah (Sacharum spontaneum)*	*Gelagah (Sacharum spontaneum)*	*Gelagah (Saccharum spontaneum)*	-	*Rumput Markani* *Korok korok*
Handicrafts and tools		*Arenga pinnata* *Durian, jengkol etc* Rubber wood	Pandanus	Banana stalk *Jengkol* wood (Archidendron pauciflorum)*, candle nut* (Aleuritus moluccana)*, durian wood*		-
Erosion prevention		*Pinang (Areca catechu)*, bamboo, *rumbia (Metroxylon spp), waru (Hibiscus tiliaceus)*		Rattan, bamboo pinang	*Waru (Hibiscus tiliaceus)* *Rambutan*, jambu *Legumes*	*Bamboo, Areca catechu*

2.5 Conclusion

This study revealed some of the local knowledge about biodiversity. People's perceptions of biodiversity were mostly based on direct use values, which related to their daily lives. Hence, to gather more specific information about each species, it would be necessary to interview a specific user or group who gain direct benefits from that species. People usually only focussed on phenotype characteristics or observable qualities.

Choosing agroforestry as the main land use depended on land availability. In Batu Silangit village, where villagers had limited access to new land, the inhabitants planted many other beneficial trees to provide additional value to the rubber trees. This was an important strategy to optimise their land use by cultivating fruit or other important trees such as candle nut (*kemiri*) and *jengkol* for subsistence and market purposes.

In the villages that were closest to forested areas, people had some alternative land cultivation methods. Rubber monoculture was more important than rubber agroforestry owing to farmers' orientation towards profit, for example, greater quantity and quality of latex. However, many farmers preferred to cultivate oil palm rather than rubber under a monoculture system. Even though they were aware of the biodiversity function of rubber agroforests and forests, the boom in oil palm production and its high price had influenced farmers' decisions. This also occurred in villages located far from the forest.

Home gardens and rubber agroforests remained important as sources of particular livelihoods for people in the three groups of villages. Although villagers did not explicitly mention that these land-use systems were important for biodiversity, the two land uses had high values for subsistence and marketing purposes, which was expressed in every discussion.

Finding a solution for the issue of animal grazing needs to be prioritised. Oil palm and rubber plantations where grasses were abundant for fodder played a role as grazing areas. These areas have the potential to be used for increased production of livestock but, on the other hand, could cause some problems for the main commodity production of the estate companies. Extension services and community development are necessary to improve the awareness of villagers in livestock management, for example, building cattle pens and introducing compost processing of cattle dung for manure. These approaches could create a win-win solution beneficial for both the company and local people.

3. Land-use and land-cover changes and trajectories in Dolok Merangir and Aek Tarum

Zuraidah Said, Andree Ekadinata and Atiek Widayati

3.1 Introduction

Analysis of land-use and land-cover changes and trajectories in the context of the QBS was conducted to understand the dynamics of the natural habitat as a result of changes to landscape composition and configuration. We analysed land-use changes and trajectories in both Dolok Merangir estate in Simalungun district and Aek Tarum estate in Asahan district. Our time series analyses are for 1970, 1990, 2002 and 2010, which covers the periods before plantations were established up to the present. The spatial extent of the land-cover change analysis extended across the plantation boundaries and 12 km buffer zone surrounding the plantations. The buffer zone was included to understand the dynamics of the nearest forest patches and the potential influence on biodiversity richness inside plantation areas. For this section, 'estate' refers to the area of PT BSRE, while 'study area' or 'area' refers to the entire area for the QBS (BSRE plantation plus the 12 km buffer zone). Figure 3 shows the location and boundaries of Dolok Merangir and Aek Tarum.

3.2 Analysis of land-use and land-cover changes and trajectories

Analysis of land-use and land-cover changes and trajectories (ALUCT) is a framework used to understand land-use dynamics over a landscape using remote sensing data (Dewi and Ekadinata 2010). The results of ALUCT are three-fold.

- Land-cover maps in time series (1970s, 1990s, 2000s and 2010)
- Land-cover change quantification of the two study areas (Dolok Merangir and Aek Tarum)
- Land-cover trajectories for the period of analysis (1970–1990, 1990–2000 and 2000–2010).

ALUCT consists of five main steps (Figure 9). The first step is data acquisition. Landsat images from different acquisition dates, sensors and spatial resolutions were collected to produce land-cover maps for the study periods. The next step was image pre-processing, which consisted of radiometric correction to improve images from atmospheric errors and geometric correction to produce images which were properly georeferenced.

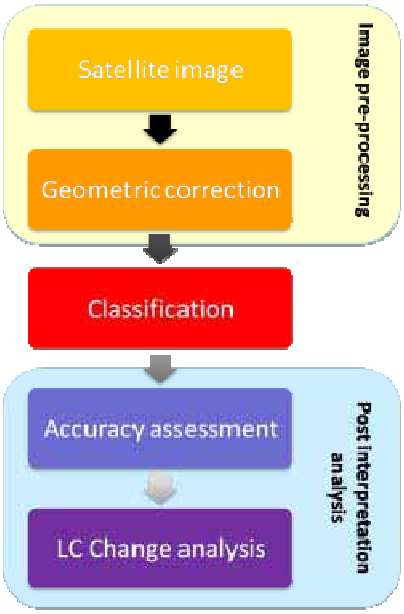


Figure 9. Overall work flow of the analysis of land-use and land-cover changes and trajectories method

After image pre-processing, the satellite images were processed to produce land-cover maps for 1970, 1990, 2000 and 2010 using hierarchical, object-based classification. Hierarchical classification means that the classification process was divided into levels, each of which had different objects to be classified (Dewi and Ekadinata 2010). In this study we only generated two levels: coarse and fine. At the coarse level, four objects were classified: forest, tree-based systems, non-tree-based systems, non-vegetation and no-data class. Each class (except no-data class) on this level was classified into more specific classes at the next level. Figure 9 describes the classification scheme applied in this study.

Figure 10. Classification scheme for Dolok Merangir and Aek Tarum study area

Field checking and 'groundtruthing' activities were necessary for the following purposes:

(a) to identify proper land-cover classes based on the study area and develop a land-use and land-cover classification scheme based on same; and

(b) to collect GPS points for classification and the accuracy asessment process (Figure 9).

An accuracy check of the satellite image interpretation was conducted on the result of the most recent image interpretation. This is because the GPS points collected during this study were collected only recently, closest in time to the most recent images.

The definition of each land-cover class is presented in Table 5.

Table 5.List of land-use and land-cover classes in the QBS study, based on data verified in the field

Class name	Description
Undisturbed forest	Undisturbed forest is high density, natural forest with dense canopy, highly diverse species and tree cover. It has no logging roads, indicating that it has never been logged, at least under large-scale operations.
Logged-over forest	Logged-over forest is a natural forest area with logging roads but still has dense tree cover and canopy.
Rubber monoculture	Monoculture plantation of rubber trees.
Smallholder rubber	Monoculture plantation of rubber trees in a small area (less than one hectare on average) usually planted by local people.
Oil palm	Monoculture plantation of oil palm planted by private companies and local people.
Mixed tree	Mixed tree garden is an agroforestry or tree-based system with more than 30% of the area consisting of various species of trees.
Shrub	Shrub land is a non-tree-based system consisting of non-tree vegetation usually less than 5–6 m (15–20 ft) tall, usually a result of swidden agriculture activities, that has been left for 2–3 years as part of a fallow/rotational system.
Cropland	Cropland is intensively cultivated land and is mostly planted with annual crops such as staple food, vegetables and fruit.
Paddy field	Paddy is rice field that includes irrigated and non-irrigated (upland) rice, usually located near settlements and appears in light blue in visible-NIR-MIR band combination.
Grassland	Area dominated by grass.
Cleared land	Area where almost no vegetation covers the land, such as an ex-logging area or slashed and burned area prepared for agriculture.
Road and settlement	Road and settlement refers to settlement area (city or village), settlements along the roads, main roads and logging roads.
Water body	Water body refers to an area covered with water.
No data	No data refers to unclassified, clouds and shadow area.

The last stage of ALUCT consists of two subsequent processes: accuracy assessment and land-cover change analysis. The objective of the accuracy assessment is to test the quality of information derived from the image-classification process. It is conducted by comparing field reference data with the most recent land-cover map.

Land-cover change analysis is the last stage in ALUCT. We apply two types of analysis: (i) area-based change analysis; and (ii) trajectory analysis. Area-based change analysis is a simple analysis conducted by comparing the total area of land-cover types in each time period. The result shows the overall trend of land-use and land-cover changes in the area. However, there is no information provided on the location and trajectories of changes. The analytical power offered from this is affected by the intensity of cloud cover or the extent of no-data areas in the map. Trajectory analysis summarises the sequences of changes in land use and land cover of each pixel on the map within the study period. The extent or area of each occurrence or sequence of changes can then be quantified. In this analysis, four trajectories were identified, that is, forest degradation, deforestation, changes to oil palm plantations and changes to rubber plantations. Table 6 provides the definition of each trajectory class.

Table 6. Definition of trajectory classes

Trajectory class	Description
Deforestation	Forest class (undisturbed forest and logged-over forest) changed into other class.
Forest degradation	Undisturbed forest changed into logged-over forest.
Change to oil palm	Any non-forest classes changed into oil palm.
Change to rubber	Any non-forest classes changed into rubber, both monoculture and smallholder.
Others	The remaining classes, excluding no-data class.

Data

Two types of spatial data are required to conduct ALUCT: (1) time-series satellite images; and (2) thematic maps.

a. Satellite images

Time-series satellite images were used to produce land-cover maps over the period of study. We used Landsat images as the primary data for land-cover mapping. Figure 11 shows the time-series Landsat images. The other dataset in this category is the 90m SRTM digital elevation model. Table 7 shows the description of data applied in this study.

Table 7. List of satellite images used for the QBS study

Sensor	Path/Row	Resolution	Acquisition Date
Landsat Multi-Spectral Scanner (MSS)	p137r058 p138r058	60 m	29-Apr-1977 3-Oct-1973
Landsat Thematic Mapper TM	p128r058 p129r058	30 m	22-Jun-1992 13-Jun-1989
Landsat Enhanced Thematic Mapper (ETM)	p128r058 p129r058	30 m	2-Feb-2002 14-Jun-2001
Landsat ETM SLC-off 2010s	p128r058 p129r058	30 m	31-May-2010 30-Jan-2010
Digital elevation Model SRTM (*Shuttle Radar Topography Mission*)		90 m	

b. Thematic maps

Thematic maps such as administrative boundaries and TGHK (Tata Guna Hutan Kesepakatan or Designated Forest Zones) were also used for analyses of land-use and land-cover changes and trajectories. Thematic maps used in this study are presented in Table 8.

Table 8. List of thematic maps used for the QBS study

Thematic	Sources
Estate boundary	Bridgestone
Administrative boundary	Ministry of Forestry
TGHK (Forestry land designation map)	Ministry of Forestry

3.3 Results

Field checking and groundtruth data collection were conducted in November and December 2010. The results of the accuracy check as an error matrix are shown in Table 9 and Table 11. Table 10 and Table 12 show the accuracy of each land-cover class as a percentage.

Table 9. Error matrix of Aek Tarum area with reference data in columns and classification data in rows

ID	Forest	Grassland	Mixed tree	Oil palm	Paddy field	Rubber monoculture	Settlement	Water body	SUM
Forest	8	0	0	0	0	0	0	0	**8**
Grassland	0	0	0	1	0	0	0	0	**1**
Mixed tree	0	0	30	7	1	0	0	0	**38**
Oil palm	0	0	3	70	1	0	0	1	**75**
Paddy field	0	0	0	0	0	0	0	0	**0**
Rubber monoculture	0	0	4	3	0	20	0	0	**27**
Settlement	0	0	0	3	0	0	3	0	**6**
Water body	0	0	0	0	0	0	0	3	**3**
SUM	**8**	**0**	**37**	**84**	**2**	**20**	**3**	**4**	**158**

Table 10. Accuracy assessment result of Aek Tarum area

No.	Accuracy	Land-cover class
1	100%	Forest
2	0%	Grassland
3	78.95%	Mixed tree
4	93.33%	Oil palm
5	NULL	Paddy field
6	74.07%	Rubber monoculture
7	50%	Settlement
8	100%	Water body
	Overall accuracy	**84.81%**

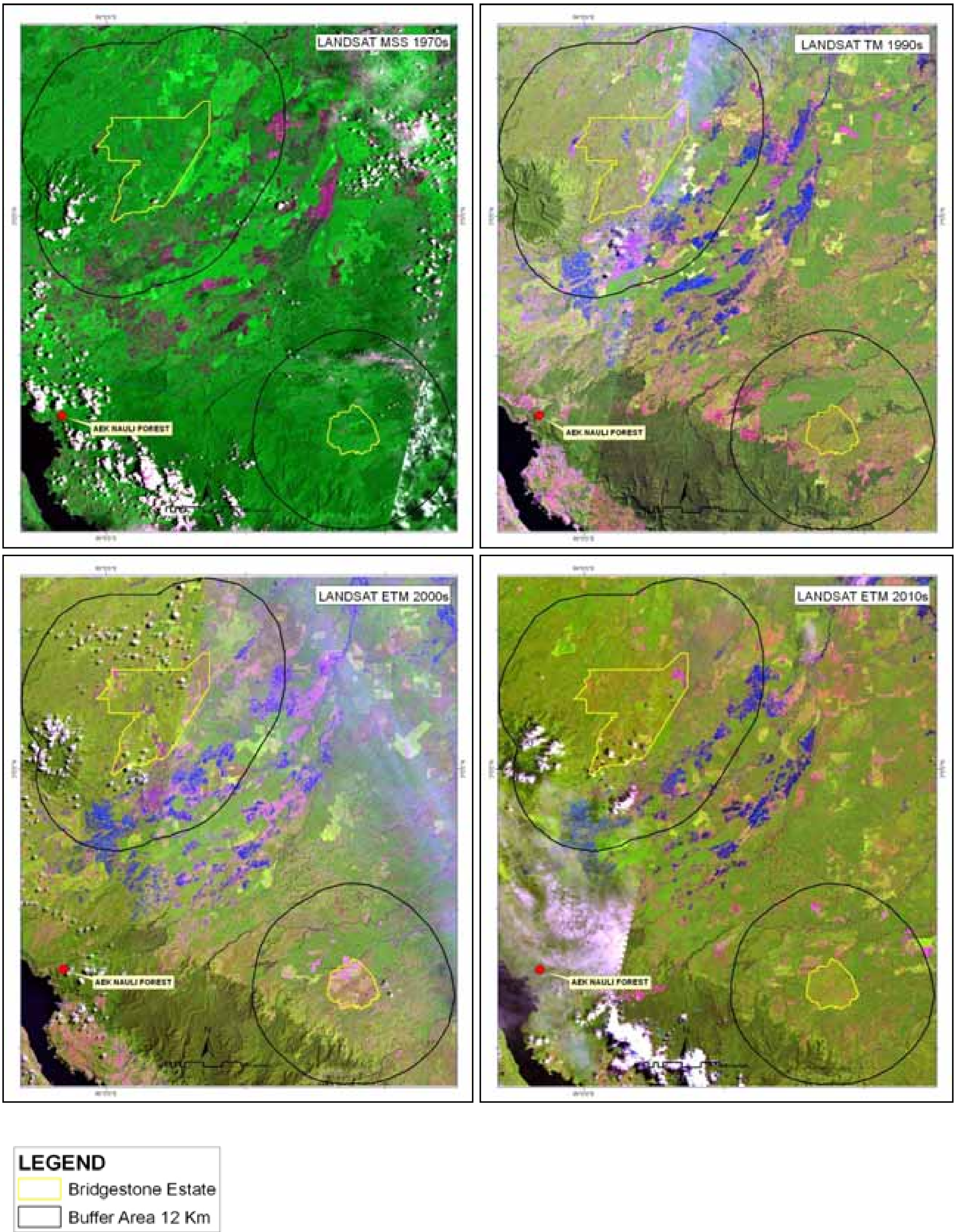


Figure 11. Landsat image time-series: 1970, 1990, 2000 and 2010

The overall accuracy of the 2010 land-cover map of Aek Tarum area was 85%. The forest (undisturbed forest and logged-over forest) and water body classes had the highest percentage of accuracy (100%), but the total reference points were quite few (only 8 and 4 points respectively). Oil palm was 93% accurate and mixed tree was 79%. Grassland had 0% accuracy because there was no reference point for this class, but grassland can be easily identified on satellite images. Paddy field had null value because the two reference points were both misclassified.

Table 11. Error matrix of Dolok Merangir area with reference data in columns and classification data in rows

ID	Cleared land	Crop land	Mixed tree	Oil palm	Paddy field	Rubber monoculture	Settlement	Shrub	Water body	SUM
Cleared land	0	0	0	0	0	0	1	0	0	**1**
Crop land	0	5	0	0	0	0	0	0	0	**5**
Mixed tree	0	1	28	1	0	6	1	0	0	**37**
Oil palm	0	1	5	25	0	7	0	0	0	**38**
Paddy field	0	0	0	0	4	0	0	0	0	**4**
Rubber monoculture	0	0	4	4	0	29	1	0	2	**40**
Settlement	0	0	0	0	0	0	11	0	0	**11**
Shrub	0	1	0	0	0	0	0	0	0	**1**
Water body	0	0	0	0	0	0	0	0	1	**1**
SUM	**0**	**8**	**37**	**30**	**4**	**42**	**14**	**0**	**3**	**138**

Table 12. Accuracy assessment result of Dolok Merangir area

No.	Accuracy	Land-cover class
1	0%	Cleared land
2	100%	Crop land
3	75.68%	Mixed tree
4	65.79%	Oil palm
5	100%	Paddy field
6	72.5%	Rubber monoculture
7	100%	Settlement
8	0%	Shrub
9	100%	Water body
	Overall accuracy	**74.64%**

The overall accuracy of Dolok Merangir area land-cover map in 2010 was 75%. Crop land, paddy field, settlement and water body had the highest percentage of accuracy (100%), meaning that all reference points were correctly classified, although the total reference points were only 5, 4, 11 and 1, respectively. The land-cover class with the highest number of reference points was rubber monoculture with 40 and this class was 72.5% accurate. Cleared land and shrub classes had 0% accuracy because there were no reference points for them. However, these classes were easily identified on satellite images.

A. Time-series land-cover maps and land-cover changes in Aek Tarum

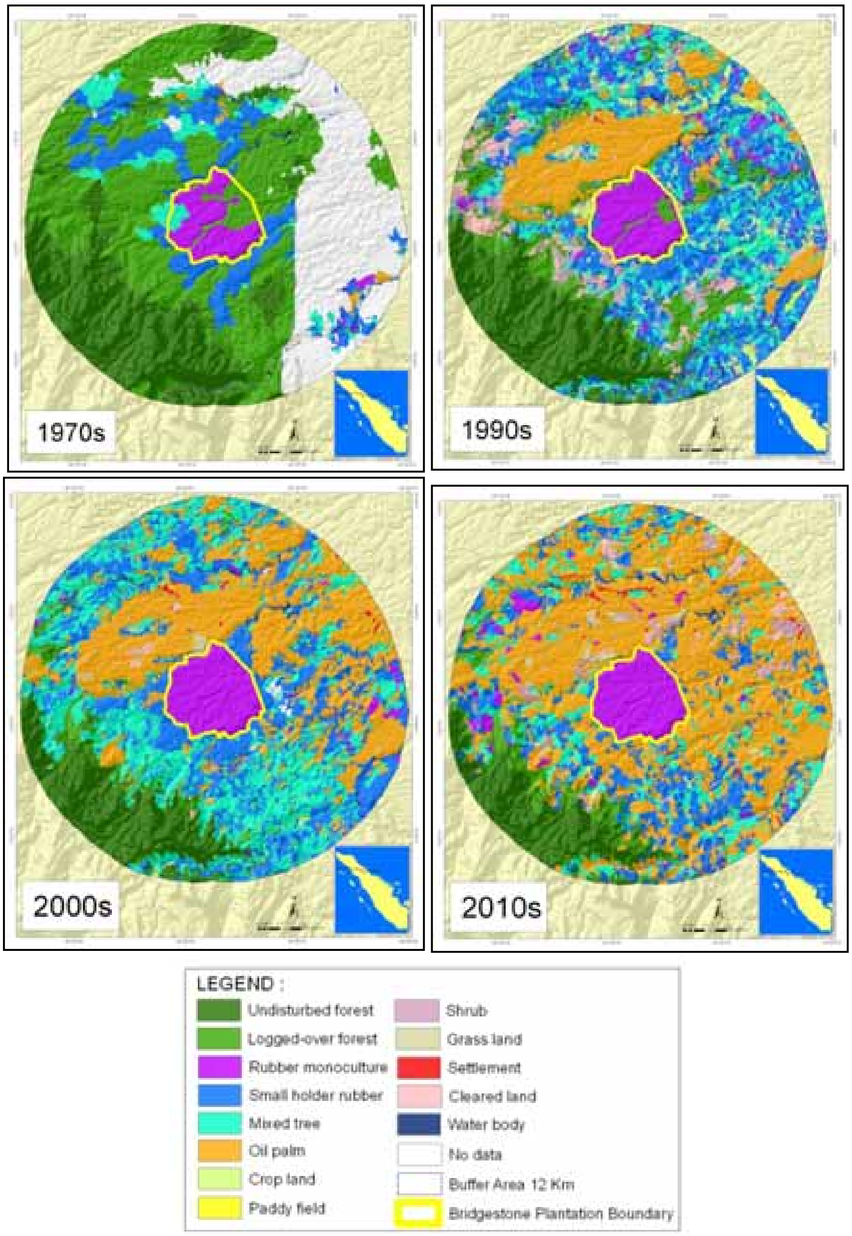


Figure 12. Time-series land-cover maps of Aek Tarum area

Table 13. Area of change for each land-cover type in Aek Tarum area, over the period of study

Land-cover class	1970		1990		2000		2010	
	Hectare	%	Hectare	%	Hectare	%	Hectare	%
Undisturbed forest	16975.89	21.2%	12658.68	15.8%	9654.30	12.1%	6842.16	8.6%
Logged-over forest	28042.74	35.1%	7360.74	9.2%	2235.78	2.8%	3377.88	4.2%
Mixed tree	3374.55	4.2%	7472.52	9.3%	15192.72	19.0%	6114.69	7.6%
Smallholder rubber	8104.05	10.1%	11840.49	14.8%	12748.95	15.9%	9136.17	11.4%
Rubber monoculture	3236.31	4.0%	5227.20	6.5%	4709.88	5.9%	5550.03	6.9%
Oil palm	368.73	0.5%	8991.36	11.2%	14618.70	18.3%	26627.94	33.3%
Crop land	10.44	0.0%	1173.06	1.5%	277.11	0.3%	240.21	0.3%
Paddy field	12.33	0.0%	3.42	0.0%	48.42	0.1%	0.00	0.0%
Shrub	19.35	0.0%	2335.05	2.9%	77.22	0.1%	1029.51	1.3%
Grassland	12.96	0.0%	557.64	0.7%	220.59	0.3%	607.05	0.8%
Cleared land	18.00	0.0%	2533.77	3.2%	279.99	0.4%	345.69	0.4%
Settlement	0.00	0.0%	16.47	0.0%	107.46	0.1%	296.28	0.4%
Water body	514.53	0.6%	519.48	0.6%	518.76	0.6%	522.27	0.7%
no data	19254.60	24.1%	19254.60	24.1%	19254.60	24.1%	19254.60	24.1%
Totals	**79944.48**	**100%**	**79944.48**	**100%**	**79944.48**	**100%**	**79944.48**	**100%**

Based on the table of land-cover change analysis in the Aek Tarum area, we note that the forest area (undisturbed forest and logged-over forest) decreased from 45 018 ha in 1970 (56.30%) to 10 220 ha in 2010 (12.80%). In the 1970s and 1990s, there were still forest areas inside the Aek Tarum estate but they disappeared in the 2000s and were changed into rubber monoculture (see Figure 12). In the Aek Tarum area, the total area of rubber monoculture increased from 11 340 ha in 1970 to 14 686 ha in 2010. Similarly, oil palm plantations, both smallholder and large scale, also significantly increased from 369 ha in 1970 to 26 628 ha in 2010.

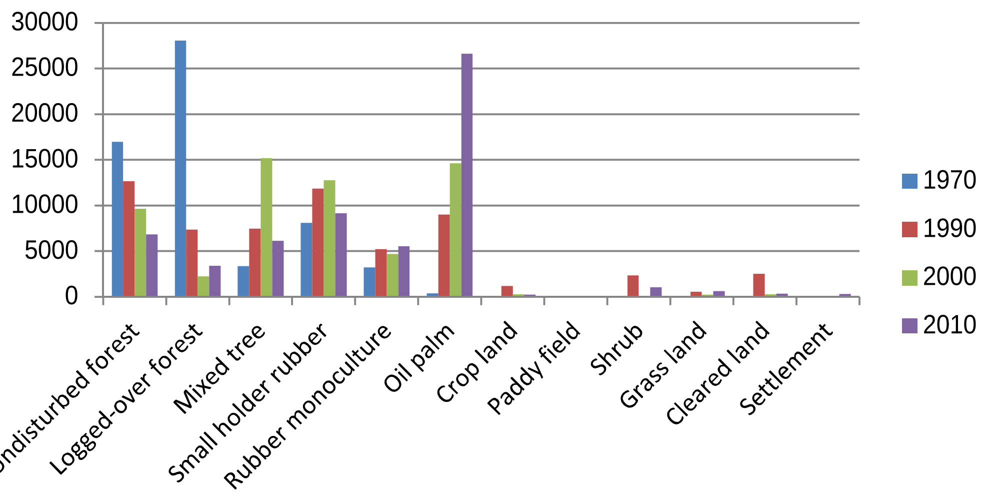


Figure 13. Overall land-cover changes in the Aek Tarum area

The biggest rate of forest loss during the study period in Aek Tarum occurred in the 1970–1990 period: 1249.96 hectare per year; while the forest loss rate during 1970–2010 was only

869.96 hectare per year on average. This forest loss was followed by an increase in tree-based systems, such as rubber monoculture and oil palm. Of the two land-use systems, the increase of oil palm area was more significant in comparison to that of rubber plantations.

B. Time-series land-cover maps and land-cover changes in Dolok Merangir

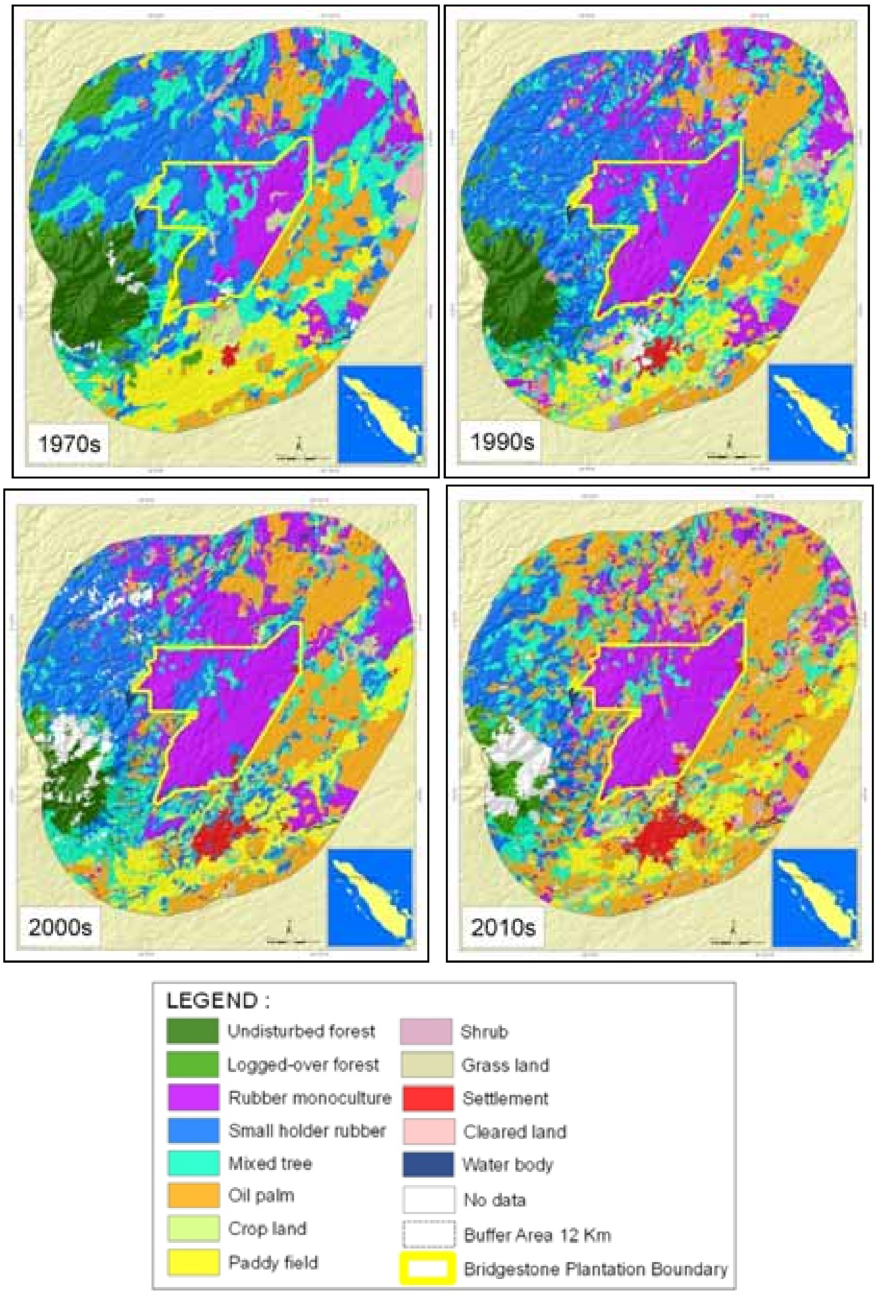


Figure 14. Time-series land-cover maps of Dolok Merangir area

Table 14. Area of change for each land-cover type of Dolok Merangir area, over the period of study

Land-cover class	1970		1990		2000		2010	
	Hectare	%	Hectare	%	Hectare	%	Hectare	%
Undisturbed forest	5688.09	4.1	2894.85	2.1	2009.43	1.4	477	0.3
Logged-over forest	5887.08	4.2	2570.85	1.8	1186.74	0.9	1832.13	1.3
Mixed tree	29586.06	21.2	17712.27	12.7	18217.08	13.1	17948.16	12.9
Oil palm	15298.92	11.0	21699.45	15.6	28024.29	20.1	49860.99	35.8
Rubber monoculture	15056.1	10.8	27194.49	19.5	30824.01	22.1	24217.83	17.4
Small holder rubber	37390.32	26.8	34771.77	25.0	30286.89	21.7	15650.37	11.2
Shrub	314.1	0.2	2736.36	2.0	1219.5	0.9	2215.44	1.6
Grassland	2120.58	1.5	1224.36	0.9	514.98	0.4	1413.09	1.0
Crop land	2071.53	1.5	5250.06	3.8	3001.68	2.2	2333.34	1.7
Paddy field	14610.78	10.5	10935	7.8	11753.46	8.4	9550.44	6.9
Cleared land	1410.03	1.0	1473.66	1.1	309.69	0.2	738.36	0.5
Settlement	334.08	0.2	1303.65	0.9	2424.87	1.7	3536.01	2.5
Water body	667.53	0.5	668.43	0.5	662.58	0.5	662.04	0.5
no data	8918.73	6.4	8918.73	6.4	8918.73	6.4	8918.73	6.4
Totals	**139353.93**	**100.0**	**139353.93**	**100.0**	**139353.9**	**100.0**	**139353.9**	**100.0**

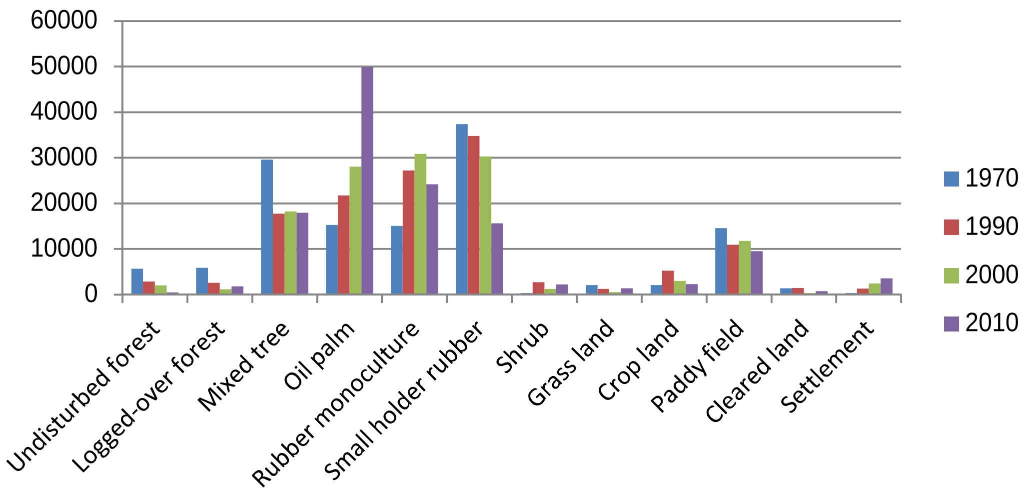


Figure 15. Overall land-cover change in Dolok Merangir area

In Dolok Merangir, the total of oil palm areas increased throughout 1970–2010, but the highest rate occurred during 2000–2010. As oil palm areas increased, smallholder rubber decreased over the entire study period, with the highest rate also in 2000–2010. According to information from local people, in the 2000s they tended to convert their rubber plantations into oil palm because they thought that oil palm was more valuable than rubber.

Since the beginning of the observation period, the total forest area in Dolok Merangir area was smaller than in Aek Tarum. Forest lost during the 1970s to 2010 was also less in Dolok Merangir than in Aek Tarum. The time-series land-cover maps of Dolok Merangir show that there was a small amount of forest inside the plantation boundary at the beginning of the observation period (1970) but it had disappeared by 1990. In the Dolok Merangir estate, the total area of smallholder rubber tended to decrease over time, in contrast to oil palm, which significantly increased over the period of observation, especially the last ten years.

C. Comparison of land-cover trajectories between the two areas

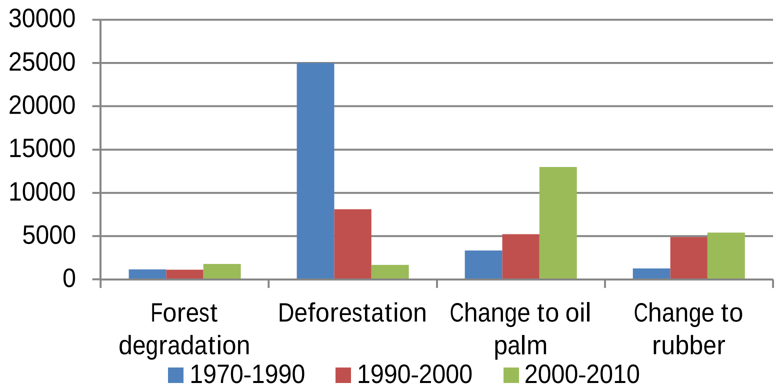


Figure 16. Land-cover trajectory changes of Aek Tarum area, over the period of study

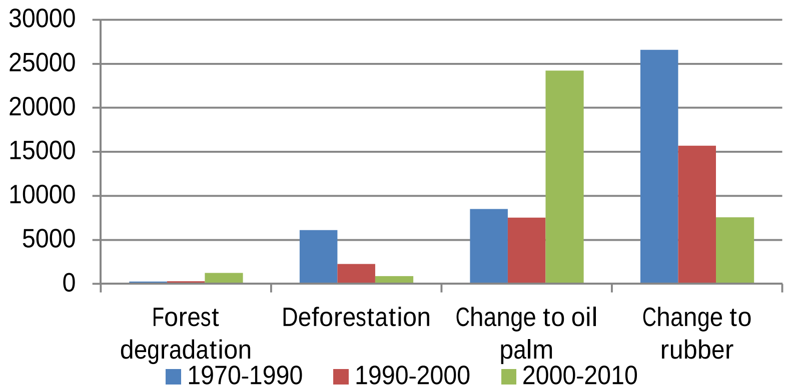


Figure 17. Land-cover trajectory changes of Dolok Merangir area, over the period of study

Analysis of land-use trajectories shows that deforestation was highest in Aek Tarum plantation compared to that in Dolok Merangir (34 808 ha in Aek Tarum and 9266 ha in Dolok Merangir). The largest decrease of forest area occurred during the period 1970–1990, when most of the forest area changed to rubber and oil palm plantations. Forest degradation happened in both areas, but with larger areas in Aek Tarum, despite the small difference between the two. The dominant trajectory in Dolok Merangir was the change to oil palm, which was 8488 ha in 1970 and 24 219 ha in 2010, with a slight decrease during 1990–2000. Change to rubber decreased throughout the period of study, from 26 578 ha during 1970–1990 to 7559 ha during 2000–2010 (see Figures 16 and 17).

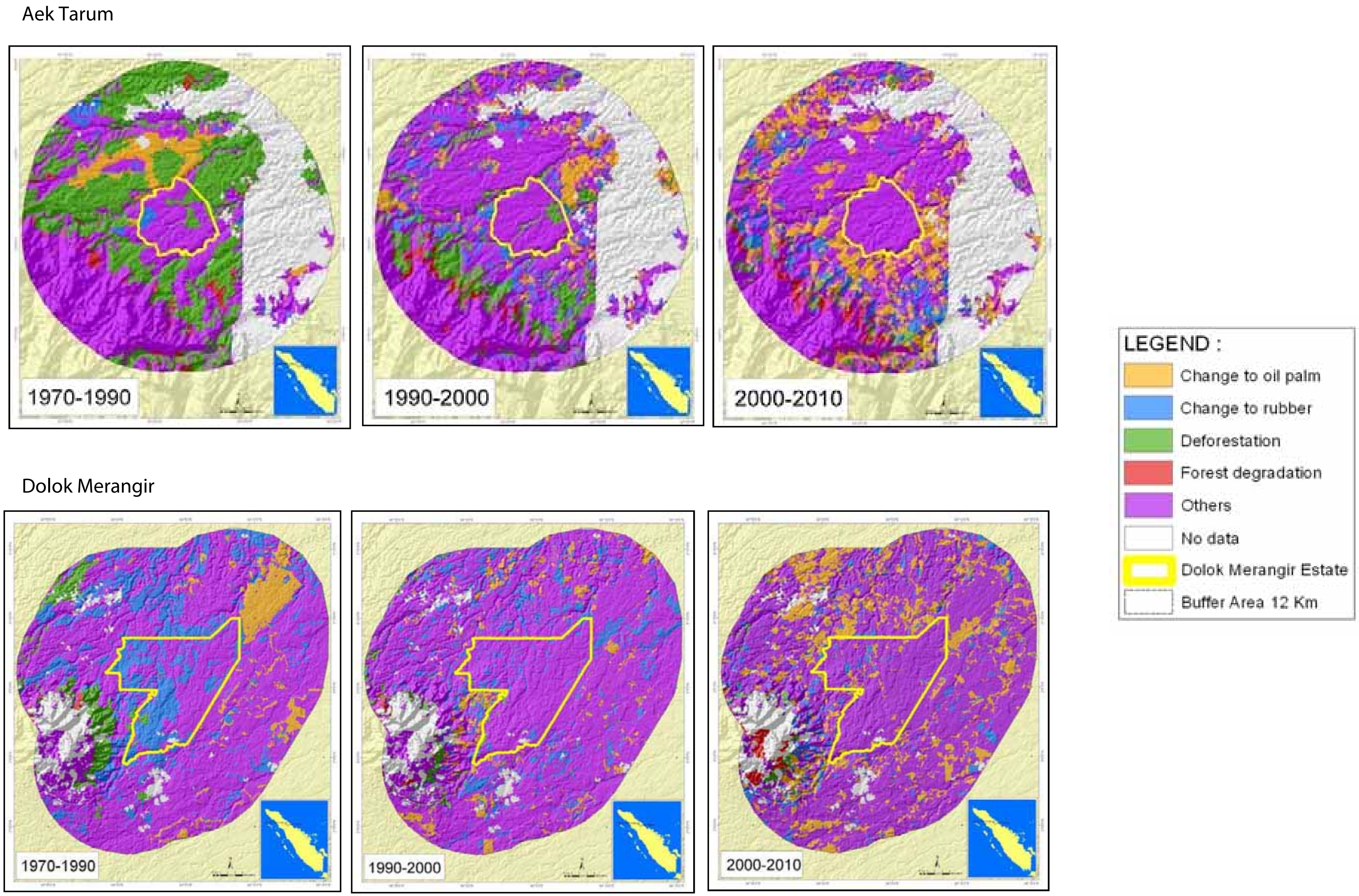


Figure 18. Land-cover trajectory maps of Aek Tarum and Dolok Merangir areas

D. Land-cover trajectories based on designated forest zones (TGHK)

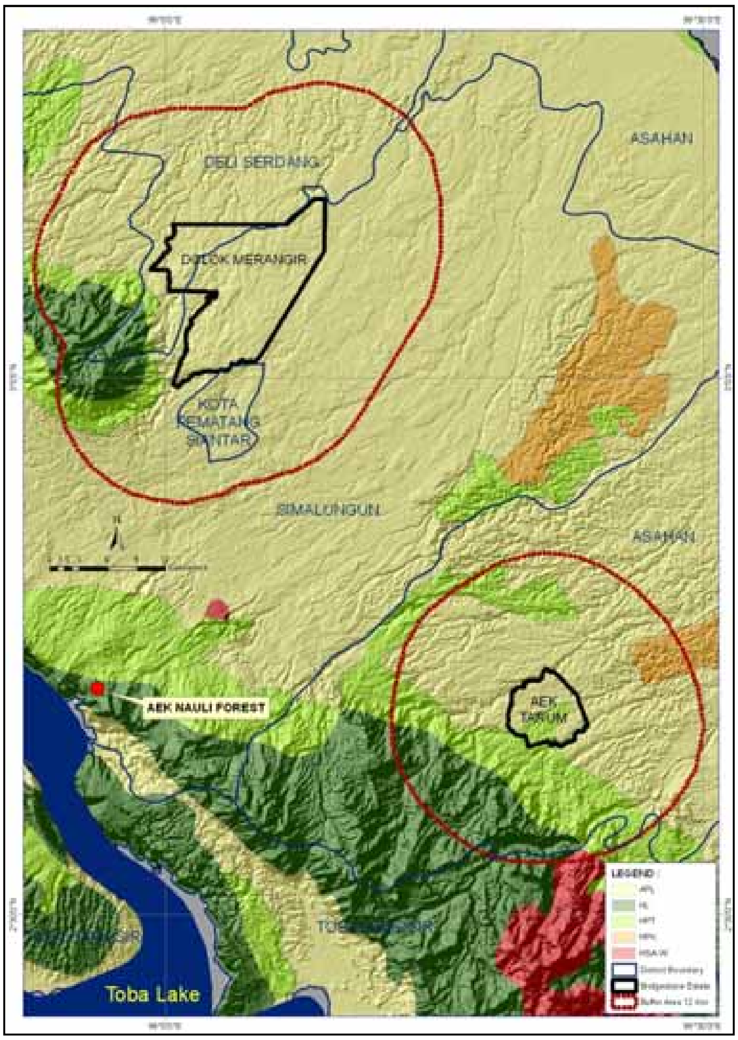


Figure 19. Forest designation map (TGHK)

In the two study areas, the areas under designated forest zone (TGHK) classes are shown in Table 15.

Table 15. Areas of three designated forest zone classes

Category	Aek Tarum	Dolok Merangir
HL (Hutan Lindung/*Protected Forest*)	12 256.47 ha	10 101.33 ha with 5379.93 ha of no data area
HPT (Hutan Produksi Terbatas/*Limited Production Forest*)	20 271.6 ha with 3342.15 ha of no data area	7049.79 ha with 848.97 ha of no data area
APL (Areal Penggunaan Lain/*Non-Forest Zone*)	44 780.13 ha with 13937.49 ha of no data area	122 202.81 ha with 2689.83 ha of no data area

* *No data area was not analysed; the areas shown in the chart (Figures 13 and 14) were total area subtracted with no data area*

During the period 1970 to 2000, deforestation occured in all TGHK classes in the study areas, on both estates. In both study areas, only small parts belonged to HP and HPT, while the largest portion was APL (57.92% in Aek Tarum and 87.69% in Dolok Merangir). For Aek Tarum, deforestation dominated in APL during 1970–1990 (15432.66 ha), while in the remaining period, the dominant change was 'others', which can include changes to cropland and the land-use classes that remained the same, and covered 21 926.16 ha in 1990–2000 and 21 209.67 ha in 2000–2010. For Dolok Merangir, the dominant changes in APL areas in all three periods of observation was 'others'. With regards to plantation establishment, changes to rubber plantations exceeded the changes to oil palm plantations from 1970 to 1990, while the trend was reversed during 2000 to 2010 (Figure 20).

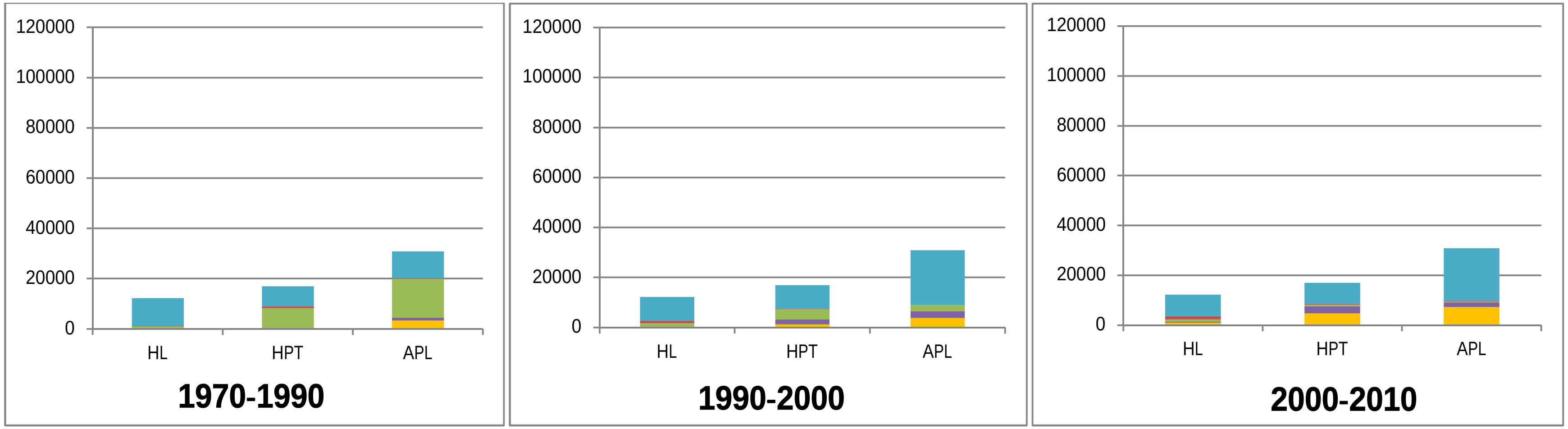


Figure 20. Land-cover trajectory changes of Aek Tarum area based on forest designation (TGHK) map

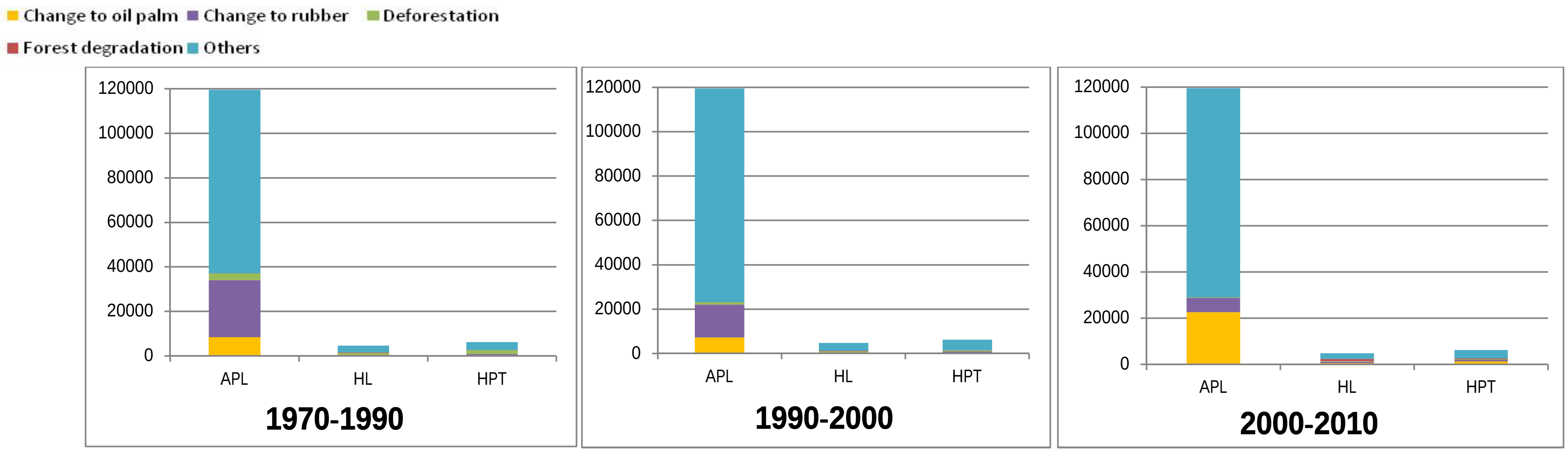


Figure 21. Land-cover trajectory changes of Dolok Merangir area based on forest designation (TGHK) map

E. Comparison of habitat changes between the two estates, 1970–2010

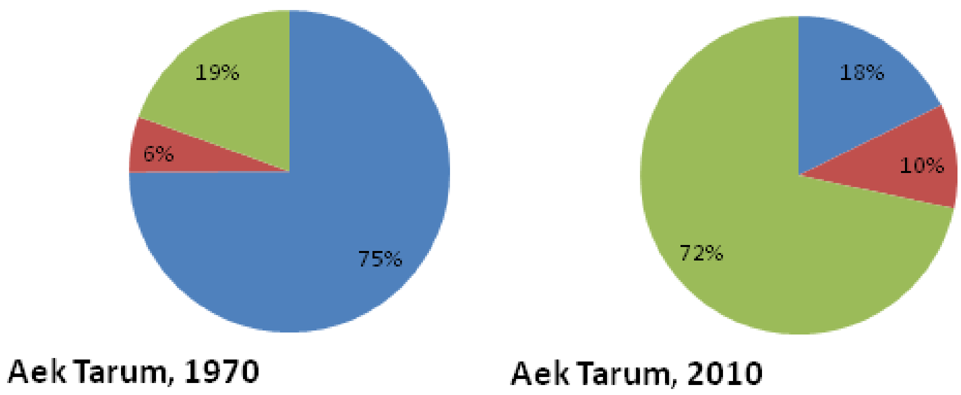


Figure 22. Habitat configuration changes between 1970 and 2010 in Aek Tarum area

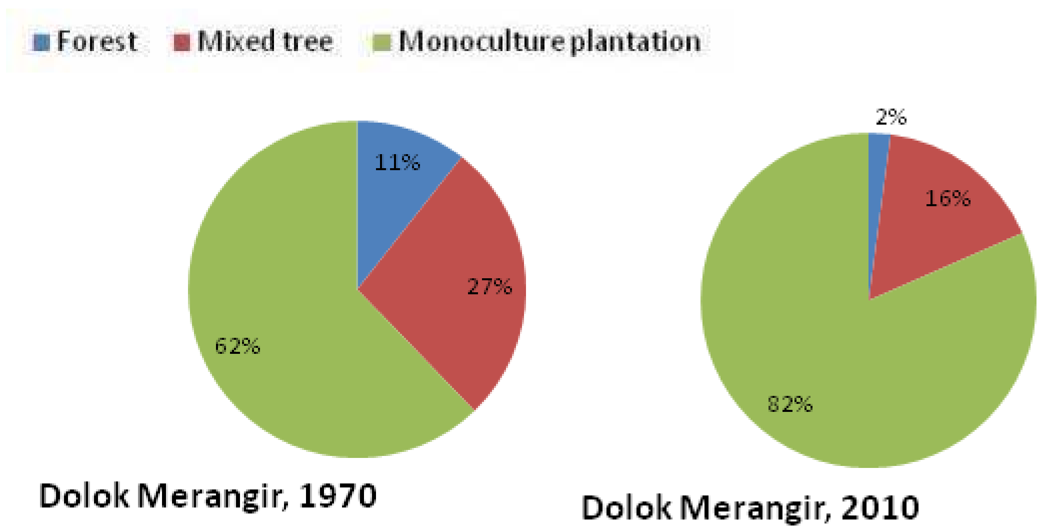


Figure 23. Habitat configuration changes between 1970 and 2010 in Dolok Merangir area

The composition of forest (undisturbed forest and logged-over forest), agroforest (mixed tree), and monoculture plantations (rubber monoculture, smallholder rubber and oil palm plantations) is different in both areas. In Aek Tarum in 1970, forest dominated the area with 75% coverage whereas in 2010 the dominant land cover was monoculture plantation (72%). In contrast to Aek Tarum, in Dolok Merangir, habitat configuration composition was relatively similar in 1970 and in 2010, with monoculture plantation dominating followed by mixed tree and forest classes respectively. However, despite the similar composition, the percentage of monoculture plantation increased in 2010 while mixed tree systems and forest areas decreased.

3.4. Discussion

Deforestation occurred in the two estate areas of PT BSRE during the period of observation (1970–2010). However, differences exist, especially with regards to the time frame of the largest deforestation and rate of forest loss. In the first period of observation (1970), the forest area was still large in Aek Tarum while it was already at a minimum in Dolok Merangir. The establishment of plantations in Dolok Merangir took place in the 1930s, well before the period of observation, therefore, forest dynamics were low in this area compared to Aek Tarum. In Aek Tarum, conversion of forest into rubber plantatation showed a consistent dynamic from 1970 to 1990, while between 1990 and 2010 the trend changed to conversion to oil palm plantation, although change to rubber still occurred. This demonstrates that owing to the existence of forest in the early periods of observation, land-use changes owing to forest conversion in Aek Tarum were relatively high. In contrast, the Dolok Merangir area had stable forest areas for the entire period of observation, while land-use changes are related more to non-forest land-use systems.

Different stages of forest conversion and plantation age had an effect on the habitat composition between the two plantation areas. For Aek Tarum, the proportion of combined forest and mixed tree systems had always been higher from 1970 to 2010, compared to the proportion in Dolok Merangir, implying better natural habitat composition in Aek Tarum than in Dolok Merangir. Nevertheless, early conversion of the forest in Dolok Merangir implies relatively stable non-forest land-use systems for a longer period of time and, by now, the rubber plantations had already developed into a mature system. The old rubber systems provide more stable habitat to the different biodiversity components in this plantation area and this might benefit biodiversity conservation since old rubber plantations have been proven to hold relatively high biodiversity values in comparison to young rubber plantations (Beukema et al. 2007).

The change from rubber into oil palm took place since the 1990s owing to the rise in the price of crude palm oil (CPO), which encouraged local people to change their commodity plantations. In the period 2000–2010, the total area of oil palm plantation was increasing in contrast to the decreasing area of smallholder rubber. This trend occurred in both estates, but with a steeper increase in Dolok Merangir. If this trend continues, it will likely result in the deflation of biodiversity in both areas. The change from rubber plantation into oil palm plantation will result in the degradation of biodiversity since the variety of flora and fauna in rubber plantations, especially the old rubber plantations, is higher than in oil palm plantations (Rasnovi, Vincent and van Noordwijk 2006).

3.5 Conclusion

Land-use and land-cover changes in the two plantation areas show distinct patterns, stages of forest conversion and rates of forest loss. These different dynamics are likely to have different effects on the dynamics of biodiversity. Understanding the dynamics of land-use and land-cover changes is the key to assessing the biodiversity values of an area. The contrasting land-use changes as shown in the case of the two PT BSRE plantations, that is, forest conversion versus non-forest land-use changes, can explain the differences in biodiversity as well as give insights that will help with efforts to conserve flora and fauna diversity related to the established tree-based land-use systems.

4. Comparison of floristic composition and diversity in rubber plantations and their surroundings

Harti Ningsih, Subekti Rahayu and Hesti L. Tata

4.1 Background

The introduction of rubber to Sumatra in the first decade of the 20th century sparked a revolutionary change in land use because the crop was found to be compatible with local forests. Rubber was also planted by smallholder farmers and managed with low intensity weeding and thinning, forming diverse biological systems. This plant and animal system is known as complex rubber agroforest (RAF). Complex RAF is characterised by a substantial share of rubber trees in the total tree biomass and also by a large diversity of species of native trees and understory plants (Laumonier 1997, Beukema et al. 2007). A study in Bungo district, Jambi province, has shown that complex RAF has considerably more tree species at the seedling stage compared to natural forest.

Research conducted by the World Agroforestry Centre in Jambi has shown that, in the case of so-called 'jungle rubber' or smallholder complex RAF areas, the main 'environmental service' that differentiates them from other 'tree crop' production systems is the diversity of plants and animals. With rubber trees (*Hevea brasiliensis*) typically making up less than 50% of the total tree basal area, the diversity of forest trees, epiphytes, birds, insects and mammals is around 50–70% of that in natural forests. In landscapes where natural forests are fast disappearing, species such as the endangered Sumatran tiger and *Rafflesia arnoldii*, the world's biggest flower, use jungle rubber areas for movement and dispersal. In many places in Sumatra, jungle rubber areas connect national parks and protected areas, hence functioning as important corridors that allow the movement of wild animals and dispersal of plant species. These agroforests are also a primary source of daily income for millions of rubber farmers. Jungle rubber provides one of the best examples of an 'integral' approach to ecological agriculture, combining conservation and income-generating opportunities (Panjiwibowo et al. 2007). The management intensity adopted by the farmers for the rubber areas was strongly related with species richness and an index of biodiversity (Rasnovi 2006).

We studied tree diversity at all growth stages in the rubber plantations of PT BSRE in Dolok Merangir and Aek Tarum compared with smallholder rubber and forest in adjacent areas.

4.2 Methods

4.2.1 Study area

The study was conducted in PT BSRE plantations at Dolok Merangir (Simalungun district) and Aek Tarum (Asahan district). The plantation at Dolok Merangin (P_DM) at 03°06'N and 99°07'E covered 18 000 ha and was established in 1917. The second plantation at Aek Tarum (P_AT) at 02°40'7"N and 99°22'6"E covered 6 000 ha. The plantations have been intensively managed (for example, regular fertilisation, weeding and tapping) and this has affected the condition of the vegetation (Figure 24). For comparison, we also conducted a study in a smallholder rubber area and in native forest. Two rubber smallholdings were located at Dolok Merangin (SH_DM) and Aek Tarum (SH_AT) where a village surrounds each plantation. There are some different management practices between a rubber plantation and smallholder rubber areas. Smallholders mix the rubber trees with other species of valuable trees to form simple agroforestry systems that use less fertilization and weeding (Figure 24). A forest (02°43′4″N and 98°56′25″E) located at Aek Nauli (Simalungun district) with an elevation range between 1200 and 1300 m asl was also studied. Since 1960, this forest has been part of a forest research area under the control of the Forestry Research Institute Aek Nauli, Ministry of Forestry. The location is shown in Figure 25.

Figure 24. Vegetation conditions at study sites
Legend: (A) rubber plantation; (B) rubber smallholding in Dolok Merangir; (C) rubber smallholder in Aek Tarum

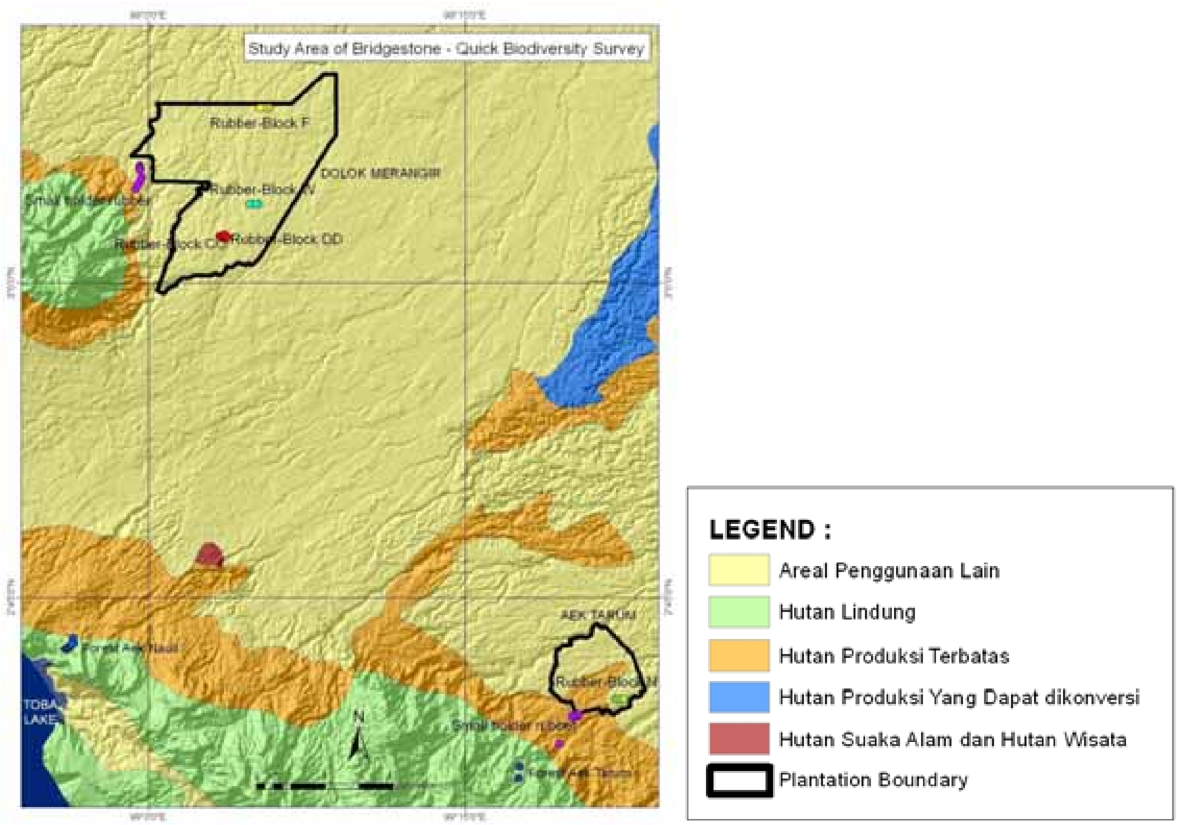


Figure 25. Location of the study area

4.2.2 Sampling methods

Vegetation was sampled in 10 plots along a 1 km transect in the smallholdings (SH_DM and SH_AT) and forest areas. The rubber plantation areas (P_DM and P_AT) were similar and were sampled using five plots along a 1 km transect. Vegetation was classified into four strata (seedlings with all understorey, saplings with height > 1.5 m, poles with height > 2 m and 10 ≤ DBH ≤ 20 cm, and trees with DBH > 20 cm).

We sampled tree vegetation in 20 × 20 m plots every 100 m along the transect (Figure 3) and poles in an 8 × 8 m nested plot within the 20 × 20 m plot. All trees and poles in each plot were identified and their diameter at breast height (DBH) measured. Saplings were recorded in a 4 × 4 m plot and seedlings in a 1 × 1 m plot laid out in successively smaller plots in a corner of the 8 × 8 m plot. All saplings and seedlings were counted and identified to the species level. Identification was carried out by reference to herbarium specimens at the Herbarium Bogoriense, Bogor.

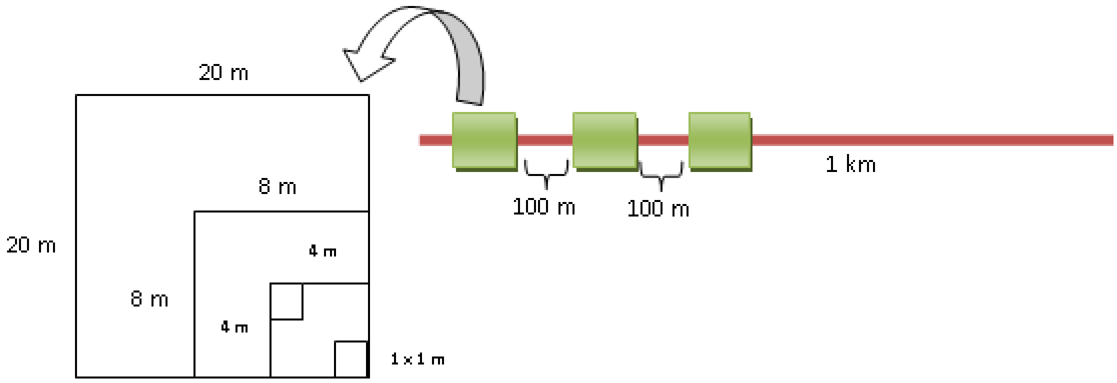


Figure 26. Vegetation sample plot layout using Quick Biodiversity Survey

4.2.3 Data analysis

The floristic composition, diversity and similarity were measured using qualitative indices. Species richness for all stages of vegetation was computed using species accumulation curves. To characterise the composition of vegetation within the study sites, we calculated the Important Value Index (IVI) (Busby et al. 2010). The IVI was calculated for each species by summing the relative values (R) of the following parameters: species density (number of individuals/sampling area), dominance (the sum of the basal areas of all individuals) and frequency (number of plots in which the species was present). To estimate diversity, we calculated the Shannon diversity index (H'). We assessed similarity in species composition between sampling plots of all stages using the Bray-Curtis similarity index. The area covered by the sample was differentiated based on the land-use systems.

1. Forest:
   a. Tree: 10 plot × (20 × 20) = 4000 m^2 = 0.4 ha
   b. Pole: 10 plot × (8 × 8) = 640 m^2 = 0.064 ha
   c. Sapling: 10 plot x (4 ×4) = 160 m^2 = 0.016 ha
   d. Seedling: 10 plot x 2 × (1 × 1) = 20 m^2 = 0.002 ha

2. Smallholder :
   a. Tree: 2 × 10 plot × (20 × 20) = 8000 m^2 = 0.8 ha
   b. Pole: 2 × 10 plot × (8 × 8) = 1280 m^2 = 0.128 ha
   c. Sapling: 2 × 10 plot × (4 × 4) = 320 m^2 = 0.032 ha
   d. Seedling: 2 × 10 plot × 2 × (1 × 1) = 40 m^2 = 0.004 ha

3. Plantation:
   a. Tree: 6 × 5 plot × (20 × 20) = 12 000 m^2 = 1.2 ha
   b. Pole: 6 × 5 plot × (8 × 8) = 1920 m^2 = 0.192 ha
   c. Sapling: 6 × 5 plot × (4 × 4) = 480 m^2 = 0.048 ha
   d. Seedling: 6 × 5 plot × 2 x (1 × 1) = 60 m^2 = 0.006 ha

4.3 Results and discussions

In total, we identified 181 species belonging to 71 families. There were 131 species (49 families) at the seedling stage, 45 species (29 families) at the sapling stage, 22 species (families) at the pole stage and 35 species (26 families) of tree. Table 16 shows the average species number at the plot level for each land use. Based on the observations at the plot level (alpha diversity), there was highest floristic diversity in the forest followed by the smallholdings and then the rubber plantation.

Table 16. Alpha diversity for all vegetation stages based on plot level observations under different land uses

Growth stage	Alpha diversity		
	Forest	Rubber smallholding	Rubber plantation
Tree	2.4	1.6	1.3
Pole	3.6	0.6	0.4
Sapling	1.6	0.9	0.2
Seedling	2.6	0.9	0.3

Based on extrapolation to the land-use level (beta diversity), the average number of species dramatically decreased, mainly at the higher growth levels, that is, for saplings, poles and trees (Table 17). However, the rubber smallholdings still maintained 85% of the species of seedlings and about 20% of the species of saplings, poles and trees. Most of the pole and tree species in the smallholding sites had been planted earlier by farmers. In the plantations, we only found rubber trees at the pole and tree stages. A lack of tree seedling species growing in the smallholdings and rubber plantations indicated that the potential regeneration of tree species was low. In contrast, the forest site contained high floristic diversity for all levels of growth, which provide a clear indication that natural regrowth and regeneration happened continuously in the forest. Compared to the smallholdings and rubber plantations, the population density of seedlings in the forest was lower, but the sapling and pole density was higher (Table 18).

Table 17. Beta diversity for all vegetation stages under different land uses

Growth stage	Transect area (ha)	Forest		Rubber Smallholding		Rubber plantation	
		number of families	number of species	number of families	number of species	number of families	number of species
Seedling	0.4	24	47	22	40	19	38
Sapling	0.064	24	37	7	9	0	0
Pole	0.016	13	17	3	3.5	1	1
Tree	0.001	18	27	5	6	1	1

Table 18. Species composition based on growth stage in different land-use systems

Growth state	Tree population density (individual ha^{-1})		
	Forest	Smallholding	Plantation
Seedling	114 500	190 750	163 000
Sapling	7 813	1 031	521
Pole	578	164	130
Tree	398	475	133

4.3.1 Seedling stage

Most of the families in the seedling stage consisted of one or two species, except for Asteraceae (10 species), Rubiaceae (10 species), Euphorbiaceae (7 species) and Fabaceae (7 species). On average, 40 species (22 families) were found in the smallholding sites and 38 species (19 families) in the rubber plantations, which were dominated by herbs. In contrast, 47 species were found in the forest, which was dominated by trees (Figure 27).

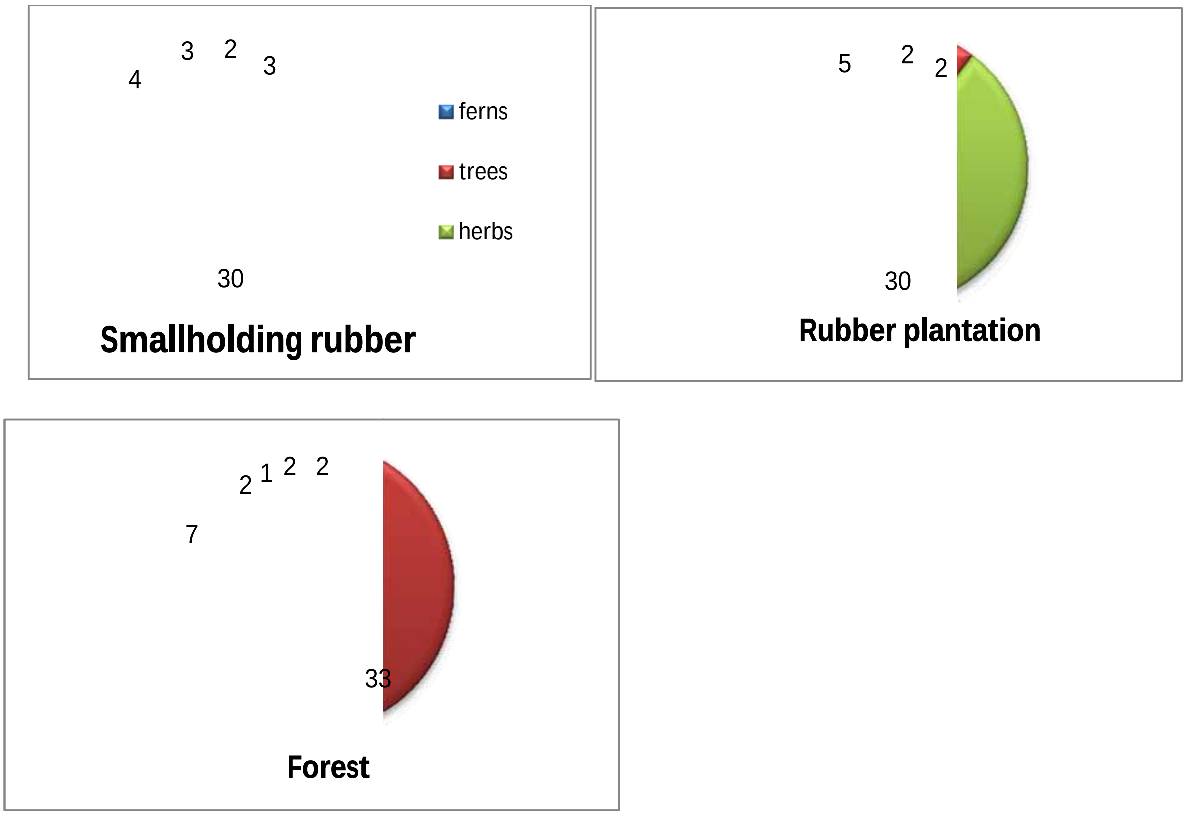


Figure 27. Seedling species composition (life form, number of species) for different land uses

Compared to the jungle rubber (rubber agroforest) at Jambi, there was a lower number of herbaceous species in the rubber smallholdings at Simalungun. There were 50 species of herbs and shrubs found in the jungle rubber area (Gouyon et al. 1993). Weeding one or two times in the rubber smallholding plantation would decrease the number of species, particularly woody shrubs.

There was a higher seedling species density in opened areas like the rubber plantation owing to invasion by dominant weed species such as *Lasianthus reticulatus, Torenia peduncularis, Phyllanthus amarus* and *Borreria alata* (Figure 28). Herbs and grasses grew immediately after weeding or herbicide application in both the rubber and smallholding plantations. *Urochloa ramosa was* one of the grass species dominant in the rubber smallholding and plantation areas. The forest was dominated by a fern (*Lygodium* sp.) and by a tree seedling (*Symplocos cochinchinensis*) that also dominated in the sapling stage, as well as by a herb (*Hemigraphis reptans*).

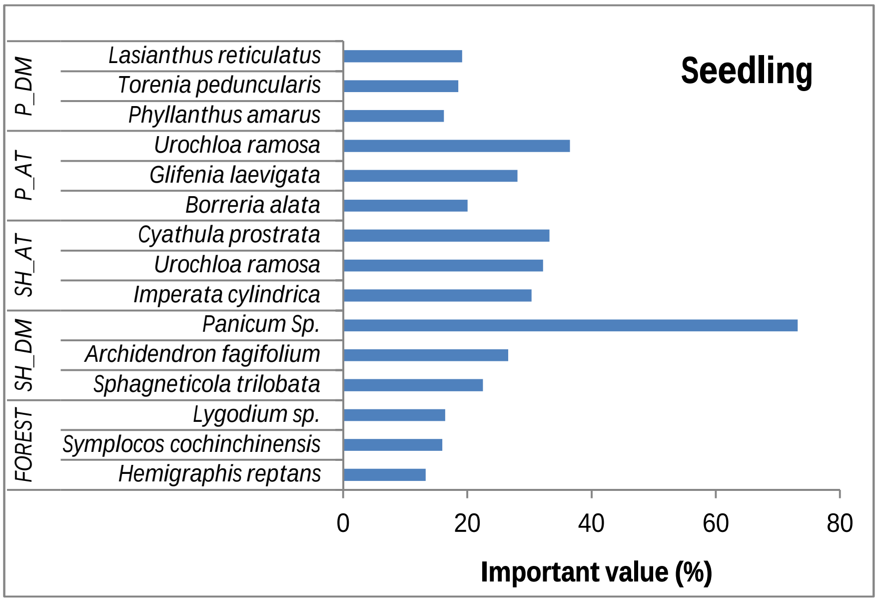


Figure 28. Three dominant seedling species in forest, smallholding (SH_DM and SH_AT), and plantation (P_AT and P_DM) based on Important Value Index

The Bray-Curtis similarity index (Figure 29) indicated that the similarity in species among land-use systems was low, even though it was likely to be considered high when compared to forest. For the seedling stage, the similarity index for the two plantations (P_DM and P_AT) had higher value between other sides, although it was only 30%. Similar management systems in both plantation types, such as herbicide application, affected the survival rate of seedlings in those areas. *Ageratum conyzoides* (a medicinal plant), *Borreria alata, Borreria repens, Clidemia hirta* (dispersed by birds, pigs, other animals and humans), *Crassocephalum crepidioides* (a medicinal plant), *Croton glandulosus, Cyperus kyllingia, Diodia ocimifolia, Imperata cylindrica, Mikania micrantha, Selaginella plana* (a medicinal plant), *Sesbania exaltata, Symplocos cochinchinensis* (dispersed by birds), *Tacca cristata* (a medicinal plant), *Torenia peduncularis* and *Vigna* sp. are groundcover species that were found in the plantation. Otherwise, the species dominance composition at Dolok Merangir and Aek Tarum was different.

The similarity between the plantation (P_DM and P_AT) and smallholding (SH_DM and SH_AT) sites was lower (26%). Some shrubs, such as *Ageratum conyzoides*, *Clidemia hirta*, *Imperata cylindrica*, *Selaginella plana, Sesbania exaltata, Symplocos cochinchinensis* and *Tacca cristata*, were found both in the smallholding and rubber plantations. *Clidemia hirta* and *Symplocos cochinchinensis* are seedling species that were found in the forest, rubber smallholding and rubber plantations, which indicated that both are common species that can be found under canopy as well as in open areas.

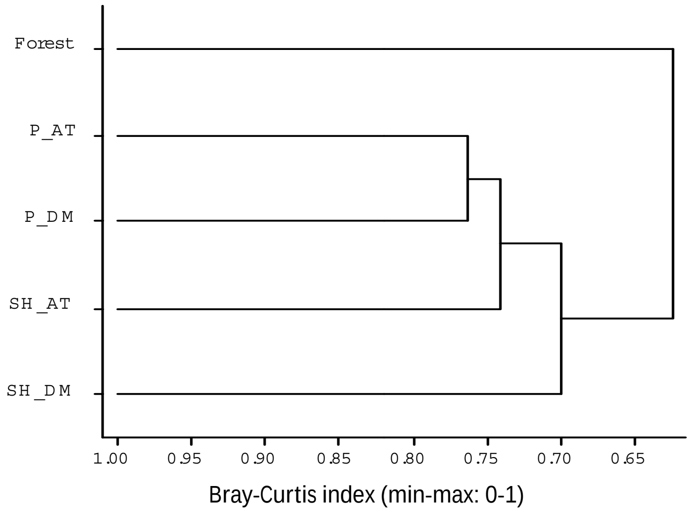


Figure 29. Dendrogram and clustering analysis of seedling species comparison between forest, rubber plantation, and rubber smallholding, where the highest value indicates the nearest similarity

Observation based on the 30 plots in the rubber plantation, the 20 plots in the smallholding rubber sites at Dolok Merangir and Aek Tarum and the 20 plots of forest at Aek Nauli indicated different patterns of species accumulation (Figure 30) and seedling diversity. The seedlings species accumulation in the rubber smallholding area was higher compared to the rubber plantation. Otherwise, species accumulation in both the smallholding and rubber plantations tended to be constant after observations of 20 plots. In contrast, the number of species was still increasing in the forest at 20 plots, so that data from more plots would be expected to increase the number of species recorded there.

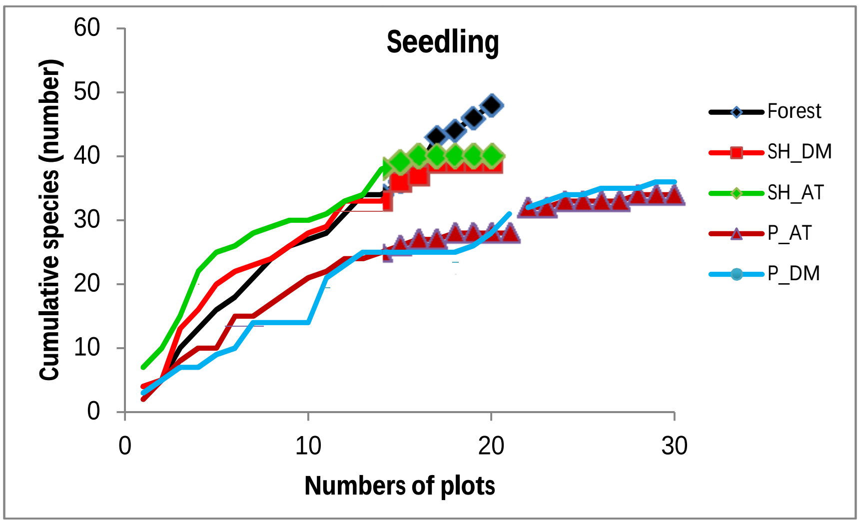


Figure 30. Species accumulation curves for seedling stage in the forest, the rubber smallholding (SH_DM and SH_AT), and plantations (P_AT and P_DM)

4.3.2 Sapling stage

There were 51 species of saplings found during the survey, comprised of 37 species in the forest and seven species in the rubber smallholding site at Dolok Merangir, that were not found in the rubber plantation. The life form of the saplings species in the forest was mostly as trees (35 species). Figure 8 shows that the sapling species at the rubber smallholding site at Dolok Merangir were dominated by *Havea brasiliensis*, *Archidendron pauciflorum* and *Piper aduncum* as food sources. *Symplocos conchinchinensis* was a common species in the rubber smallholding and rubber plantations. *Persea odoratissima* and *Schima wallichi* were the dominant saplings in the forest. In addition, we also found *Arenga pinnata, Coffea arabica, Elaeis guineensis, Salacca zalacca* and *Theobroma cacao* on the smallholding sites. The farmers planted and kept these species as food sources and as marketable items.

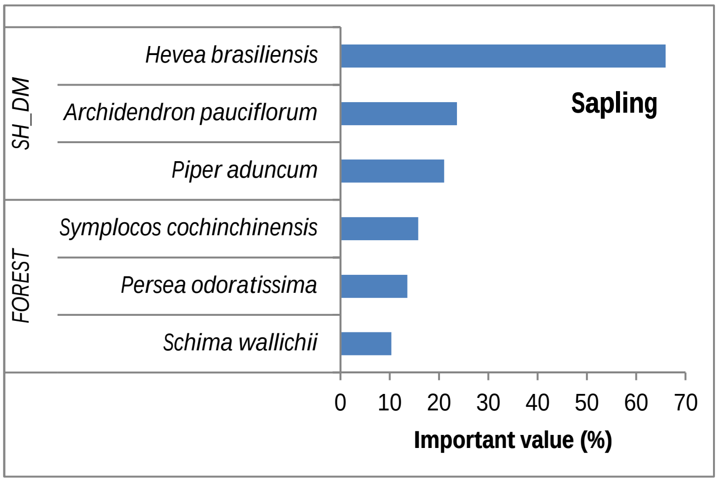


Figure 31. Three dominant sapling species in forest, smallholding (SH_DM and SH_AT) and plantation (P_AT and P_DM) based on Important Value Index

The species selected by the farmers in the rubber smallholding areas affected the species richness. Sapling species decreased after observation from eight sampling plots and the IVI value did not change with increased sampling (Figure 32). However, an increase in the IVI value occurred in the forest, so that data from more plots would be expected to increase the number of species recorded there.

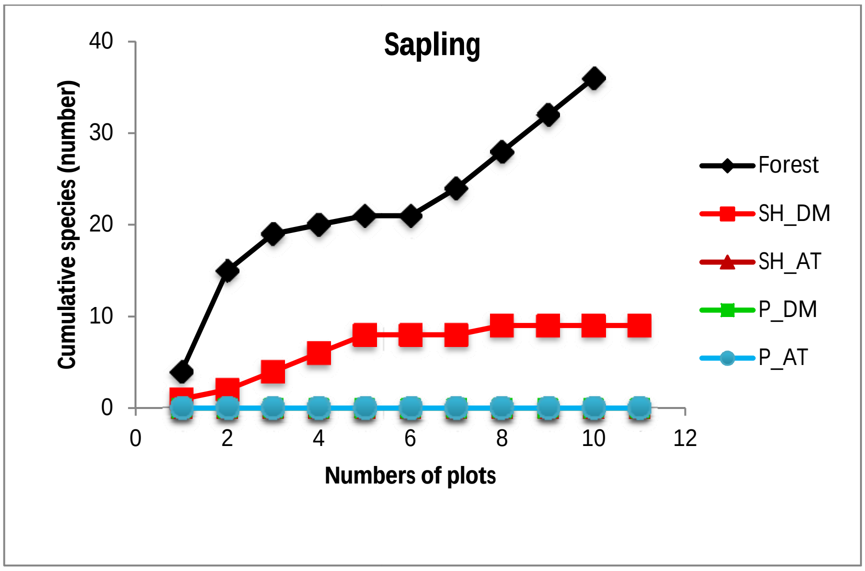


Figure 32. Species accumulation curve for sapling stage in the forest, rubber smallholding (SH_DM and SH_AT) and plantations (P_AT and P_DM)

The lack of species at the sapling stage in the rubber plantations and smallholdings at Aek Tarum indicated that intensive management, particularly weeding, had been applied to this system resulting in failure of the seedling species to survive to the sapling stage. We found a different situation in the smallholding site at Dolok Merangir, where some sapling species, such as *Archidendron pauciflorum*, *Piper aduncum* and other species, were able to survive up to the sapling stage because of the low intensity management system used there.

4.3.3 Pole stage

At the pole stage we found 16 species in the forest and six species in the smallholding area at Dolok Merangir, but only one species of pole (*Hevea brasiliensis*) in the plantation as well as in rubber smallholding area at Aek Tarum (Figure 33). The rubber smallholding system at Dolok Merangir was managed by integrating fruit trees such as *Aleurites moluccana*, *Durio zibethinus*, *Parkia speciosa* and a timber tree (*Swietenia mahogany*) in the rubber systems. Human intervention by planting species in the rubber system at Dolok Merangir was the main factor influencing the species richness there.

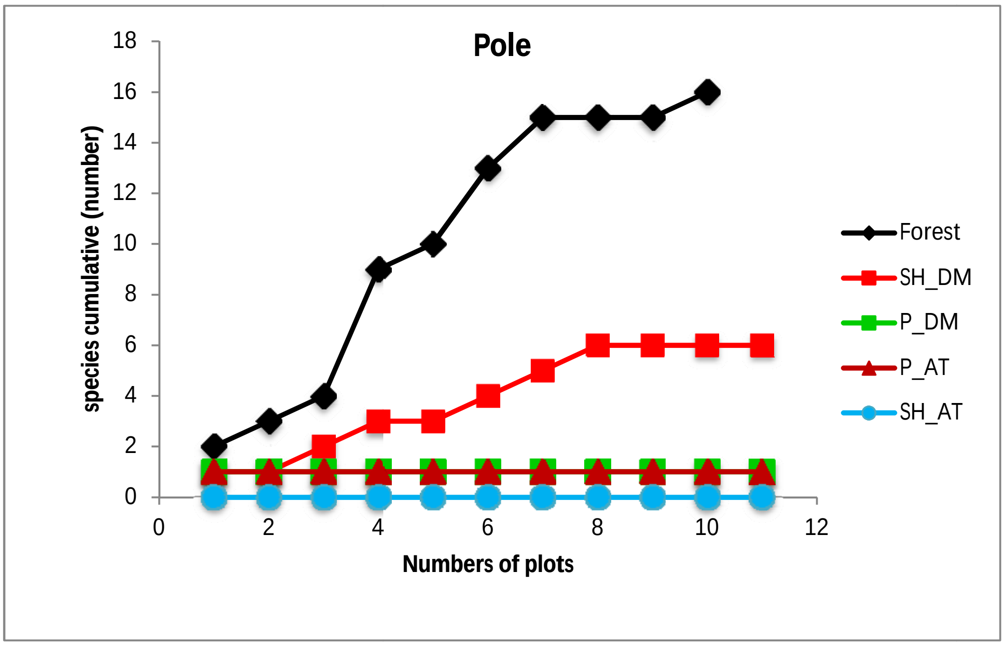


Figure 33. Species accumulation curve for pole stage in the forest, rubber smallholding (SH_DM) and plantations (P_AT and P_DM)

Different conditions were identified at Aek Tarum, where the farmers grew only rubber trees in their smallholding systems. Compared to the forest, the species structure of saplings and poles in the rubber smallholdings and plantation areas was totally different. Rubber, *Aleurites moluccana* and *Durio zibethinus* were the dominant species in the smallholding system at Dolok Merangir (Figure 34). Otherwise, the dominance index was equally distributed across the remaining species.

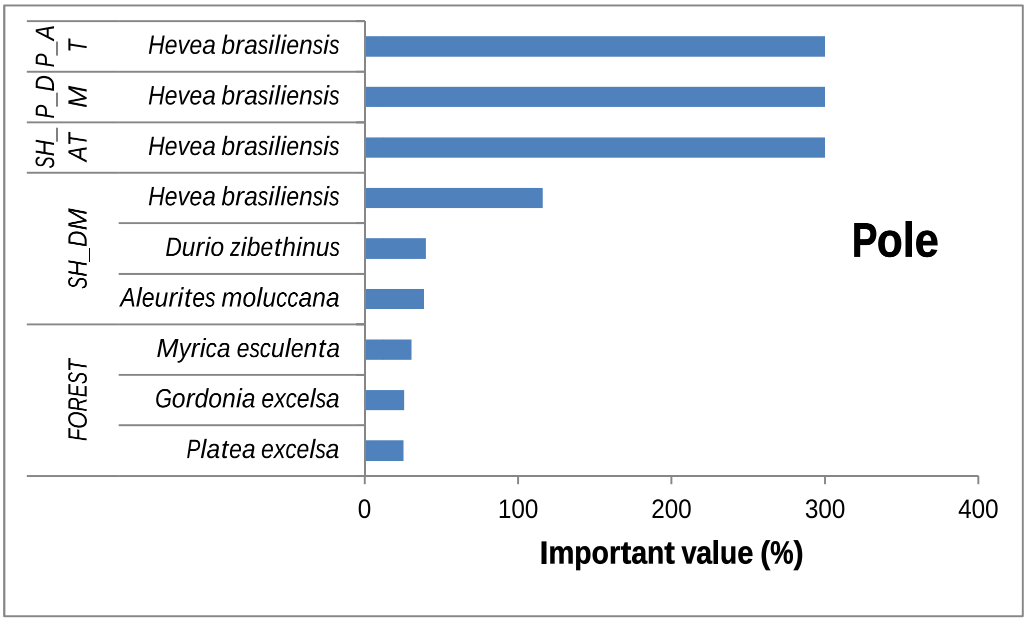


Figure 34. Three dominant pole species at forest, rubber smallholding (SH_DM and SH_AT) and plantation (P_AT and P_DM) based on Important Value Index

4.3.4 *Tree stage*

Tree species richness in the smallholding system at Aek Tarum was lower than that at Dolok Merangir (Figure 35). The accumulation curve shows that the number of species became stagnant after observation of 10 plots. The tree species growing in rubber smallholding systems at Aek Tarum and Dolok Merangir were similar, while the number of tree species in the forest was still increasing after 10 plots.

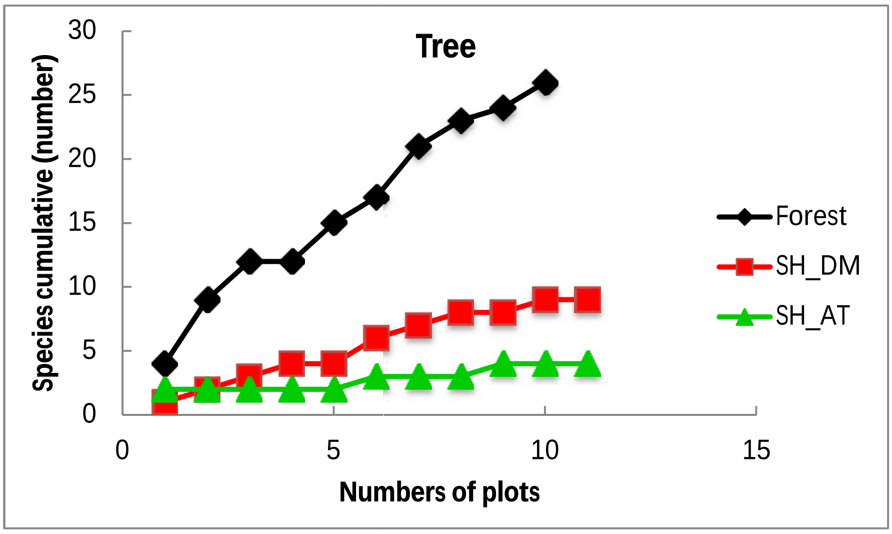


Figure 35. Species accumulation curve for tree stage in the forest and rubber smallholding (SH_DM and SH_AT)

Bamboo (*Phyllostachys bambusoides),* rubber *(Hevea brasiliensis)* and durian *(Durio zibethinus*) were dominant trees at Dolok Merangir, while the trees at Aek Tarum were dominated by rubber (*Hevea brasiliensis*), *jengkol* (*Archidendron pauciflorum)* and oil palm *(Elaeis guineensis*), as shown in Figure 36. Others species that we found in the smallholder systems were *Swietenia mahagoni, Arenga pinnata* and *Cocos nucifera*, which have a market value and the farmers depended on these species for their livelihoods. Fruit trees such as durian and *jengkol* growing in the rubber smallholder systems also had a market value as well as being suitable as a food source for daily local consumption (see Chapter 2 of this report) and as a food source for animals, such as mammals, birds and bats.

Transformation of forest to more intensive land management, such as smallholder rubber and rubber plantations, decreased the diversity of vegetation drastically. Almost 100% of the tree species were lost in rubber plantations. The species composition of seedlings also changed. This was clear evidence that forest vegetation cannot naturally regenerate in an intensive or semi-intensive management system, except with human intervention.

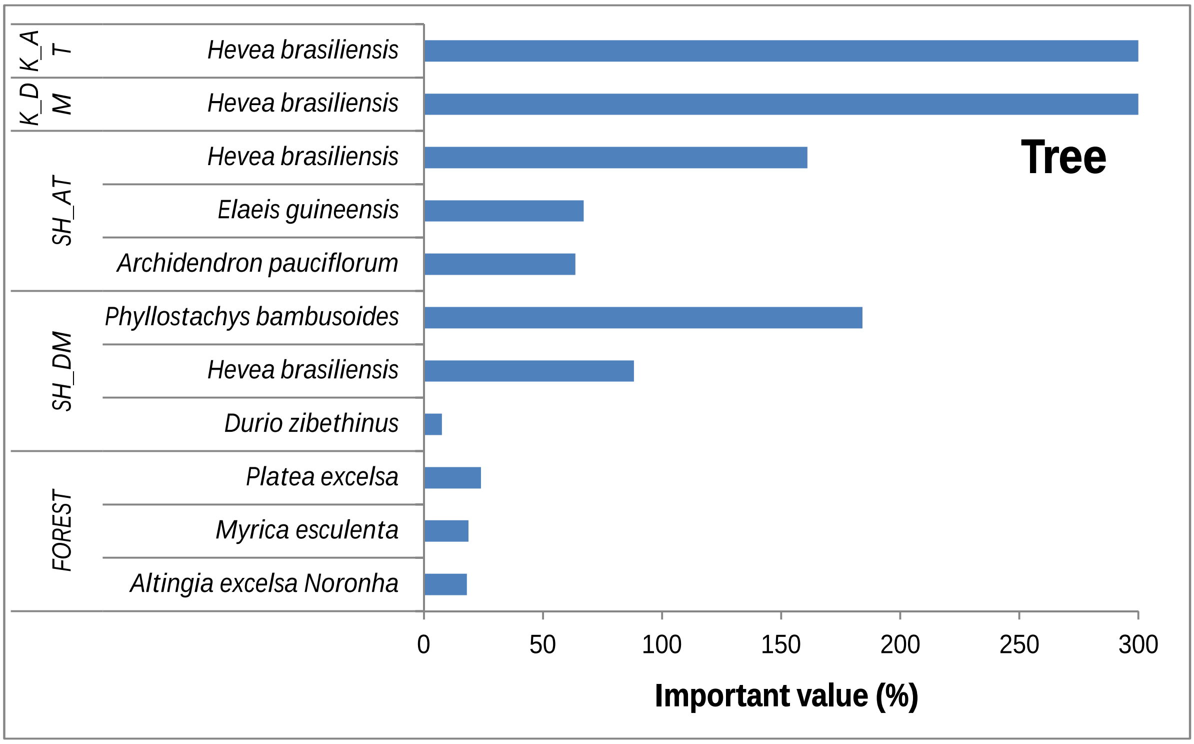


Figure 36. Three dominant tree species in forest, smallholding (SH_DM and SH_AT) and plantation (P_AT and P_DM) based on Important Value Index

4.3.5 Plant diversity in every land use

The Shannon-Wiener index (H’) was used to show vegetation diversity under different land uses based on species richness and abundance. The highest diversity of plants occurred in the forest (3.14), followed by rubber smallholding (SH_AT, SH_DM) and rubber plantations (P_AT, P_DM) for all stages of vegetation (Figure 37).

The lowest diversity index was found in the rubber plantation owing to plantation management practices such as weeding, fertilisation and slashing all non-rubber trees. Such management practices were done intensively to raise latex productivity. The same conditions were also found on the rubber smallholding sites, where the intensity of management practices was as frequent as in the plantations. However, traditional farmers generally planted useful species and selectively protected seedlings (Beukema et al. 2007) to help maintain plant diversity at all stages.

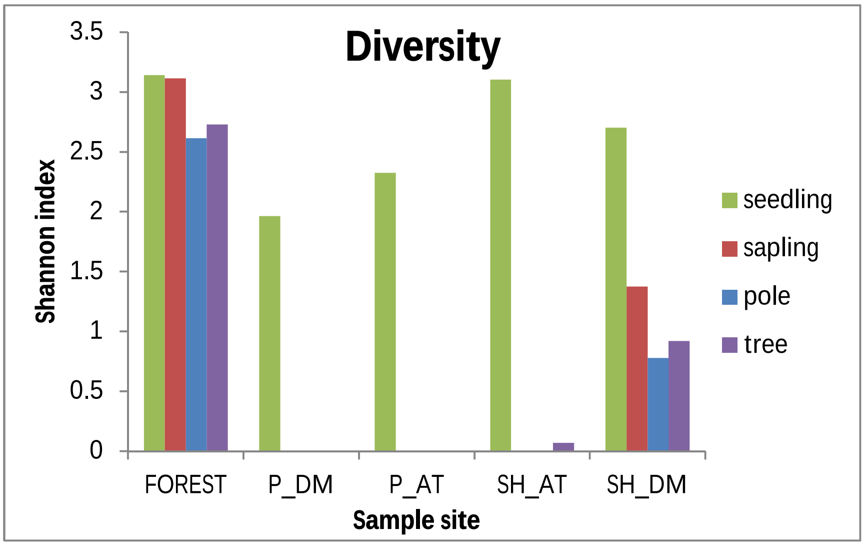


Figure 37. Shannon-Wiener diversity index for all stages of vegetation in forest, plantation (P_DM and P_AT) and smallholding (SH_AT and SH_DM)

4.3.6 Soil

Carbon and nitrogen are two important elements in soil organic matter, particularly with regard to their relationship to each other, known as the carbon-nitrogen ratio. Miller (2000) stated that a carbon nitrogen ratio below 17 indicates that the amount of nitrogen stored in the soil was increasing. Soil analysis in the rubber plantation and smallholder rubber areas indicated that the carbon-nitrogen ratio was relatively constant across the soil depth in a range of 9 to 11, but was slightly lower than that in forest soil where it ranged from 13 to 14 (Figure 38). Fertiliser application may have affected the nitrogen content in the plantation and smallholders' areas.

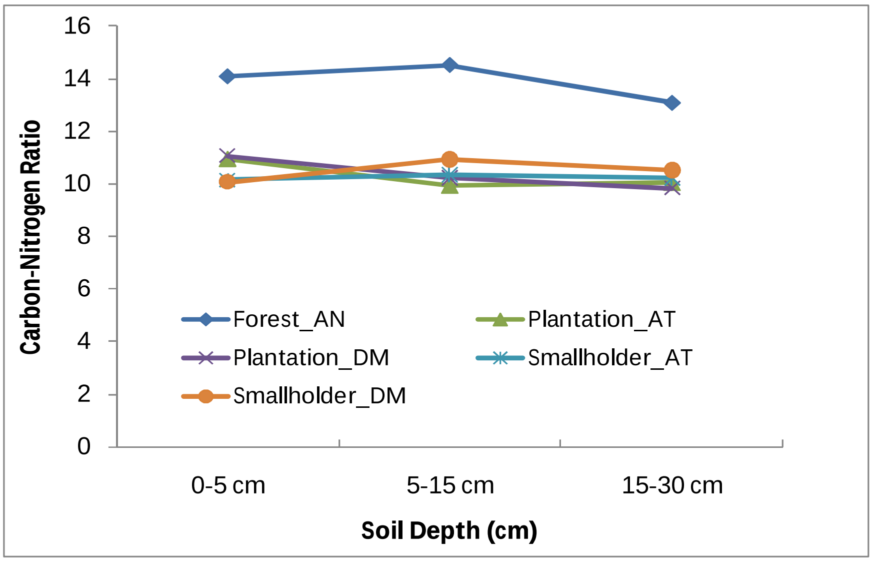


Figure 38. Carbon-nitrogen ratio at different soil depths at each sampling site

The ratio between carbon organic content (C_{org}) and a carbon reference (C_{ref}) indicates soil degradation in a certain area. C_{ref} is the carbon content that is corrected with reference to the pH, clay and silt content as well as site elevation. C_{ref} was calculated using the equation developed by van Noordwijk et al. (1997):

$$C_{ref} = (Z_{sample}/ 7.5)^{-0.42} \exp(1.333 + 0.00994*\%clay + 0.00699* \%silt - 0.156*pHKCl + 0.000427* H)$$

where: Z_{sample} = soil sample depth, cm; H =elevation, m above sea level.

The ratio of C_{ref} to C_{org} in the rubber plantation and smallholder rubber areas ranged between 0.5 and 1.2, which was lower than in the forest where the range was between 2.9 and 3.9 (Figure 39). These data indicated that soil fertility in the smallholder and rubber plantations was lower than in the forest.

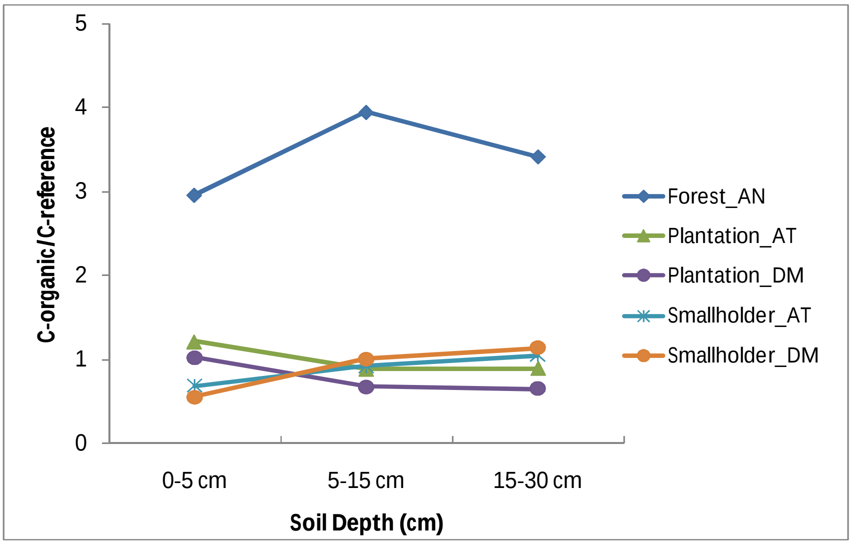


Figure 39. Ratio of carbon organic content and carbon reference in the forest, rubber smallholdings and rubber plantations

4.4 Conclusions and recommendations

4.4.1 Conclusions

- The rubber plantations in the two study areas had the lowest floristic diversity compared to the other land-use sites sampled.
- The rubber smallholding area at Dolok Merangir had a higher floristic density compared with rubber smallholding area at Aek Tarum, as shown by the tree diversity from plantings in addition to the rubber trees.

- The management practices applied in the rubber smallholding and plantation areas were the main drivers for the change in floristic composition and the loss of plant species.

4.4.2 Recommendations

Some areas in the plantation could be designated as conservation or sanctuary areas, such as riparian areas, with some fruit and timber tree species being planted in those areas. The promotion of an agroforestry system in smallholder rubber areas in the surrounding plantations could enrich plant species and thus preserve biodiversity.

5. Bird diversity in rubber plantations and their surroundings

Asep Ayat

5.1 Introduction

Sumatra is the island with the lowest endemic bird species in Indonesia. This is related to the geological history of separation from the plains of Asia. MacKinnon and Phillips (1993) state that Sumatra has 306 bird species that are also found in Borneo, 345 species that can be discovered in the Malayan peninsula and 211 species that also live in Java. A total of 583 species recorded inhabit the island of Sumatra and 438 species are breeding in Sumatra (Andrew 1992). This number increased to 602 and 450 species when combined with other types that inhabit the small islands along the coast of Sumatra. Marle and Marle (1988) reported there are twelve endemic birds species in the lowlands of Sumatra.

North Sumatra has considerable forest areas including Batang Gadis, Bohorok, Batang Toru and other patchily forested areas, although most of these areas are fragmented and experience considerable pressure from land-use change (MacKinnon et al. 1998, Sirait 2007). One of them is Simalungun district, which has little information about the state of its natural resources, especially in relation to birds. Based on data from the Forestry Agency of Simalungun, there are approximately 12 bird species protected under Indonesian Government Regulation No. 7/1999.

One hundred and eighteen of Indonesia's 1598 bird species are threatened with extinction. Bird extinction is becoming rapid owing to land-use transformation to more intensive management and to degraded land. Besides hunting and trade, deforestation and habitat destruction are the most dominant drivers of bird species extinction. Human activities alter natural environments, such as forest, into agricultural land, plantations and infrastructure for industrial activities. These types of activities cause loss of bird habitat and decrease the number of bird species. An alternative form of land management is necessary to reconcile ecological and economic objectives. Agroforestry is one such alternative that can balance the need to generate income while being friendly to the environment.

The majority of Sumatra's lowlands are dominated by rubber smallholdings, that is, rubber plantations managed by farmers under an extensive management system, close to secondary forest. These systems are formed from a mixture of plants that include trees, lianas, shrubs and herbaceous plants (Sibuea and Herdimansyah 1993). Compared with natural forest, basal area of rubber plantations is lower because there are no big trees. In addition, jungle rubber provides a comfortable habitat for wildlife, especially the Helmeted Hornbill *(Rhinoplax vigil).* From the results of direct observation studies, Rewarding Upland Poor for Environmental Services project team in Bungo found 167 bird species in rubber agroforestry systems, two of which are nearly extinct: the Crested Fireback *(Lophura ignita)* and the Blue-banded Kingfisher *(Alcedo euryzona)* (Joshi et al. 2002).

In conservation, it is important to analyse response of bird on habitat fragmentation and its diversity in a fragmented habitat, such as rubber monoculture. Yet, bird conservation activities tend to be focused on protected primary forests and emphasise threatened species faced with extinction. Currently, little attention is given to common species or species that inhabit secondary forests, even though most of the remaining forest in Sumatra is secondary. In this study, we observed the structure of bird communities in secondary and primary forests, rubber agroforestry smallholders' systems and rubber plantations at Simalungun, North Sumatra (particularly in PT BSRE).

5.2 Survey locations

The study was conducted from December 2010 to January 2011 in the PT BSRE area Simalungun, North Sumatra. The location of the observation survey was the expanse of monoculture rubber plantations found on PT BSRE, which consists of two locations: Dolok Merangir and Aek Tarum areas (Figure 25). In addition, observations were conducted in rubber agroforests *(*smallholdings) and forest areas. The forest areas are located at BPK Aek Nauli forest education and protected forest in Aek Tarum. Administratively, the whole area is included in Simalungun and Asahan districts of North Sumatra province.

5.3 Methods

The birds were observed by using descriptive survey methods through implementing a quick biodiversity survey for birds, where data were collected along a line transect of 1 km and from the list of 20 MacKinnon's bird species (MacKinnon and Phillips 1993). The MacKinnon's list is an established method used to record and verify species and to calculate the density. Data were tabulated and birds were identified referring to the nomenclature (Sukmantoro et al. 2007). Guild[4] composition was modified from Wong (1986), the threat of fragmentation on bird species referred to Lambert and Collar (2002), while IUCN status referred to Birdlife International (2001). Comparison of abundance was calculated from the percentage ratio of the individual number of a species compared to the total individual number that can be caught. Diversity was calculated using the Shannon-Wiener index (Magurran 1988).

Each bird species encountered in the study area was recorded in a list containing the names of the first 20 species encountered, after which the recording began on a new list. This list was used to generate a curve of bird species' richness among different sites. Observations were conducted twice a day, in the morning from 06:00 to 11:00 and in the afternoon from 15:00 to 17:30 (except on rainy days). Tools used in this activity were binoculars (Bushnell 10 x 25), GPS Garmin Oregon 300, digital voice recorder (Olympus WS-560M) and Nikon D80 (70–300 mm Tele Lens). MacKinnon and Phillips (1993) and King et al. (1975) were used as field identification guides.

[4] A 'guild' is defined as a group of species that utilise the same resource class in the same way (Wiens 1989).

5.4 Results

5.4.1 Bird richness and diversity

We conducted a survey along 10 transects in four habitats of forests, smallholdings, plantations and emplacements. In total, 142 species of birds from 42 families were recorded in the PT BSRE areas (Appendix 1). From the total birds species recorded, 122 species were recorded in the forest, 30 in the rubber plantations, 39 were encountered in the emplacement and 46 were found in the smallholdings (Table 19). There were 728 individuals of birds encountered. Forests were the most diverse in bird species, indicated by a Shannon-Wiener index of 4.49 (Table 19), followed by smallholdings (3.61), emplacements (3.61) and plantations (2.98). All bird species were distributed evenly in every type of habitat, as shown by the evenness index values of almost 1 (ranged 0.87–0.94).

Table 19. Statistical summary of birds at PT BSRE Simalungun, North Sumatra

Habitat Type	Abundance	Species Number	H'	E'
Forest	267	122	4,49	0,94
2–6 yo rubber plantation	49	15	2,47	0,91
12–15 yo rubber plantation	37	18	2,74	0,95
22–25 yo rubber Plantation	56	20	2,60	0,87
Smallholding	103	46	3,61	0,94
Emplacement	211	39	3,07	0,84

H'= Shannon-Wiener index, E'=Eveness index
Forest=Protected area in Aek Tarum and forest education in Dolok Merangir
Rubber Plantation=Young rubber plantation (2–6 years), medium rubber plantation (12–15 years) and old rubber plantation (22–25 years)
Emplacement=Settlement area for Bridgestone staff with mixed fruit trees

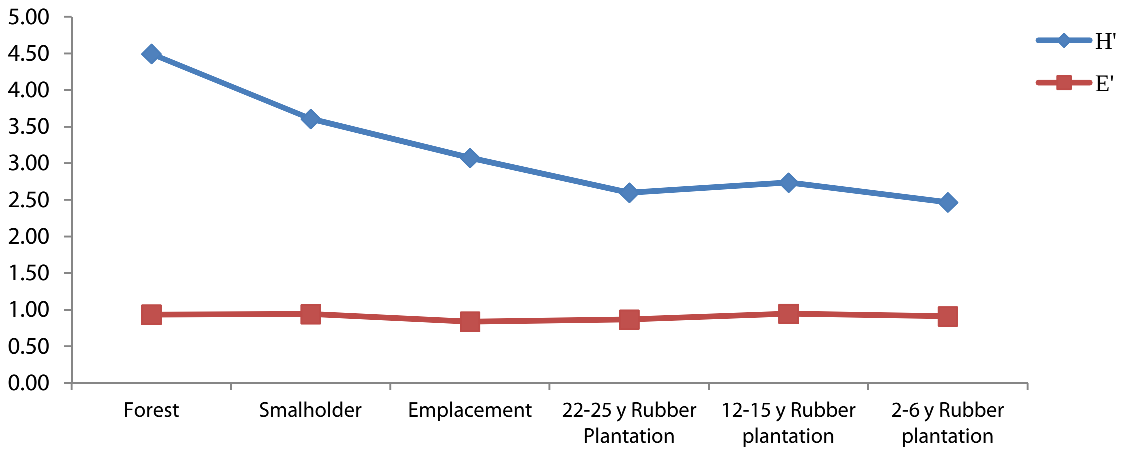


Figure 40. Value of Shannon-Wiener (H') and Eveness (E') indices in different habitat types in PT BSRE and its surroundings

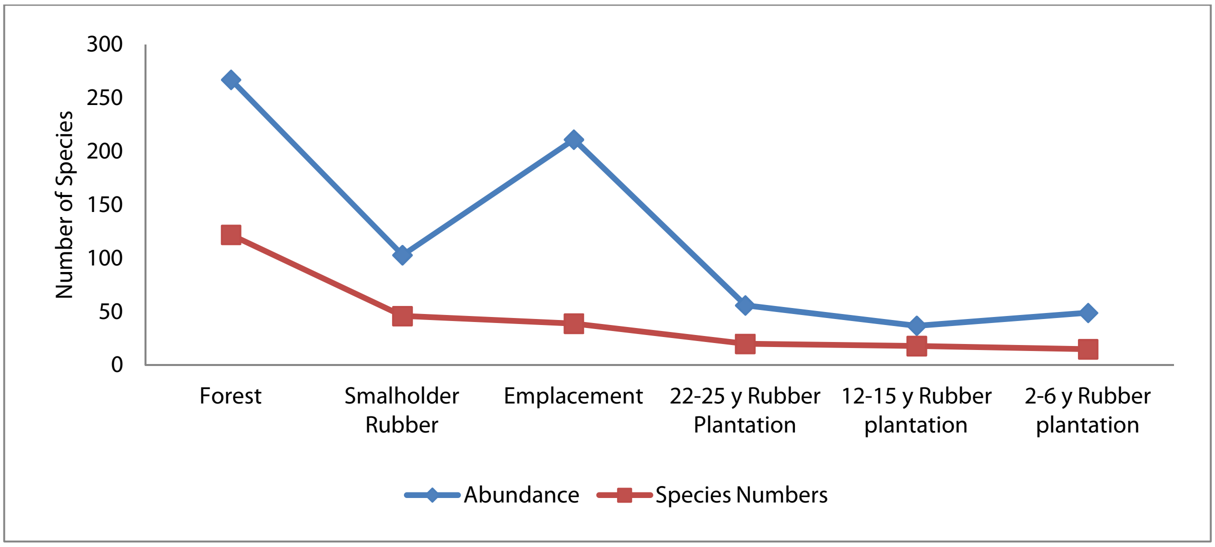


Figure 41. Number of species and individuals (abundance) in different habitat types in PT BSRE and surroundings

5.4.2 Bird composition

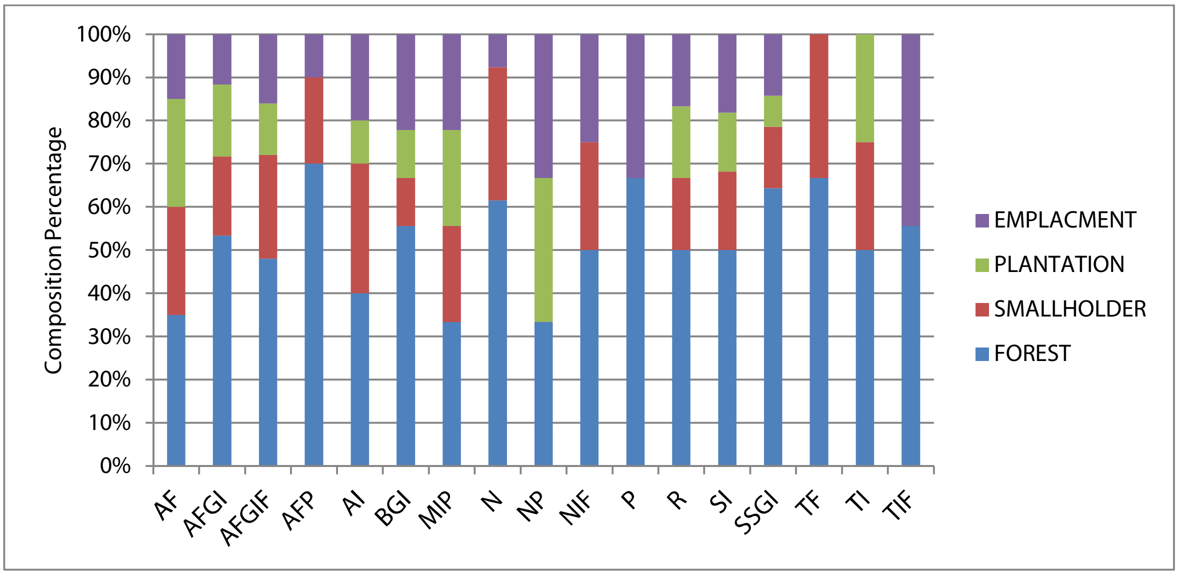


Figure 42. Bird composition guilds in different habitat types at PT BSRE

Legend: AF = arboreal frugivore; AFGI = arboreal foliage gleaning insectivore; AFGIF = arboreal foliage gleaning insectivore-frugivore; AFP = arboreal frugivore-predator; AI = aerial insectivore; BGI = bark gleaning insectivore; MIP = miscellaneous insectivore-piscivore; N = nectivore; NP = nocturnal predator; NIF = nectivore-insectivore-frugivore; P = pinsivore; R = raptor; SI = sallying insectivore; SSGI = sallying substrate gleaning insectivore; TF = terrestrial frugivore; TI = terrestrial insectivore; and TIF = terrestrial insectivore-frugivore

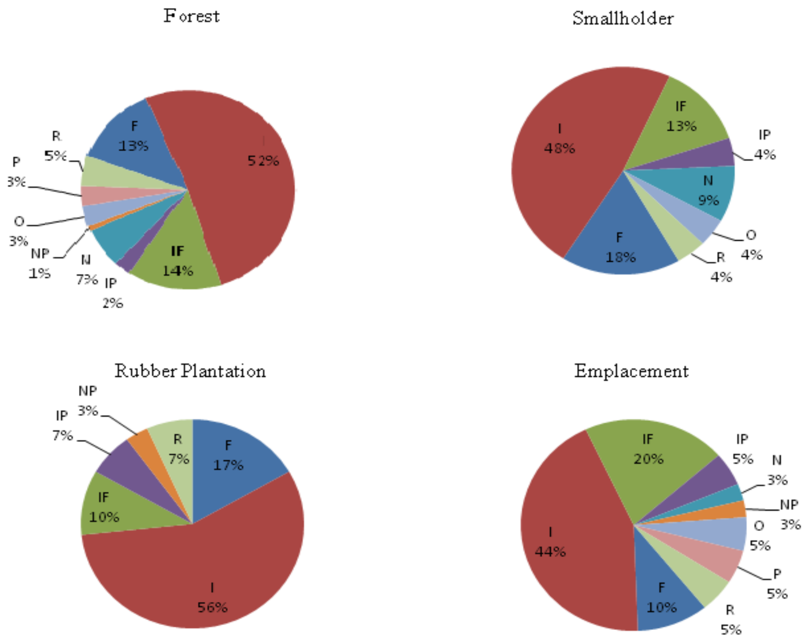


Figure 43. Bird composition guilds in different habitat types at PT BSRE
Legend: F = frugivore (AF, AFGI, AFGIF, AFP, TF); I = insectivore (AI, BGI, MIP, SI, SSG, TI); N = nectivore; NP = nocturnal predator; IF = insectivor-frugivore; (TIF), P = piscivore; R = raptor; and O = omnivore (NIF)

The birds in the ecosystem were classified based on their roles. There were 17 guilds represented: arboreal frugivore (AF), arboreal foliage gleaning insectivore (AFGI), arboreal foliage gleaning insectivore-frugivore (AFGIF), arboreal frugivore-predator (AFP), aerial insectivore (AL), bark gleaning insectivore (BGI), miscellaneous insectivor-pincifore (MIP), nectivore (N), nocturnal predator (NP), nectivore-insectivore-frugivore (NIF), piscivore (P), raptor (R), sallying insectivore (SI), sallying substrate gleaning insectivore (SSGI), terrestrial frugivore (TF), terrestrial insectivore (TI) and terrestrial insectivore-frugivore (TIF) (Figure 42). The guilds were further categorised, based on feeding habits, into eight groups, such as frugivore, insectivore, nectivore, nocturnal predator, insectivore-frugivore, piscivore, raptor and omnivore (Figure 43). Bird species composition in the habitat of the rubber plantation was different from the three other habitats. Two feeding groups of birds were not encountered in the plantation, that is, omnivores and nectivores. This is evidence that the monoculture system does not provide a suitable environment for some specific bird species with particular roles. Rubber is not pollinated by birds, but usually through controlled pollination by insect bristle (Warmke 1952).

5.4.3 Protected bird status

Bird species encountered in the four habitats were grouped based on the International Union for Conservation of Nature and Natural Resources (IUCN) status. We recorded 12 species categorised as *near-threatened* (NT) and two species categorised as *vulnerable* (VU). Referring to the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES[5]), one

[5] CITES is an international agreement between governments (Appendices I,II and III).

species was listed under Appendix criteria I and 12 species were classified under Appendix II. Regarding Indonesian regulations, under Law no. 7/1999 we found that 26 of the species identified were listed as protected.

Table 20. List of bird status based on IUCN, CITES and Indonesian law

Scientific Name	English Name	Status[1]	CITES[2]	Law[3]
Accipiter virgatus	Besra		II	AB
Alcedo meninting	Blue-eared Kingfisher			AB
Anthreptes singalensis	Ruby-cheeked Sunbird			AB
Anthreptes malacensis	Brown-throated Sunbird			AB
Anthreptes rhodolaema	Red-throated Sunbird	NT		AB
Anthreptes simplex	Plain Sunbird			B
Arachnothera affinis	Streaky-breasted Spiderhunter			B
Arachnothera longirostra	Little Spiderhunter			AB
Ardea alba	Great Egret			AB
Argusianus argus	Great Argus	NT	II	AB
Buceros rhinoceros	Rhinoceros Hornbill	NT	II	AB
Calyptomena viridis	Green Broadbill	NT		
Chloropsis venusta	Blue-masked Leafbird	NT		
Cinnyris jugularis	Olive-backed Sunbird			AB
Collocalia vulcanorum	Volcano Swiftlet	NT		
Criniger finschii	Finsch's Bulbul	NT		
Dicrurus sumatranus	Sumatran Drongo	NT		
Egretta garzetta	Little Egret			AB
Gracula religiosa	Common Hill Myna		II	AB
Halcyon chloris	Collared Kingfisher			AB
Halcyon smyrnensis	White-throated Kingfisher			AB
Haliaeetus leucogaster	White-bellied Sea Eagle		II	AB
Haliastur indus	Brahminy Kite		II	AB
Harpactes kasumba	Red-naped Trogon	NT		AB
Ictinaetus malayensis	Black Eagle		II	AB
Meiglyptes tukki	Buff-necked Woodpecker	NT		
Padda oryzivora	Java Sparrow	VU	II	
Rhinoplax vigil	Helmeted Hornbill	NT	I	AB
Rhipidura javanica	Pied Fantail			AB
Rhopodytes diardi	Black-bellied Malkoha	NT		
Rhyticeros undulatus	Wreathed Hornbill		II	AB
Spilornis cheela	Crested Serpent Eagle		II	AB
Spizaetus alboniger	Blyth's Hawk-Eagle		II	AB
Spizaetus cirrhatus	Crested Hawk-Eagle		II	AB
Treron capellei	Large Green Pigeon	VU		

[1] Status based on IUCN [2] CITES [3] **Indonesian laws:** A = Undang-undang RI no. 5/1990; B = Peraturan Pemerintah no. 7/1979

Appendix I lists species that are the most endangered among CITES-listed animals and plants They are threatened with extinction and CITES prohibits international trade in specimens of these species except when the purpose of the import is not commercial, for instance, for scientific research

Appendix II lists species that are not necessarily now threatened with extinction but that may become so unless trade is closely controlled. It also includes so-called 'look-alike species', that is, species of which the specimens in trade look like those of species listed for conservation reasons

Appendix III is a list of species included at the request of a Party that already regulates trade in the species and that needs the cooperation of other countries to prevent unsustainable or illegal exploitation.

5.5 Discussion

5.5.1 Bird species' richness

In general, the richness of bird species in PT BSRE and its surroundings is high. Various comparisons with bird species' richness in other regions showed a relatively high diversity for birds recorded in PT BSRE. Andrew (1992) reported that in Sumatra there were 583 of the 1,589 bird species found in Indonesia. PT BSRE and its surrounding areas has 24% of the total bird species in Sumatra or 8.9% for the whole of Indonesia.

The species' richness in Simalungun and Asahan area (142 species) is close to the richness of bird species encountered in Batang Toru. The same amount of species was found in forests and smallholder rubber agroforests in Batang Toru, Sibulan Bulan, North Sumatra (Jihad 2009). There was not much difference between species' composition in the two areas owing to similar characteristics of habitat. Forest habitat has the highest species' richness (122 species), followed by rubber agroforests (46 species), emplacement (39 species) and plantation (30 species). The number of species in the plantation was the lowest owing to the monoculture system. There was no vegetation other than rubber trees (see Chapter 4), except along the sides of rivers, which have more diverse vegetation. Smallholder rubber agroforests had greater richness of species compared with emplacements and plantations. Many food trees and trees suitable for nesting were still available in the smallholder rubber agroforests, such as *Durio*, *Aleurites mollucana* (Euphorbiaceae) and other fruit trees. The bird species in the emplacement were less than that those in smallholder rubber agroforests, although there were some food trees for birds, such as Ficus and fruit trees in the emplacement. Smallholder rubber agroforests indicated a compatible bird habitat, with mixed vegetation composed of fruit trees, such as durian (*Durio* spp.), *duku* (*Lansium domesticum*), *jengkol* (*Pithecellobium lobatum*), mangosteen and cacao. The compostion attracted birds searching for food and nesting material and sites. Compared with natural forests, the basal area of rubber plantations is lower because there are no big trees. In addition, smallholder rubber agroforests provide a comfortable habitat, especially for the Helmeted Hornbill *(Rhinoplax vigil)*. The result of direct observation studies conducted by the RUPES Bungo team, showed 167 birds species were encountered in rubber agroforests in Bungo. Two species were recognised as nearly extinct, namely the Crested Fireback *(Lophura ignita)* and Blue-banded Kingfisher *(Alcedo euryzona)* (Joshi et al. 2002).

5.5.2 Bird diversity

Birds have one of the highest species diversity on Earth. Diversity at a given site may reflect equally high biodiversity of other wildlife in the ecosystem (McNeely 1988; ICBP 1992 in Yoza 2000). Bird species diversity in PT BSRE and its surroundings varied between 4.49 in forests to 2.98 in plantation areas. The diversity of bird species depends on environmental conditions. The decrease in the bird diversity index from forest to plantation related to the decrease of environment conditions, such as structure and composition of vegetation. Bird diversity in the rubber plantation was categorised as 'middle value', based on the Shannon-Wienner index. The decline of diversity value relates to the decline of carrying capacity. The higher the value of diversity, the higher the carrying capacity of the habitat. Considering the middle value of bird diversity in the rubber plantation, we recommend enrichment planting with other tree species that support birds.

The bird diversity index in forests was significantly different from that in agroforests and plantations. This was not influenced by the width of the area, but rather by the stratification of vegetation in the region (Idris 2002). James (1971) in Welty (1982) argues that factors such as cover crop, canopy height and diversity of tree species, determines the diversity of bird species. While van Balen (1984) and van Helvoort (1985) explain that elevation and habitat diversity affect composition and richness of bird species.

The abundance of bird species is described by an index of equitability or evenness (E′). Krebs (1989) showed that species' balance in a community or ecosystem distributes from 0 to 1. An evenness (E′) value of nearly 1 means that bird species in an area are distributed evenly or so equitably. The evenness index for PT BSRE and its surroundings was close to 1, meaning that there was not one dominant among the four habitats. The evenness index value is between 0 and 1 and the closer a value is to 1 indicates dominance (Ludwig and Reynolds 1988, Magurran 1988).

5.5.3 Bird composition in different habitat types

Species that were absent from bird communities in different habitats (forests, smallholdings, plantation and emplacement) allowed comparison of function of the habitat. In general, species' composition was dominated by insect-eaters (insectivores) and seed or fruit-eaters (frugivores). The areas of primary (Aek Tarum forest) and secondary forests (Aek Nauli forest education) were composed of similar bird species. By contrast, logged areas or cleared land, such as areas converted to rubber agroforests and rubber monoculture plantations, had different composition of species compared to the forests, either primary or secondary. The difference in guild composition between open-canopy (such as plantation rubber) and closed-canopy (such as forest) areas indicated that smallholder rubber was a transition area between forests and rubber plantations. Bird groups of insectivore, frugivore, nectivore were commonly found in secondary forests and at the forest edge up to an open area, whereas bird groups of arboreal frugivore, terrestrial frugivore and bark gleaning insectivore preferred to live in the middle of the forest.

Species composition of bird communities in the area of PT BSRE and its surroundings as shown in Figure 42 showed a dominance of Nectariniidae and Pycnonotidae families. These birds prefer to live in secondary forests, forest edges and settlements (MacKinnon et al. 1998). This is related to the availability of their main food, such as insects and nectar. Several other studies also revealed that bird communities were usually dominated by a few specific types, which have high relative of abundance, and most other species were considered as rare (Karr et al. 1983, Wong 1986, Nagata et al. 1996, Prawiradilaga et al. 2002).

5.5.4 Bird species' composition in forests and smallholdings

In general, species composition of birds in forests was extraordinary (122 species) compared to other habitats. Species were more diverse at the two forest sites—Aek Tarum primary forest and forest research area of Aek Nauli—than in smallholder rubber and plantations. Although the forest research area at Aek Nauli is categorised as disturbed forest, its bird composition was similar to the primary forest of Aek Tarum. Bird species composition in the three habitats decreased sharply from 122 species in forest through 46 species in smallholdings to only 18 species in plantation (Table 19). Hornbill (Bucerotidae) and woodpecker species could be seen in forests, however, they were not encountered in other habitats. These species like big trees for nesting and foraging, which only grow in the forests. Generally, composition of species declined on more intensivly managed lands.

However, each group of birds has different factors that cause its absence from a habitat. Logging and land clearing not only change the vegetation structure and its composition but also change the bird species composition (Lammertink 2001).

Based on the guild feeding groups, species' compositions in forests and smallholdings were relatively similar (Figure 43), dominated by the insectivore and frugivore types, followed by nectivore, piscivore, raptore and granivores. Bird communities in the study area clearly showed the existence of a mix of bird species that prefer central parts of forests (Picidae, Capitonidae, Trogonidae, Pittidae) and forest edges (such as Pycnonotidae, Nectariniidae, Sylviidae, Laniidae, Timaliidae). In the forests, we found frugivore birds (Bucerotidae, Capitonidae, Columbidae, Pycnonotidae, Decidae and Chloropsidae). This suggests that there were various fruit trees growing in the forests. The presence of fruit trees in forests is an indicator of a good ecosystem, where forest trees provide refuges, perches and feeding places for many bird species.

Our observation showed that bird species found in the study area have different tolerance to fragmentation and canopy openings. Some bird species, such as hornbills and woodpeckers, are very sensitive to habitat change, whereas some other species have a wide range of adaptation abilities, such as Pycnonotidae (Bulbus), Columbidae (Pigeon and Dove) and Sylvidae (Prinias and Wabler). This shows the importance of the forest edge as a buffer zone for bird diversity and as an area for the succession process of bird communities (Novarino et al. 2005). This also shows the importance of the *ecoton* (intermediate region between two adjacent ecosystems) in sustaining the level of diversity of bird species. Ecoton is defined as a zone that allows various types of life at the limits of tolerance of local conditions and which are very well adapted to seeing changes in the environment (Fitri and Ford 2003), for example, riparian and emplacement areas in Dolok Merangir. Odum (1971) stated that the diversity of bird species in an ecoton is a combination of species in the area and species that come from the surroundings. Hence, bird species diversity in an ecoton is usually higher than that of the surrounding area. Alikodra (1990) stated that there is a positive correlation between diversity of habitat and bird diversity: the more diverse the habitat, the more diverse the bird species.

Figure 44. Eight species encountered in forests and smallholdings

Legend: (1) Collared Owlet (*Glaucidium brodiei*), (2) Oriental Magpie-robin (*Copsychus saularis*), (3) Finsch's Bulbul (*Criniger finschii*), (4) Coppersmith Barbet (*Megalaima haemacephala*), (5) Pink-necked Green Pigeon (*Treron vernans*), (6) Streaky-breasted Spiderhunter (*Arachnotera affinis*), (7) Blue-crowned Hanging Parrot *(Loriculus galgulus*), (8) Black-belled Malkoha (*Rhopodytes diardi*)

5.5.5 Bird composition in rubber plantation and emplacement

Bird composition in plantation was clearly different from bird composition in rubber plantation. Only four groups of birds were found in rubber plantations, namely insectivore, frugivore, piscivore and raptore. The other four groups found in forests were not encountered in plantation areas. Compositions in three different stand-ages of rubber plantations were not significantly different. Birds types were dominated by Alcedinidae, Pycnonotidae, Strigidae, Apodidae, Sylviidae, Cuculidae and Columbiae. Insectivorous groups contributed a large percentage in plantation areas. This group also contributed in large number in all habitat types. Insectivore birds consisted of Yellow-vented Bulbul (*Pycnonotus goiavier)*, Common Tailorbird *(Orthotomus sutorius)*, Ashy Tailorbird *(Orthotomus ruficeps)* and Yellow-browed Warbler *(Phylloscopus inornatus)*. In addition, miscellaneous insectivore-piscivore species were in high abundance in the plantation, like White-throated Kingfisher *(Halcyon smyrnensis)* and Collared Kingfisher *(Halcyon chloris)*. There were also groups of nocturnal predators, which have an important function in maintaining biological balance in the plantation, such as the Buffy Fish-Owl *(Ketupa ketupu)*.

Birds play a role in controlling insect populations, consuming up to one third (1/3) of their body weight (Peterson 1980 in Hernowo et al. 1991). Prawiradilaga (1990) mentioned that of the 494 bird species that occur in Java (MacKinnon and Phillips 1993), 331 species (67%) are insectivorous, with 79 species (24%) being primary insectivorous and 252 species (76%) being secondary insect eaters. Some insects are known as pests of plants, such as Ortoptera (grasshoppers, crickets), Homoptera (leafhoppers, mites) and Heteroptera (ladybugs). The insectivore birds consume such insects as their diet, playing an important role as a biological control in the ecosystem.

Frugivorous birds act as a dispersal agent for plants (Welty 1982). Nectivorous birds act as polinators (MacKinnon and Phillips 1993). Birds also help nitrogen and phosphorus cycles (Odum 1971). There were high numbers of large arboreal frugivores encountered in the rubber plantation, such as Spotted Dove *(Streptopelia chinensis)* and Zebra Dove (*Geopelia striata)*. In addition, two groups of birds were found in ground-cover of the rubber plantation in all stand-ages, namely sallying insectivores and arboreal foliage gleaning-insectivores, such as the Tiger Shrike (*Lanius tigrinus)*, Drapie and Hill Prinia *(Prinia atrogularis)*. *Mucuna* as a cover crop provided insect food for these two species.

We found distinct compositions of bird communities in the emplacement area. Emplacement sites, which are located inside the rubber plantations, were planted with a variety of large trees. Some trees, such as ficus, pine, palm, banana, mango, rambutan and cocoa and hardwood species provide suitable sites for nesting, resting and foraging. The number of birds that like the forest edge or open areas increased, such as minas, barbets, sparrows, bulbuls, pigeons, cuckoos, doves, prinias, white-eyes, woodpeckers and raptors.

In the emplacement area, *Ficus* trees were the food source for the frugivores. Tropical Asia supports about 60% of the world's known *Ficus* species and 83 species of these occur in Java. A recent estimate suggests that 900–1200 species of frugivorous birds occur in the orient and approximately 990 species of birds feed on *Ficus* species globally. A total of 23 species of birds in 11 families were recorded at the three *Ficus* trees, 17 of which were recorded eating fruit. Barbets and bulbuls were common on *Ficus caulocarpa* and *Ficus microcarpa*, which have relatively small fruit. Large frugivorous, such as Imperial Pigeon and hornbills, were not observed at these trees, although they were frequently seen flying overhead.

Birds are one of the most important seed dispersersal agents in tropical forests (Whitmore 1984). Plants are a food source for animals and, vice versa, animals are very useful for plants. Effective seed dispersal may reduce competition between plants and their derivatives, as well as enabling distribution of plant species to a new place. If there are no animals that can disperse the seeds, the seeds from the parent plant will fall and grow around the parent tree only.

Figure 45. Nine bird species visited rubber pantations and emplacements

Legend: (1) Buffy Fish-Owl (*Ketupa ketupu*), (2) Zebra Dove (*Geopelia striata*), (3) Spotted Dove (*Streptopelia chinensis*), (4) Sooty-headed Bulbul (*Pycnonotus aurigaster*), (5) White-throated Kingfisher (*Halcyon symrnensis*), (6) Yellow-browed Warbler (*Phylloscopus inornatus*), (7) Hill Prinia (*Prinia atrogularis*), (8) Tiger Shrike (*Lanius tigrinus*), (9) Collared Kingfisher (*Halcyon chloris*)

5.5.6 Birds' status (IUCN, CITES, restricted rare species)

One hundred and forty-two (142) bird species have been recorded at PT BSRE and its surroundings. We recorded 12 *near-threatened* (NT) species and 2 *vulnerable* (VU) species as recorded in the IUCN Red List (IUCN 2008). Based on CITES (2009), we recorded 12 species in Appendix II and one species in Appendix I. Furthermore, we recorded 9 species of the 24 restricted range species. A restricted range species is one with a known breeding area that is less than 500 000 km^2 (Sudjatnika et al. 1995) and, by virtue of its small range, is been considered most suitable for identifying areas for conservation. Holmes and Rombang (2001) recorded 34 Important Bird Areas (IBA) in Sumatra, 5 IBA areas in North Sumatra and 24 restricted range species.

Some noteworthy bird species that are protected under Indonesian law were encountered in the PT BSRE area, such as the Great Argus *(Argusianus argus)*, Red-naped Trogon *(Harpactes kasumba)*, Rhinoceros Hornbill *(Buceros rhinoceros), Wreathed Hornbill (Rhyticeros undulatus),* Blue-masked Leafbird (*Chloropsis venusta),* Java Sparrow *(Padda oryzivora),* Sumatran Drongo *(Dicrurus sumatranus),* Finsch's Bulbul *(Criniger finschii),* Large Green Pigeon *(Treron capellei)*, Blue-crowned Hanging Parrot *(Loriculus galgulus),* Black-bellied Malkoha *(Rhopodytes diardi),* Volcano Swiftlet

(*Collocalia vulcanorum*), Barn Owl *(Tyto alba),* Buffy Fish Owl *(Ketupa ketupu),* Collared Owlet *(Galucidium brodiei),* Helmeted Hornbill *(Rhinoplax vigil),* Buff-necked Woodpecker *(Meiglyptes tukki),* Green Broadbill *(Calyptomena viridis)* and the Common Hill Myna *(Gracula religiosa).*

Additionally, a large number of raptor bird species were also found in the area, such as the Brahminy Kite *(Haliastur indus)*, White-bellied Sea Eagle *(Haliaeetus leucogaster)*, Black Eagle *(Ictinaetus malayensis)*, Crested Hawk-Eagle *(Spizaetus cirrhatus)*, Blyth's Hawk-Eagle *(Spizaetus alboniger)* and the Crested Serpent Eagle *(Spilornis cheela).* All these raptors are protected under Indonesian law. Moreover, the high number of raptor birds in this area implied it has an important value as part of their home range. Raptors are known to have a wide home range compered to other bird species. PT BSRE and its surroundings areas may provide significant amounts of food. Prey of raptor bird includes various mammals and reptiles, such as squirrels, rats and lizards.

Figure 46. Hornbill and raptor birds recorded along observation
Legend: (1) Wreathed Hornbill (*Rhyticeros undulatus*), (2) Crested Hawk-Eagle (*Spizaetus cirrhatus*), (2) Crested Serpent Eagle (*Spilornis cheela*), (4) Besra (*Accipiter virgatus*), (5) Brahminy Kite (*Halias*)

It is surprising to see the numbers of protected bird species that were observed in the PT BSRE rubber plantation area and its surroundings. However, rapid land-use change and high deforestation in North Sumatra province are threatening the diversity and conservation status of birds. Efforts for conserving biodiversity are needed to balance the functions in ecosystems.

6.2.1 Implications of changes on bird habitats

Forests are not sufficient to protect bird diversity in a habitat. Each species of bird will occupy a particular habitat in accordance with the purposes of its life and played a certain role also in the environment (Mulyani 1985). The diversity of bird species in general is affected by a decline in the carrying capacity of the habitat. Changes of vegetation structure and composition in disturbed forests and cleared land determine the area of species' richness, thus altering the composition of the bird species' composition. The differences in tree composition in the three habitats of PT BSRE area and its surroundings (see Chapter 4) influence the species' richness, diversity and composition. There is a positive correlation between tree diversity and bird diversity.

When forest habitat is destroyed, rubber agroforests are an alternative sanctuary area in which birds can nest and forage. The vegetation in rubber agroforests provides a good carrying capacity for bird diversity. To improve biodiversity in the PT BSRE area, we recommend preserving intermediary regions, such as along riverbanks and the main roads in the plantation. An intermediary region could be a corridor or a link between one region and other regions along the border of the plantation. In such places, we recommend not planting only rubber trees but a mix with fruit trees, such as *Ficus*, that could provide habitat carrying capacity for wildlife, especially birds.

Table 21. List of birds in different habitat types in PT BSRE and its surroundings

Scientific Name[1]	EnglisH Name	Guild[2]	Status[3]			P	Habitat			
			IUCN	CITES[4]	UU/PP RI[5]		F	P	S	E
Ardeidae										
Ardea cinerea	Grey Heron	P				s	#			#
Ardea purpurea	Purple Heron	P				s	#			#
Ardea alba	Great Egret	P			AB	s	#			
Egretta garzetta	Little Egret	P			AB	s	#			
Accipitridae										
Haliastur indus	Brahminy Kite	R		II	AB	s	#			
Haliaeetus leucogaster	White-bellied Sea Eagle	R		II	AB	s	#			
Ictinaetus malayensis	Black Eagle	R		II	AB	s	#		#	#
Spizaetus cirrhatus	Crested Hawk-Eagle	R		II	AB	s	#			#
Spizaetus alboniger	Blyth's Hawk-Eagle	R		II	AB	s	#			
Spilornis cheela	Crested Serpent Eagle	R		II	AB		#	#	#	
Accipiter virgatus	Besra	R		II	AB	s		#		
Phasianidae										
Lophura inornata	Salvadori's Pheasant	TIF				h+r	#			
Gallus gallus	Red Junglefowl	TIF				h+r	#			
Argusianus argus	Great Argus	TIF	NT	II	AB	h	#			
Turnicidae										
Turnix suscitator	Barred Buttonquail	TIF				s	#			
Rallidae										
Amaurornis phoenicurus	White-breasted Waterhen	TIF				s	#			
Columbidae										
Treron capellei	Large Green Pigeon	AF	VU			s	#			
Treron olax	Little Green Pigeon	AF				s	#			
Treron vernans	Pink-necked Green Pigeon	AF				s	#	#	#	#
Macropygia ruficeps	Little Cuckoo Dove	AF				s+h	#			
Streptopelia chinensis	Spotted Dove	AF				s+h	#	#	#	#
Geopelia striata	Zebra Dove	AF						#	#	
Psittacidae										
Loriculus galgulus	Blue-crowned Hanging Parrot	AF		II		s	#		#	
Cuculidae										
Cuculus saturatus	Oriental Cuckoo	AFGI				s		#		
Cacomantis sepulcralis	Rusty-breasted Cuckoo	AFGI				h				#
Surniculus lugubris	Asian Drongo-Cuckoo	AFGI				h	#	#		
Eudynamys scolopaceus	Asian Koel	AFGI				h	#			
Rhopodytes diardi	Black-bellied Malkoha	AFGI	NT			s	#			
Rhinortha chlorophaeus	Raffles's Malkoha	AFGI				s	#			
Centropus sinensis	Greater Coucal	TI				s+h	#			
Centropus bengalensis	Lesser Coucal	TI				h	#	#	#	
Tytonidae										
Tyto alba	Barn Owl	NP		II		s				#
Strigidae										
Ketupa ketupu	Buffy Fish-Owl	NP		II		s		#		
Glaucidium brodiei	Collared Owlet	NP		II		s	#			
Apodidae										
Collocalia vulcanorum	Volcano Swiftlet	AI	NT			s	#			
Collocalia fuciphagus	Edible-nest Swiftlet	AI				s				#
Collocalia esculenta	Glossy Swiftlet	AI				s	#	#	#	
Collocalia linchi	Cave Swiftlet	AI				s			#	

Hirundapus caudacutus	White-throated Needletail	AI				s	#			
Apus nipalensis	House Swift	AI				s	#		#	#
Hemiprocnidae										
Hemiprocne comata	Whiskered Treeswift	SI				s	#			#
Trogonidae										
Harpactes kasumba	Red-naped Trogon	SSGI	NT		AB	s+r	#			
Alcedinidae										
Alcedo meninting	Blue-eared Kingfisher	MIP			AB	s	#			
Halcyon smyrnensis	White-throated Kingfisher	MIP			AB	s	#	#	#	#
Halcyon chloris	Collared Kingfisher	MIP			AB	s	#	#	#	#
Meropidae										
Merops leschenaulti	Chestnut-headed Bee-eater	SI				s			#	
Merops viridis	Blue-throated Bee-eater	SI				s	#	#		#
Bucerotidae										
Buceros rhinoceros	Rhinoceros Hornbill	AFP	NT	II	AB	h	#			
Rhyticeros undulatus	Wreathed Hornbill	AFP		II	AB	s+h	#			
Rhinoplax vigil J	Helmeted Hornbill	AFP	NT	I	AB	h+r	#			
Capitonidae										
Psilopogon pyrolophus	Fire-tufted Barbet	AFP				s	#			
Megalaima chrysopogon	Golden-whiskered Barbet	AFP				s	#			
Megalaima oorti	Black-browed Barbet	AFP				s+h	#			
Megalaima haemacephala	Coppersmith Barbet	AFP				s+h	#		#	#
Calorhamphus fuliginosus	Brown Barbet	AFP				s			#	
Picidae										
Picumnus innominatus	Speckled Piculet	BGI				s				#
Picus flavinucha	Greater Yellownape	BGI				s	#			
Dinopium javanense	Common Goldenback	BGI				s	#			
Meiglyptes tukki	Buff-necked Woodpecker	BGI	NT			s	#			
Dendrocopos moluccensis	Sunda Pygmy Woodpecker	BGI				s	#	#	#	#
Reinwardtipicus validus	Orange-backed Woodpecker	BGI				s	#			
Eurylaimidae										
Serilophus lunatus	Silver-breasted Broadbill	SSGI				s	#			
Psarisomus dalhousiae	Long-tailed Broadbill	SSGI				h	#			
Calyptomena viridis	Green Broadbill	SSGI	NT			h	#			
Hirundinidae										
Delichon dasypus	Asian House Martin	AFGI				s	#	#	#	#
Campephagidae										
Pericrocotus divaricatus	Ashy Minivet	AFGI				s	#			
Pericrocotus flammeus	Scarlet Minivet	AFGI				s	#			
Hemipus picatus	Bar-winged Flycatcher-shrike	AFGI				s	#			
Aegithinidae										
Aegithina tiphia	Common Iora	AFGI				s+h	#		#	#
Chloropseidae										
Chloropsis venusta	Blue-masked Leafbird	NIF	NT			s	#			
Chloropsis sonnerati	Greater Green Leafbird	NIF				s	#			
Pycnonotidae										
Pycnonotus atriceps	Black-headed Bulbul	AFGIF				s	#			
Pycnonotus melanicterus	Black-crested Bulbul	AFGIF				s	#		#	
Pycnonotus aurigaster	Sooty-headed Bulbul	AFGIF				s	#	#	#	#
Pycnonotus bimaculatus	Orange-spotted Bulbul	AFGIF				s	#			
Pycnonotus goiavier	Yellow-vented Bulbul	AFGIF				s	#	#	#	#
Pycnonotus simplex	Cream-vented Bulbul	AFGIF				s	#		#	
Pycnonotus erythropthalmos	Spectacled Bulbul	AFGIF				s	#			
Criniger finschii	Finsch's Bulbul	AFGIF	NT			s	#			

Laniidae									
Lanius tigrinus	Tiger Shrike	SI			s	#	#		
Lanius cristatus	Brown Shrike	SI			s	#			
Lanius schach	Long-tailed Shrike	SI			s	#		#	#
Turdidae									
Brachypteryx montana	White-browed Shortwing	AFGI			h+s			#	
Copsychus saularis	Oriental Magpie-robin	AFGI			s	#	#	#	#
Copsychus malabaricus	White-rumped Shama	AFGI			h+s	#		#	
Timaliidae									
Malacocincla sepiarium	Horsfield's Babbler	AFGI			h	#			
Malacocincla abboti	Abbott's Babbler	AFGI			h	#			
Stachyris rufifrons	Rufous-fronted Babbler	AFGI			h	#			
Macronous gularis	Striped Tit-Babbler	AFGI			h	#			
Garrulax leucolophus	White-crested Laughingthrush	AFGI			h+r	#			
Garrulax lugubris	Black Laughingthrush	AFGI			h+r	#			
Sylviidae									
Cettia vulcania	Sunda Bush-warbler	AFGI			h	#		#	
Prinia atrogularis	Hill Prinia	AFGI			s	#	#	#	
Prinia familiaris	Bar-winged Prinia	AFGI			s	#		#	
Orthotomus cuculatus	Mountain Tailorbird	AFGI			s	#			
Orthotomus sutorius	Common Tailorbird	AFGI			s	#	#	#	
Orthotomus atrogularis	Dark-necked Tailorbird	AFGI			s	#			
Orthotomus sericeus	Rufous-tailed Tailorbird	AFGI			s	#			
Orthotomus ruficeps	Ashy Tailorbird	AFGI			s	#			#
Phylloscopus inornatus	Yellow-browed Warbler	AFGI			s	#	#	#	
Phylloscopus borealis	Arctic Warbler	AFGI			s	#	#		
Phylloscopus trivirgatus	Mountain Leaf Warbler	AFGI			s				
Seicercus grammiceps	Sunda Warbler	AFGI			s	#			
Abroscopus superciliaris	Yellow-bellied Warbler	AFGI			s	#		#	#
Muscicapidae									
Saxicola caprata	Pied Bush Chat	SI			s	#		#	
Muscicapa dauurica	Asian Brown Flycatcher	SI			s	#			
Ficedula hyperythra	Snowy-browed Flycatcher	SI			s	#			
Ficedula westermanni	Little Pied Flycatcher	SI			s	#		#	
Acanthizidae									
Gerygone sulphurea	Golden-bellied Geryone	SI			s+h	#	#		#
Rhipiduridae									
Rhipidura javanica	Pied Fantail	SI		AB	h	#			
Paridae									
Parus major	Great Tit	SI			s				
Dicaeidae									
Dicaeum sanguinolentum	Blood-breasted Flowerpecker	NIF			s	#			
Dicaeum cruentatum	Scarlet-backed Flowerpecker	NIF			s	#		#	
Dicaeum trochileum	Scarlet-headed Flowerpecker	NIF			s+h			#	#
Dicaeum trigonostigma	Orange-bellied Flowerpecker	NIF			s				#
Nectariniidae									
Anthreptes simplex	Plain Sunbird	N		B	s	#			
Anthreptes singalensis	Ruby-cheeked Sunbird	N		AB	s	#		#	
Anthreptes malacensis	Brown-throated Sunbird	N		AB		#			
Cinnyris jugularis	Olive-backed Sunbird	N		AB	s	#		#	#
Arachnothera longirostra	Little Spiderhunter	N		AB	s	#			
Arachnothera affinis	Streaky-breasted Spiderhunter	N		B	s	#		#	
Anthreptes malacensis	Brown-throated Sunbird	N		AB		#		#	
Anthreptes rhodolaema	Red-throated Sunbird	N	NT	AB	s	#			

Zosteropidae										
Zosterops palpebrosus	Oriental White-eye	AFGI				s	#	#		#
Zosterops everetti	Everett's White-eye	AFGI				s	#			
Zosterops montanus	Mountain White-eye	AFGI				s	#	#		
Estrildidae										
Lonchura striata	White-rumped Munia	TF				s	#			#
Lonchura leucogastroides	Javan Munia	TF				s	#		#	#
Lonchura maja	White-headed Munia	TF				s				#
Padda oryzivora	Java Sparrow	TF	VU	II		s				
Ploceidae										
Passer montanus	Eurasian Tree Sparrow	TF				s				#
Sturnidae										
Acridotheres javanicus	White-vented Myna	AF				s		#	#	#
Gracula religiosa	Common Hill Myna	AF		II	AB	r	#	#		
Oriolidae										
Oriolus chinensis	Black-naped Oriole	AFGIF				s	#	#	#	#
Dicruridae										
Dicrurus macrocercus	Black Drongo	SSGI				s	#	#		
Dicrurus leucophaeus	Ashy Drongo	SSGI				s	#			
Dicrurus remifer	Lesser Racquet-tailed Drongo	SSGI				s+h	#		#	
Dicrurus sumatranus	Sumatran Drongo	SSGI	NT			s	#		#	#
Artamidae										
Artamus leucorynchus	White-breasted Woodswallow	SSGI				s	#			#
Corvidae										
Dendrocitta occipitalis	Sumatran Treepie	AFGIF				s	#			
Corvus enca	Slender-billed Crow	AFGIF				s	#			
Corvus macrorhynchos	Large-billed Crow	AFGIF				s	#		#	#
							122	30	46	39

[1]Clasification name based on Sukmantoro et al. (2007)
[2]Clasification of guild composition based on Lambert and Collar (2002): AF=arboreal frugivore, AFGI=arboreal foliage gleaning insectivore, AFGIF= arboreal foliage gleaning insectivore-frugivore, AFP=arboreal frugivore-predator, AI=aerial insectivore, BGI=bark gleaning insectivore, MIP=miscellaneous insectivor-piscivore, N=nectivore, NP=nocturnal predator, NIF=nectivore-insectivore-frugivore, P=piscivore, R=raptivore, SI=sallying insectivore, SSGI=sallying substrate gleaning insctivore, TF=terrestrial frugivore, TI=terrestrial insectivore and TIF=terrestrial insectivore-frugivore. AI, N, NIF, SI, MIP, SSGI*:* This group of birds forages in the air, while flying. BGI: This group forages in trees, by searching in or disassembling bark. TF, TI, TIF:This group forages on the ground or the forest floor.
[3]Status: IUCN=International Union Conservation of Nature, CITES=Convention on the International Trade in Endangered Flora and Fauna, A = Undang-undang RI No. 5/1990; B = Peraturan Pemerintah No. 7/1979
[4] Birds' presence in location survey (P): s=seen, h=heard, r=reported
[5]Habitat: F (forest), S (smallholding), P (plantation), E (Emplacement)

6. Bat diversity in rubber plantations and their surroundings

Pandam Nugroho, Sephy Noerfahmy, Insani Taufik and Hesti L. Tata

6.1 Introduction

Bats are one of the orders of mammals that can fly. They are most active at night (nocturnal). Bats can be found in most parts of the world, especially in countries having a tropical or subtropical climate. The order containing bats, Chiroptera, has the second-largest number of species after rodents and covers 188 genera comprising 977 species. Chiroptera is classified into two suborders, namely Megachiroptera and Microchiroptera (Corbet and Hill 1992).

In Indonesia, there are 205 or 21% of the world's known bat species, consisting of 72 species of fruit-eaters and 133 species of insect-eaters. Suyanto (2001) stated that the nine families found in Indonesia consist of Pteropodidae Megadermatidae, Nycteridae, Vespertilonidae, Rhinolophidae, Hipposideridae, Emballonuridae, Rhinopomatidae and Molossidae. Bats have several ecological roles, namely, (a) as seed dispersal agents of tropical forest vegetation. Because of their feeding behavior and their ability to fly far, bats disperse seeds distant from the mother trees, which can be plant species such as Solanaceae (eggplant), sandalwood, banyan (*Ficus* sp.), rubber, breadfruit tree, guava, *duwet*, *sapodilla*, sugar apple and walnut; (b) as pollinators of flowering plants, including plants of high economic value, such as *Durio zibethinus* (durian), *Parkia* sp., sugar palm, *Calliandra* sp., banana, mangroves, *Ceiba pentandra* (kapok); (c) insectivorous bats have an important role in pest control in nature; (d) as producers of guano fertiliser that is rich in sodium, phosphorus and potassium.

Seed dispersal agency is important in the germination of tropical plant species (Suyanto 2001). Bats carry seeds because the seeds are covered by a seed-coat fruit or flesh that contains nutrition and is high in energy. Bats only eat the fleshy part by chewing the fruit to remove its fluid, while fibers of the fruit flesh and the seeds are discarded. As a result, the seeds are cleaned from the fruit flesh so that they can grow well. This activity distinguishes bats from other mammals (Suyanto 2001). For example, the seeds of *Maesopsis eminii* are dispersed by the Flying Fox (*Cynopterus brachyotis*) (Maryanto and Yani 2003).

Van der Pijl (1982) reported that bats disperse seeds of the fruit of Palmae, Moraceae, Chrisobalanaceae, Annonaceae, Sapotaceae, Anacardiaceae and Leguminosae. Other studies showed that when the Cave Nectar Bat (*Eonycteris spelaea*) is looking for food such as stamens of flowers, at the same time it is also pollinating flowers of durian (*Durio zibethinus*), *Sonneratia alba*, *Rhizophora* sp., *petai* (*Parkia speciosa*), coconut (*Cocos nucifera*), sugar palm (*Arenga pinnata*), banana (*Musa* spp.) and kapok (*Ceiba pentandra*). *Macroglossus minimus* and *Syconycteris australis* are known as pollinators of all kinds of banana trees, so they have become a determining factor in any increase or decrease in banana production. The durian tree has a large flower, white petals and a lot of nectar and so attracts bats (Start and Marshall 1976). Therefore, fruit-eating bats

(Megachiroptera) are a key taxon in maintaining the balance of tropical forest ecosystems (Suyanto 2001).

Bats are susceptible to habitat changes owing to forest logging, which causes a decrease in forest cover (Kingstone 2008; Struebig et. al. 2010). Therefore, bat surveys were conducted in three habitats—rubber monoculture plantation, smallholder rubber gardens and primary forest—to compare the types of bats in the different habitats. We aimed to identify the level of bat species' richness and the role and function of bats in the rubber plantation of PT BSRE using the quick biodiversity survey. The research findings can be used as a reference to determine the necessary environmental conditions for bats and are expected to be used to formulate recommendations for sustainable management of rubber plantations and surrounding areas.

6.2 Methods

6.2.1 Location and period of research

The survey was conducted in January and February 2011 in the rubber plantations of PT BSRE at Dolok Merangir and Aek Tarum. The forest sites were situated at Aek Nauli and Aek Tarum. A map of the study sites is shown in Figure 19.

The bat survey was implemented in three habitat types: (1) plantation (young: 2–6 years after planting; and older than 25 years after planting); (2) smallholder rubber area; and (3) primary forest. The first two habitats were located in the plantations at Dolok Merangir and Aek Tarum, while forest sites were located at Aek Nauli (close to Dolok Merangir) and Aek Tarum. Each site is described in Table 22.

Table 22. Bat survey site characteristics at Dolok Merangir and Aek Tarum

Dolok Merangir area (1)	Aek Tarum area (2)
Young rubber plantation (KM1): This area was located at an altitude of 873–895 m above sea level (masl). Plants in this young rubber plantation were aged about 4 yo (first planted in 2007). Two transects were established: transect 1 was located in block BB 17-CC17, CC18, while transect 2 was in DD18. Rubber trees at the sites were just being tapped. The garden is surrounded by an older rubber plantation. It was close to a deep river with mixed vegetation along the riverbanks.	**Young rubber plantation (KM2):** This habitat was located in the village of Aek Tarum, Bandar Pulau subdistrict, Asahan district, at an altitude of 745–779 masl. Rubber plants were aged 6 yo. Three transects were laid out on this site: transect 1 was located in block M48-M49, transect 2 was in block N53-N54 and transect 3 was in block M56-57. Transect 3 was situated on the border of an old rubber plantation and there were shrubs in a small graveyard close by the block.
Old Rubber Plantation 1 (KT1): This area was located at an altitude of 683–747 masl and was aged about 22 yo (planted in 1989). Two transects were established: transect 1 was located in the blocks of X23-Y23 and transect 2 in the block of W22-W23. Locations JRA youth, the blocks of W21 and W22 were located in Dolok Batunanggar subdistrict, district Simalungun. Almost all rubber trees in the vicinity were the same age. In the vicinity were some insect-eating birds (*Gerigone sulphurea*, *Halcyon smyrnensis*, *Prinia* ***flaviventris***) and seed-eating birds *Pycnonotus goeavier, Streptopelia chinensis, Geopelia striata*. Nocturnal birds (*Caprimulgus* spp. and *Ninox scutulata*) were also found.	**Old Rubber Plantation2 (KT2):** This area was located in the same village as the young rubber plantation. This region lies between an altitude of 769 and 785 masl and has a poor, dry soil. The rubber trees were aged 18 yo, and were the oldest rubber trees at this site. Two transects were laid out: transect 1 was located in L46-L47 and transect 2 in K45, L45 and M45.

Smallholder rubber (KR1):	Smallholder rubber (KR2):
This site was situated in the village of Babolon, Batu subdistrict Nanggar, Simalungun district on the border of a state-estate plantation (PT Perkebunan Negara, PTPN) at an altitude of 706–730 masl. Two transects were established and some plots were laid in the adjacent oil palm plantation owned by PTPN. Most people from this area were retirees from PT BSRE, so the rubber planting was nearly a monocultural system. There were also some rubber trees planted in a mix with other crops such as cocoa, durian and oil palm. Some other plots were laid out in a mixed garden of cocoa and rubber.	This site was located in the Napah hamlet, Rao Huta village, subdistrict of Bandar Pulau, Asahan district at an altitude of 736–805 masl. Three transects were laid out. Data were collected in an old rubber plantation that had been tapped. Most communities planted rubber trees with oil palm and, rarely, with cacao.
Forest 1 (H1), Aek Nauli:	**Forest 2 (H2), Aek Tarum:**
The forest area at Aek Nauli belongs to the Forest Research and Development Agency (FORDA) and was managed by the Forest Research Institute of Aek Nauli. Administratively, the forest is located in Sibaganding village, Girsang Simpangan Bolon subdistrict, Simalungun district, approximately 120 km to the south of Dolok Merangir. Aek Nauli forest is a montane forest, with two types of vegetation: homogeneous pine forest and heterogeneous forest dominated by *Schima wallichii*. In the heterogeneous forest, lianas were still present, although rattan as an indicator of disturbed forest was also encountered. Some animals were found: squirrel (*Callosciurus* spp.) and *siamang* (*Symphalangus syndactilus*). Three transects were laid out at altitudes ranging from 767 to 1211 masl.	This site was located in the same subdistrict and district as the young and old rubber plantations and the smallholder rubber area, and is known as *bartong* forest. It lies at an altitude between 995 and 1030 masl. The forest was categorised as protected forest, however, some people had converted some forest area to estate plantations of oil palm and rubber. Three transects were laid out with transect 1 on the forest edge to the centre. Transects 2 and 3 were inside the protected forest. Some of the plots were established following a trail and others were laid out perpendicular to the stream.

6.2.1 Quick bat diversity survey

The survey was conducted using the quick biodiversity survey method for bats in conjunction with mist nets developed by the World Agroforestry Centre. We used mist nets with a width of 2.7 m and a mesh size of 30–32 mm. The length of the mist net varied between 6 and 9 m. The nets were placed at intervals of 200 m along a 1–2 km transect at appropriate locations (open space, forest borders, fruit trees or along the river banks). In the plantation, transects were aligned with the rubber planting rows. Installation of mist nets was performed in the afternoon before sunset. Each mist net was regularly checked every 30 minutes, 19:00 until 22:00 hours, to catch any animals as soon as they were trapped in the mist net. Bats caught in the net were kept in a cotton bag. Morphometric data, consisting of weight (g), forearm length of wing (mm), ear length (mm), tail length (mm) and length of thigh (mm), were measured and recorded. Next day in the morning, the animals were checked again and bats that had been identified were released.

Bat identification was carried out using the *Survey of forest bats using harp trap* by Struebig and Sujarno (2006), a key contained in the book, *Field guide to bats in Indonesia*, by Suyanto (2001) and, *A field guide to the mammals of Borneo*, by Payne et al. (1985). The nomenclature was recorded based on Suyanto (2001) and Payne et al. (1985). Protection status was determined according to the IUCN's Red List (IUCN 2008).

6.2.3 Data analysis

• Species' richness

Species' richness was calculated using Margalef's species' richness index (Krebs 1989), by the following equation:

$$d = \frac{(s-1)}{\ln N}$$

where,
d = Margalef's species' richness index
s = Number of species found
N = Number of individuals found

• Diversity index of Shannon-Wiener

The Shannon-Wiener index (Krebs 1989) was used to determine the diversity of mammal species on each transect and is described by the following equation:

$$H' = \sum_{i=1}^{n} -(pi \ \ln pi)$$

where,
H '= Shannon-Wiener diversity index
p_i = Probability of species (relative density)
n = number of species

• Simpson's dominance index (D_2)

This was used to estimate the dominance of species and is described by the following equation:

$$D2 = \{\sum_{i=1}^{n} p_i{}^2\}\text{-}1$$

D_2 = Simpson's dominance index
p_i = Probability of species (relative density)

• Pielou's evenness index (J')

This was used to estimate the evenness of the species distribution of mammals (Krebs 1989) and is described by the following equation:

$$J' = \frac{H'}{H'max}$$

where,
J'= Pielou's evenness index
H' = Shannon-Wiener diversity index
S = Number of species

• Group analysis (cluster analysis)

Cluster analysis groups were used to determine the level of similarity or dissimilarity between species found in each different habitat type. The Palaentological Statistics (PAST)[6] program software was used for this analysis.

6.2.4 Data bias

Weather conditions in the survey area during the period from January to February 2011 varied from dry to wet, with rainy days hampering data collection on several transects. Some mist nets were damaged in the mid-observation period owing to the active movement of trapped animals. These factors caused bias in the data collection. To reduce the bias, data were collected along each transect within 3 days. Where rain interrupted the sampling procedure, data collection was extended for another day. The mist net was checked regularly, to avoid escapes.

6.3 Results and discussions

6.3.1 Composition of bat species

Based on the results of data collection from all study sites (Table 21), 234 individual bats were trapped from three families and 11 species, with eight species from the suborder Megachiroptera (fruit eaters), while the remaining three species were from Microchiroptera (insect eaters). The species of bats identified were *Cynopterus sphinx, Cynopterus brachyotis, Cynopterus horsfieldii, Cynopterus titthaecheilus, Chironax melanocephalus, Eonycteris spelaea, Macroglossus sobrinus, Penthetor lucasi, Rhinolophus pusillus, Rhinolophus affinis* and *Hipposideros diaderma*.

Table 23 shows that *Cynopterus sphinx* (Greater Short-nosed Fruit Bat) was the most common bat species found in the area from a transect total of 1765.8 m. Only one individual of *Hipposideros diaderma* (Diadem Roundleaf Bat) was found in the young rubber plantations. There were three species—*Chironax melanocephalus* (Black-capped Fruit Bat), *Rhinolophus pusillus* (Least Horseshoe Bat) and *R. affinis* (Intermediate Horseshoe Bat)—that were only found in the forest, with the last two of these classified as Microchiroptera, or insectivorous. Interestingly, the Long-tongued Fruit

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[6] http://folk.uio.no/ohammer/past/index.html (Accessed March 2011)

Bat (*Macroglossus sobrinus*) was only found in the smallholder rubber area. Images of some bat species found in the forests, rubber plantations and rubber smallholder areas are shown in Figures 3, 4 and 5, respectively.

The density of each species is shown in Figure 47. Of the total 27 bat species, 73% were from the family Pteropodidae (Megachiroptera) and the remaining 27% consisted of the two families Rhinolophidae and Hipposideridae (Microchiroptera). This result was likely influenced by the method of data collection using a mist net, which could be recognised by bats of the Microchiroptera, as bats from this suborder have an ultrasonic sensor that enables them to recognise any physical hindrance in their path. Morphologically, they usually have a lighter weight and narrower wing load compared with the Megachiroptera, which enables them to fly in a closed canopy such as a forest (Crome and Richard 1988; Norberg and Rayner 1987). Declining populations of insect-eating bats owing to the loss of forest habitat threatens the health of ecosystems and humans. Insect-eating bats play an important role as predators of mosquitoes and other pests. One individual insect-eating bat can consume up to one third of its bodyweight in insects or the equivalent of 1000 mosquitoes in one hour (Kingstone 2006).

Table 23. Species density composition of bats in different habitats

Type	Bat species	Young rubber plantation		Old rubber plantation		Smallholding		Forest		Total Density (%)
		KM1	KM2	KT1	KT2	KR1	KR2	H1	H2	
Fruit&nectar-eaters	*Cynopterus sphinx*	31.89	2.06	21.61	-	16.46	6.512	-	0.51	79.05
	Cynopterus brachyotis	6.17	-	2.57	-	0.51	-	-	0.51	9.77
	Cynopterus horsfieldi	0.51	-	-	-	-	-	1.03	-	1.54
	Cynopterus titthaechelius	-	1.25	1.03	-	3.60	-	-	-	5.86
	*Chironax melanocephalus**	-	-	-	-	-	-	3.09	-	3.09
	Eonycteris spelaea	-	1.24	-	2.47	2.57	-	-	-	6.28
	Macroglossus sobrinus[+]	-	-	-	-	2.57	1.03	-	-	3.60
	Penthetor lucasi	-	1.65	-	-	-	0.34	-	-	1.99
Insect-eaters	*Rhinolophus pusillus**	-	-	-	-	-	-	0.34	-	0.34
	*Rhinolophus affinis**	-	-	-	-	-	-	0.34	0.51	0.86
	Hipposideros diaderma[#]	-	0.41	-	-	-	-	-	-	0.41
	Effort (meters night)	194.4	243	194.4	162	194.4	291.6	291.6	194.4	1765.8
	Total species	3	5	3	1	5	3	4	3	27
	Total Individuals (n)	75	16	49	4	50	23	14	3	234

Figures are percentages for each species in each habitat
KM = young rubber plantation; KT = old rubber plantation; KR = smallholder rubber; H = forest; 1= Dolok Merangir site; 2 = Aek Tarum site
* = found in forest only; [+] = found in smallholder rubber only; [#] = found in plantation only

All bat species encountered in the study area were categorised as 'least concern' conservation status. However, the habits of some local people, such as the Bataks, who consume bats as part of their diet, need to be considered as a threat to the possible extinction of bat species in the future.

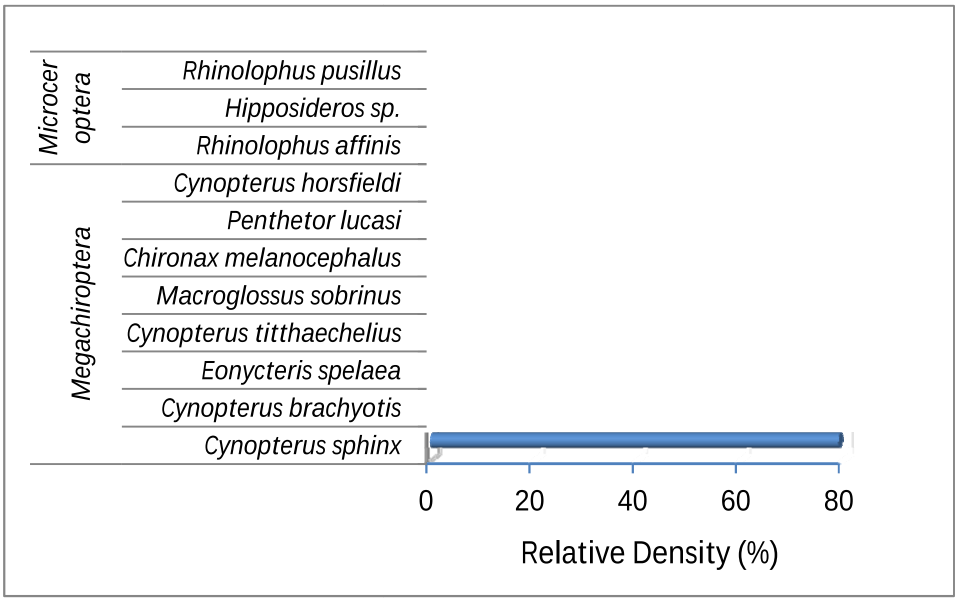


Figure 47. Bat density across all sampled habitat types

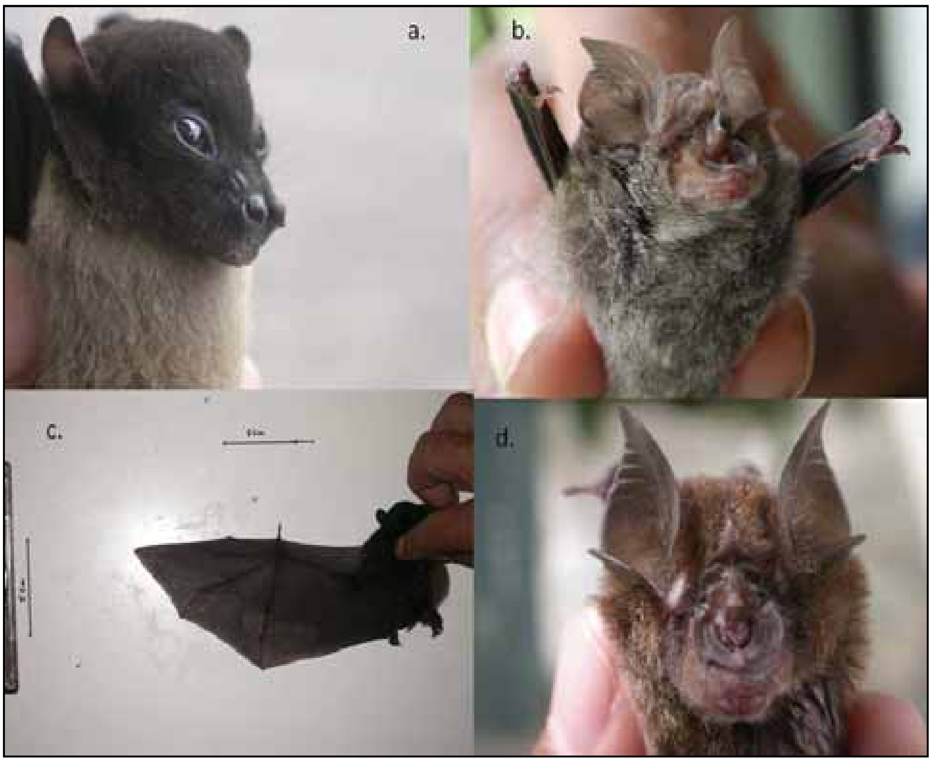


Figure 48. Bat species sampled in forest

Legend: (a) *Chironax melanocephalus*; (b) *Rhinolophus pusillus*; (c) wing loading of *C. melanocephalus*; (d) *Rhinolophus affinis*

Figure 49. Bats species sampled in rubber plantation

Legend: (a) *Hipposideros diadema*; (b) *Penthetor lucasi*; (c) *Cynepterus sphinx*; (d) *Cynopteris horsfieldii*

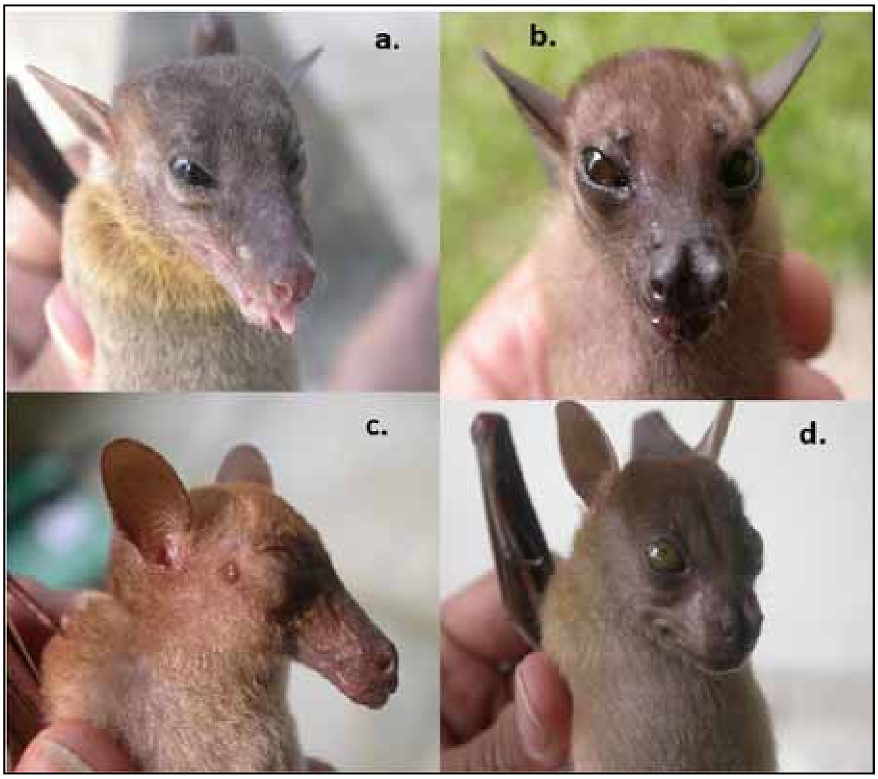


Figure 50. Bats species sampled in rubber smallholder area

Legend: (a) *Eonycteris spelaea*; (b) *Penthetor lucasi*; (c) *Macroglossus sobrinus*; (d) *Cynopterus titthaechelius*

6.3.2 Richness and abundance of species

The richness and abundance of species was calculated from the number of species obtained multiplied by the number of individuals that were trapped in the nets (Figure 51).

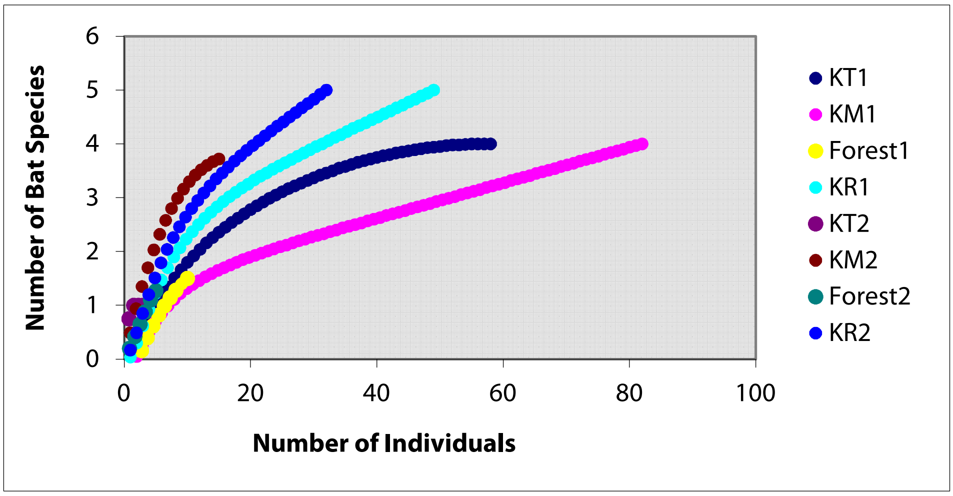


Figure 51. Curve of bat species richness in the study area

Legend: KM = young rubber plantation; KT = old rubber plantation; KR = smallholder rubber; 1= Dolok Merangir site; 2 = Aek Tarum site

Figure 51 shows the richness of species in each habitat type. The curves of species trapped in the old rubber plantation areas (KT1 and KT2) show a comparable number of species and individuals caught, with the curves tending towards a horizontal line or asymptote. It can be assumed that the bat species' richness at those two locations was well represented by the sampling. If we had taken additional samples, it is likely that no additional species would have been found. In the young rubber plantations (KM1 and KM2), the ratio between the number of species and individuals is beginning to reach a horizontal line (asymptote), while the curves representing the species trapped in the smallholder rubber areas (KR1 and KR2) have not reached an asymptote, which implies that there is still the possibility of additional species being found if additional trapping were carried out. In the old rubber plantation area at Aek Tarum (KT2), an asymptote could have been reached owing to the small number of individuals of the same species (*Eonycteris spelaea*), commonly known as the Cave Nectar Bat.

6.3.3 Species' richness, dominance, diversity and evenness indices

The richness and abundance of bat species in different habitat types are shown in Figures 51 and 52.

The highest bat species' richness was found in the forest habitat at Aek Tarum (H2), followed by the young rubber plantation at Aek Tarum (KM2) and the forest at Aek Nauli (H1). Based on observation, the forest at Aek Tarum was a secondary forest where many trees had grown up after the canopy had been opened, while the forest at Aek Nauli was a low-intensity, disturbed forest. Nevertheless, the current threat from illegal loggers in the Aek Tarum forest may cause habitat loss for bats and lead to a decrease in diversity.

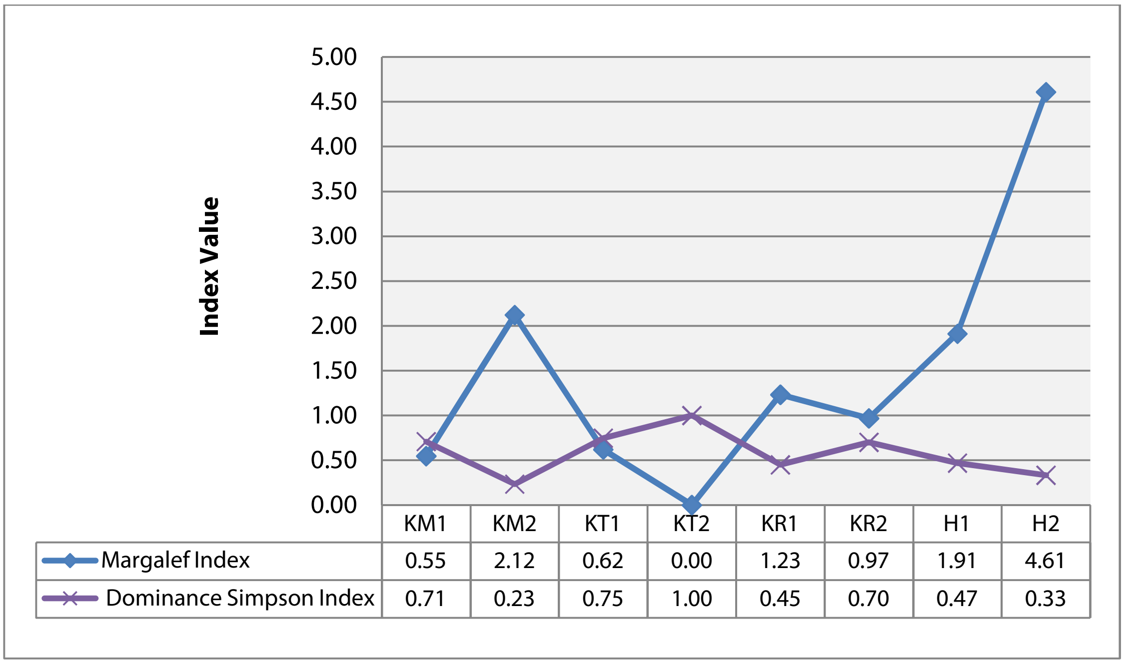
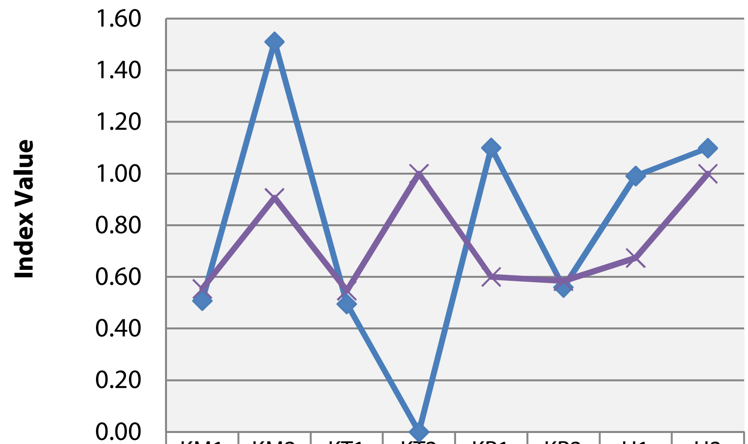


Figure 52. Comparison of Simpson's dominance index and Margalef's diversity index at different study sites

Legend: KM = young rubber plantation; KT = old rubber plantation; KR = smallholder rubber; H = forest; 1 = Dolok Merangir site; 2 = Aek Tarum site

A very low level of richness of bat species was found in the old rubber plantation at Dolok Merangir (KT1), the young rubber plantation at Dolok Merangir (KM1) and the old rubber plantation at Aek Tarum (KT2). The dominance value in KT2 was high, but on the other hand the diversity index was zero. This means that only one species was observed at KT2 with a high number of individuals being trapped (*E. spelaea)*. The dominance index is inversely related to the diversity. Simpson's dominance index values are between 0 and 1: the closer the value gets to 1 indicates a higher dominance and when the values get close to 0, then the population tends to have no dominance (Ludwig and Reynolds 1988; Magurran 1988). The weather conditions during the observation period consisted of a bright moon and extended rain from the evening until the next morning and these affected our observations. According to Morrison (1978), when the moon is bright, bats tend to be afraid of ambush by predators and when rain falls, bats tend to stay under shelter or in a permanent nest. Lekagul and McNeely (1977) stated that bats have the ability to hibernate when it is raining or during winter.

Based on the analysis, the young rubber plantation at Aek Tarum (KM2) had the highest value of the Shannon-Wiener diversity index, followed by the forest at Aek Tarum (H2) and the forest at Aek Naul (H1). The Shannon-Wiener diversity index values were comparable to the species richness and the evenness of species (Pielou's evenness index), as shown in Figure 53. According to Ludwig and Reynolds (1988) and Magurran (1988), a Shannon-Wiener index value of less than 1 can be categorised as a low level of diversity. The diversity index indicates the species' richness in a community and also shows the balance in the distribution of the number of individuals of each species (Odum 1971). A diversity index with the minimum value of 0 occurs when a single sample or plot produces only one individual, while the index reaches a maximum when the species present are spread evenly. The diversity index value will increase if the number of species found at the study site increases.



	KM1	KM2	KT1	KT2	KR1	KR2	H1	H2
Shannon Wienner Index	0.51	1.51	0.50	0.00	1.10	0.56	0.99	1.10
Pielou Evennes Index	0.55	0.91	0.55	1.00	0.60	0.58	0.67	1.00

Figure 53. Comparison of Shannon-Wiener diversity index and Pielou's evenness index for different habitats

Legend: KM = young rubber plantation; KT = old rubber plantation; KR = smallholder rubber; H = forest; 1 = Dolok Merangir site; 2 = Aek Tarum site

According to Krebs (1989), Pielou's evenness index (J') shows the level of equilibrium distribution of species in communities or ecosystems. A J' value ranges between 0 and 1, with the maximum value indicating a balanced distribution or no dominance, while the minimum value suggests a tendency to dominance.

The low value of mammal diversity, specifically of bat species, along each transect illustrates that the condition of the rubber plantations is alarming, owing to the imbalance in the number of individuals of each species within a community. However, the research location could potentially have high species' richness but with an unequal distribution. Hence, we recommend that it is necessary to establish a 'buffer zone' or conservation area on the borders of the plantation. The buffer zone plays the role of a stepping stone or corridor for animals to reach the forest vegetation. Research on the potential of rubber plantations as corridors for animals moving between the forest and non-forest vegetation types has been carried out by RUPES (2005).

6.3.4 Dissimilarity of species of bats analysed using Euclidean distance method

The species' composition of bats per transect was analysed using the clustering method of unweighted pair group method with arithmetic mean and Euclidean distance dissimilarity. Distance dissimilarity showed an inequality of bat species in the different habitats. Figure 54 shows that the clustering analysis resulted in a level of inequality of 4.8 and the bat species in the different habitat types were clustered into three groups: Group 1 (*Cynopterus sphinx*); Group 2 (*Cynopterus horsfieldii*, *Cynopterus titthaecheilus*, *Chironax melanocephalus, Eonycteris spelaea,* *Macroglossus sobrinus, Penthetor lucasi, Rhinolophus pusillus, Rhinolophus affinis* and *Hipposideros diaderma*); and Group 3 (*Cynopterus brachyotis*).

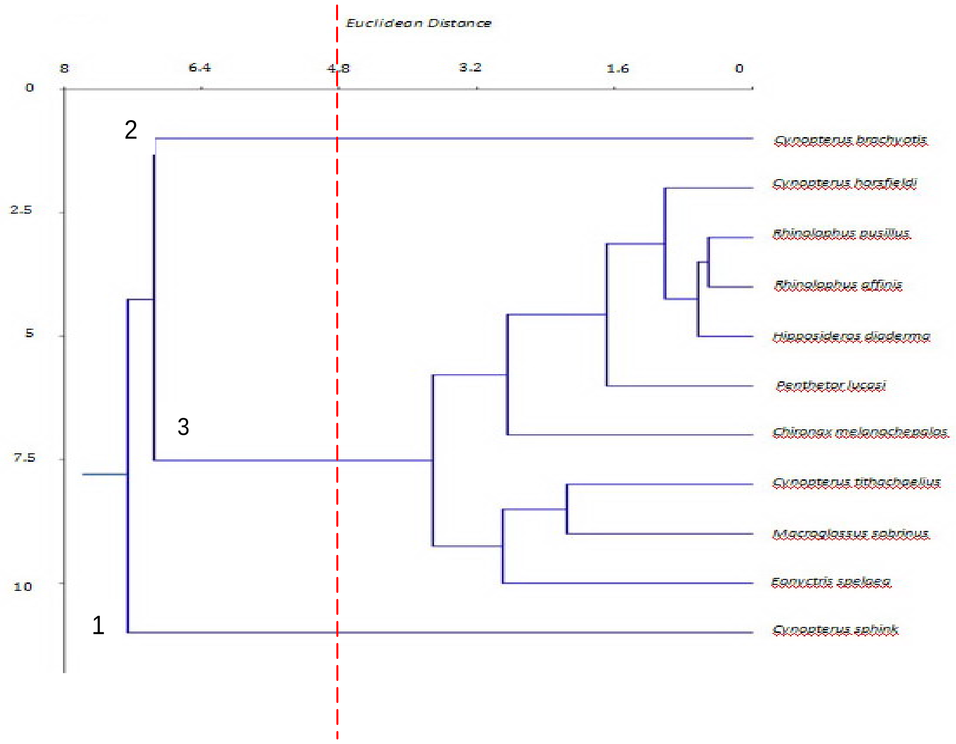


Figure 54. Dendogram of bat species dissimilarity in different habitats based on unweighted pair group method with arithmetic mean clustering method and Euclidean distance
Note: The broken red line indicates level of inequality of 4.8

The bats clustered into Group 1 can be assumed to be dominant in all habitat types; bats in Group 2 have a tendency to be selective in choosing habitats; while Group 3 can be assumed to be species that are the most selective in choosing a habitat type. Many researchers have reported *Cynopterus* spp. was the most common species found in rubber plantations and disturbed forest (Danielsen et al. 1995; Maryanto et al. 2008; Nugroho and Sukandar 2008; Suyanto et al. 2009). Moreover, this bat species is an indicator of forest disturbance (Suyanto et al. 2009). *Cynopterus* spp. and other fruit-eating bats play important roles as pollinators and seed dispersal agents, so that they help forest rehabilitation (Marshall 1983; Howe 1984; Whittaker and Jones 1994). These animals are indicators of forest quality.

6.3.5 Dissimilarity of types of bat habitat analysed using Euclidean distance method

The types of bat habitat were analysed based on the bat species' composition in each habitat using the unweighted pair group method with arithmetic mean and the Euclidean distance. The results are shown as a dendogram in Figure 55, which indicates that the pattern of habitat formation based on bat species' habitats was at a dissimilarity level of 16%. This level divided the habitats of the study sites into the two regions of Aek Tarum and Dolok Merangir. This provides clear evidence that these two locations are composed of different bat species.

The two clusters of habitat types were: Group 1, which can be classified as the Aek Tarum region, consisting of young rubber plantation habitat (KM2), old rubber plantation (KT2), smallholder rubber (KR2), forest (H1) and forest (H2); and Group 2, which can be classified as the Dolok Merangir region, consisting of young rubber plantation habitat (KM1), old rubber garden (KT1) and smallholder rubber (KR1).

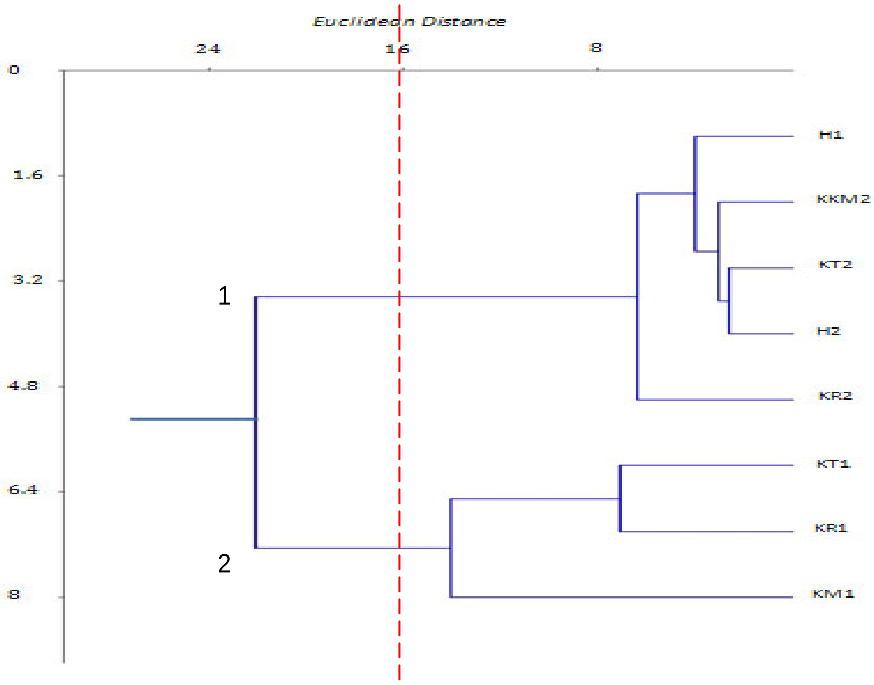


Figure 55. Dendogram of dissimilarity of habitat types based on bat species encountered at the study sites using unweighted pair group method with arithmetic mean) clustering method and Euclidean distance

Legend: KM = young rubber plantation; KT = old rubber plantation. The broken red line indicates level of inequality of 16

Based on the habitat types, Group 1 can be assumed to consist of bat species found at those study sites that were affected by forest (H1 and H2), whereas Group 2 can be assumed to consist of bat species found in this area that were not affected by forest. Group 1 consisted of 69% of the bat species and they were distributed evenly. On the other hand, Group 2 consisted of only 31% of the bat species because the composition of habitats in Group 1 was more varied compared with Group 2. Maryanto and Yani (2003) stated that the distribution of bat species and species' diversity is more varied in a broad landscape with various types of habitats.

The relationship between the results of the clustering analysis based on the type of bat habitat with the effect of changes in land use caused the grouping of the types of bats by different land use. The bat species composition in the two regions showed that land-use changes, such as from forest with natural vegetation and a complex composition to more intensive monocultural plantation, affected the composition of bat species. There are several types of bats that are usually found in the forest that are also found in rubber plantation areas.

Some bat species are commonly found in forest, such as *Chironax melanochepalos* and *Pentethor lucasi* (Maryanto and Yani, 2003). In this study, *P. lucasi* was also found in other habitats, such as rubber plantation and smallholder rubber areas. The smallholder rubber and rubber plantation areas at Aek Tarum (located near forest areas containing *bartong*) and at Aek Nauli forest, can be refuge areas for bats flying to and from their nearby natural habitat in forest areas. Natural vegetation in forests is responsible for supporting a substantial component of the bat population and its variety. Therefore, forest areas need to be conserved, especially where they are subjected to high pressure from various threats, such as deforestation, habitat loss owing to economic reasons, agricultural intensification, low local awareness and government policy.

Because bats are important for maintaining the stability of ecosystems, conservation of their habitat by reducing the conversion of land needs to be given special attention so that the balance of the ecosystem can be sustained. IUCN status of bats in study areas is shown in Table 24.

Table 24. IUCN status of bat species in the two study areas

Family	Common name	Species	IUCN status*
Pteropodidae	Short-nosed Fruit Bat	*Cynopterus brachyotis*	Lc
Pteropodidae	Greater Short-nosed Fruit Bat	*Cynopterus sphinx*	Lc
Pteropodidae	Horsfield's Fruit Bat	*Cynopterus horsfieldii*	Lc
Pteropodidae	Fruit Bat	*Cynopterus spp.*	Lc
Pteropodidae	Indonesian Short-nosed Fruit Bat	*Cynopterus titthaechelius*	Lc
Pteropodidae	Black-capped Fruit Bat	*Chironax melanocephalus*	Lc
Pteropodidae	Greater Long-tounged Nectar Bat	*Macroglossus sobrinus*	Lc
Pteropodidae	Cave Nectar Bat	*Eonycteris spelaea*	Lc
Pteropodidae		*Penthetor lucasi*	Lc
Rhinolophidae	Least Horseshoe Bat	*Rhinolophus pusillus*	Lc
Rhinolophidae	Intermediate Horseshoe Bat	*Rhinolophus affinis*	Lc
Hipposideridae	Diadem Roundleaf Bat	*Hipposideros diadema*	Lc

*Lc = least concern

6.4 Conclusions and recommendations

6.4.1 Conclusions

The following conclusions are based on the results.

1) There were 234 individual bats identified during the study consisting of three families and 11 species. The family Pteropodidae (Megachiroptera) dominated, with 73% of all individuals, while the remaining 27% came from the families Rhinolophidae and Hipposideridae (Microchiroptera).

2) The highest bat species' richness was found in H2 (forest at Aek Tarum), followed by the young rubber plantation at Aek Tarum (KM2) and the forest at Aek Nauli (H1).

3) The forest at Aek Tarum had the highest value of species' richness index (Margalef's index = 4.61). The highest bat diversity (Shannon-Wiener index) was

4) in the young rubber plantation at Aek Tarum (H' = 1.51), while the lowest index

5) value was the smallholder rubber habitat at Aek Tarum. The greatest dominance was in the old rubber plantation rubber at Aek Tarum, (D_2 = 1) and the lowest was in the young rubber plantation at Aek Tarum (D_2= 0.234).

6) Habitat type was divided into two groups: habitat that was affected by forest (Aek Tarum) and habitat not affected by forest (Dolok Merangir).

7) Distribution of the family of Pteropodiadae was more concentrated in smallholder rubber and forest hill areas up to an elevation of 1200 masl, but only for the species *Cynopterus horsfieldii* and *Chironax malanocephalus*. *Hipposideros diadema*, a bat species that occupies primary forests and rubber agroforests, was encountered at the study sites and could be an indication that rubber agroforests play a role as a corridor for bats to reach the forest. Species from the family Rhinolophidae were still found only in the forest.

6.4.2 Recommendations

The existence of old rubber plantations and forest buffers are expected to act as wildlife corridors in the migration pathway to and from the forest. While old rubber plantations can perform this function, the main obstacle is that company policy tends to be more profit-oriented and, thus, advocates the conversion of more forest into monocultural plantations. This needs to be predicated with due regard to environmental rules, so that a balance can still be maintained between the different ecosystems. Therefore, raising awareness and a common understanding on the value of biodiversity must be promoted as priorities among the related companies, local citizens and governments.

7. Synthesis and recommendations

Hesti L. Tata

The five study components in the area of Dolok Merangir and Aek Tarum used a comparison of smallholder rubber and forest ecosystems with the PT BSRE areas to consider biodiversity conservation and the consequences for sustainable management. The study was carried out recognising that many forest ecosystems are being depleted and biological diversity is under threat because many species and ecological functions of the forest ecosystem have no market value. When conservation competes with conversion, conversion wins because conversion has a market value, such as conversion to tree crop estates. There is increasing recognition worldwide that an ecosystem can have natural capital that supplies life-support services (Daily et al. 2009). Do rubber plantations have low diversity? Do rubber plantations contain distinct species in common with a forest? How can a rubber plantation have more biodiversity? This final chapter presents the conclusions and recommendations from the study on how to increase diversity in rubber plantations.

7.1 Value of biodiversity from the perception of the local people

The perceptions of local people on biodiversity and the value of land-use types gave an insight into their awareness with regard to biodiversity and their priorities. Local perceptions on biodiversity differ from the scientific, where biodiversity is simply related with its function. For local people, biodiversity was closely associated with livelihoods patterns and social life, as biodiversity contributed to their daily needs, and related to specific knowledge. Perceptions of different user groups (for example, farmers and hunters) varied. People recognised several animals and useful tree species across land uses. They used several tree species for food, fuel, sources of income, construction, medicinal purposes, fodder, handicrafts and other tools, and for erosion prevention. Land-use values referred to the use (and non-use categories) and the importance of the land in people's lives, which cannot be easily recognised using remote sensing imagery. Local people will maintain biodiversity as long as they benefit from the species in their local environment. Obviously, economic forces drive forest depletion and land-use change to more profitable land uses. Nevertheless, not all local knowledge supports biodiversity conservation; some activities and traditional beliefs are contradictory to conservation efforts, such as consuming bats as a food source and trapping birds for pets and trading.

7.2 From complex to simple species composition

Forest conversion in North Sumatra has been changing the landscape of the province for many years now. A complex composition of forest vegetation is not found in the plantation areas, which are dominated by rubber trees as the main commodity of the estate. The landscape of Dolok Merangir is relatively flat compared with Aek Tarum, which is undulating. The forest ecosystems in North Sumatra, particularly in both study areas, have been depleted owing to their transformation into more profitable land uses, such as estate crop plantations. The establishment of crop estates, such as rubber and oil palm, that have been in the landscape for hundreds of years now, has created a relatively stable landscape dominated by plantations of monocultures. From a total area of 139 354 ha, the area of agroforestry or mixed trees decreased from 27% in 1970 to 16% in 2010. Forest cover was only 2% of the total area in 2010. On the other hand, in Aek Tarum, with a total area of 79 944.5 ha, forest cover has decreased even more drastically from 75% in 1970 to 18% in 2010. Meanwhile, the area of plantations in Aek Tarum sharply increased from 19% to 72% over the same period. This is evidence of dynamic land-use change in North Sumatra.

The loss of forest cover has decreased significantly the species' richness of vegetation, birds and bats in the rubber smallholder and plantation areas. Forest (the third habitat type studied) had the most diverse range of tree species compared to the other two habitats. At the seedling stage, woody species, such as *Symplocos cochinchinensis* and *Hemigraphis reptans*, dominated the forest habitat. Meanwhile, rubber smallholder areas were dominated by herbs, such as *Urochola ramosa*, *Glifenia laevigata, Borreria alata* and grass. Although the local people considered the rubber plantations were valuable as grazing areas, where grass and fodder for cows and goats grew in abundance, our observations did not show that grass was dominant at the seedling stage in a rubber plantation because intensive management of weeding had been applied to the plantation areas.

In the tropics, the diversity of vegetation has a positive relationship with animal diversity, in particular that of bird and bat species. Forest vegetation supports animal life, in particular, birds and bats with regard to foraging and nesting sites. In the forest ecosystem, different animals occupy different niches, separated from each other in space, in time of activity or by the plants or animals utilised for food (Whitmore 1984). All feeding guild groups of birds were encountered in the forest ecosystems of Aek Nauli and Aek Tarum. Loss of forest vegetation in the monocultural rubber plantation and smallholder rubber areas decreased the number of bird and bat species. Bird diversity was strongly associated with the structural complexity of the plantation (Styring et al. 2011). Some bird species were very sensitive to habitat change, such as hornbills and woodpeckers, since they need big trees for nesting and have special guild feeding types. Monocultural rubber plantation would not be sufficient to support their existence. Some other bird families have wide ranges of adaptation, such as the Pycnonotidae (Bulbuls), Columbidae (Pigeons and Doves) and Sylvidae (Prinias and Warblers), which can be found in all habitat types. The wide-ranging generalist species appear well adapted to a broad range of successional environments, and many frugivores and nectarivores benefit from the increase in the number of plant fruits and flowers. It appears that the abundance of species in feeding guilds that use two or more groups of food tends to increase after forest disturbance (Meijaard et al. 2005).

Bats, like birds, are important pollinators of trees and valued crops and are significant fruit dispersal agents. Fruit bats such as *Cynopterus* spp., *Chironax melanocephalus, Eonycteris spelaea* and *Macroglossus sobrinus* were encountered at the two study sites. *C. sphinx* was found in all habitat types, while *Rhinolophus pussilus, R. affinis* (Microchiroptera) and *C. melanocephalus* were only encountered in forest habitat. This shows that *C. sphinx* is a generalist species, which can adapt to a wide range of habitats, while *Rhinolophus* spp. is a specialist species, which has low adaptability to a range of habitats.

Vertebrates such as birds and bats are vulnerable to environmental disruption. Vulnerability is conferred by life history traits that combine low fertility, prolonged maternal care and slow development; these are all adaptations for life in a stable, predictable habitat and where the population is maintained close to the carrying capacity of the environment (Purvis and Hector

2000). Vulnerability of species can be shown by their extinction status. We found 12 bird species listed by the IUCN that were classified with 'near threatened' status and two bird species with 'vulnerable' status, besides the two species listed in Appendix I of CITES and the 12 species listed in Appendix II of CITES. Meanwhile, all bat species that were observed at the study sites are listed with 'least concern' status by IUCN. Hence, there needs to be priority given to the conservation of animals that play important roles in the habitat with regard to pollination, seed dispersal and biological control. An ecoton is defined as a transition zone between two distinct landscape elements[7]. In the PT BSRE area, this matrix of landscapes can be found in emplacement areas, where some big trees were planted and have been maintained. These trees, including fig, pine, palm, banana, fruit trees (mango, rambutan and cocoa) and other hardwood species, provide suitable sites for nesting, resting and foraging for many animals, particularly birds and bats. There was also an increase in the number of birds that prefer edge or open areas such as minas, barbets, sparrows, bulbuls, pigeons, cuckoos, doves, prineas, white-eyes, woodpeckers and raptors.

7.3 Ecosystem services of biodiversity

Forest ecosystems provide goods and services that benefit humankind. While the demand for ecosystem services such as food, feed, fuels and clean water are increasing, human activities at the same time are diminishing the capability of many ecosystems to meet these demands. As mentioned in earlier chapters, forest loss and change to other land-use types has reduced the biodiversity of flora and fauna (in particular, birds and bats). The loss of specialist species and the abundance of generalist species in the rubber plantation are warning indicators of a disturbed ecosystem not in equilibrium.

The increased production of estate crops such as rubber latex to improve human well-being can be aligned with conservation efforts if the rubber plantations are managed sustainably. Most local people recognised the benefits of rubber plantations for the provision of fuelwood and income, as grazing areas and for erosion control. The level of awareness of local people regarding the indirect benefit of biodiversity, in particular, birds and bats, in maintaining the equilibrium of the ecosystem should be increased through extension and community development.

The number of leaders worldwide who now recognise that ecosystems are a source of natural capital that supplies life-support services is increasing (Daily et al. 2008). Understanding the economic value of biodiversity is important to improve the recognition of the importance of biodiversity. The economic value of biodiversity can be divided into the two categories of use and non-use economic values. Use values consist of direct and indirect values. Direct-use values include such things as eco-tourism, exploitation of genetic material for pharmaceuticals and crop breeding, the consumption of non-timber forest products such as nuts and rattan, and sustainable forestry, amongst others. Indirect-use values include carbon sequestration, flood control and nutrient cycling, amongst others (IUCN 1994). Hence, balancing development and conservation beyond reserve areas and beyond biodiversity is challenging.

UNEP (2011) states that a 'green' economy results in 'improved human well-being and social equity, while significantly reducing environmental risk and ecological scarcities'. The key aim for a

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[7] www.wikipedia.com

transition to a green economy is to eliminate the trade-offs between economic growth and investment, and environmental quality and social inclusiveness. Recognising the value of biodiversity outside natural ecosystems and protecting these ecosystems while improving productivity for development at the same time is a real action of green economy development. If mixed planting rubber with other trees was implemented in the plantation, the growth of the trees can be predicted using a model, such as the Spatially Explicit Individual-based Forest Simulator (SExI-FS) developed by the World Agroforestry Centre. The model has been used to predict the growth of rubber planted with *Shorea selanica* and *S. lamellata* (Dipterocarpaceae) in rubber agroforests in Jambi. The results showed that the spacing and time of planting of the *Shorea* spp. trees affected the growth of the rubber trees (Tata et al. 2009). However, the productivity of rubber latex cannot be predicted using this model.

7.4 Recommendations for improving biodiversity in rubber estate plantations

The monocultural plantation system aims to minimise competition for nutrients and light from non-crop trees to improve target crop productivity. On the other hand, monocultural systems have low biodiversity of plants and animals. Birds and bats play important roles as pollinators, seed dispersal agents and biological controllers of pests and predators. A solution to improve animal diversity in the rubber plantation is enrichment of the tree species planted. What species can be planted? Where should they be planted?

The trees to be planted should have a narrow canopy and a moderate-to-deep rooting system, to minimise competition for nutrients and light with the rubber trees. Several tree species can be planted that provide food for birds and bats but are not preferred by humans, such as *Ficus* sp., *Calliandra*, 'kapok' (*Ceiba pentandra*), canarium nut (*Canarium indicum*), *salam* (*Syzigium polyanthum*), *Inga* sp., *Sonneratia* sp. and *Palmae* sp. Bamboo can protect against soil erosion and also supports birds and bats by providing places for nesting.

Enrichment planting with food tree species can be carried out along riverbanks and other areas, in the gardens along asphalt roads and along the roads between main blocks and social facilities, such as in yards, schools, hospitals and settlements (for housing). Enrichment planting can also be implemented on steep slopes to prevent erosion and landslides.

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Biological diversity (biodiversity) is a description of the number, variety and variability of living organisms, which can be described in term of genes, species and ecosystems. As an ecosystem, tropical rainforest is characterized by high diversity and species richness. In Indonesia, owing to high deforestation, many forest areas, particularly in Sumatra, are declining rapidly. Large forest areas were lost due to interactions between the granting of logging concessions, overcapacity in the pulp and paper industry, increased accessibility to formerly remote areas, spontaneous and state-sponsored migration and profitable opportunities for tree-crop plantations, such as rubber and oil palm. In North Sumatra alone, rubber and oil palm were introduced during the colonial era in the early 1990s. Rubber plantation estates in Dolok Merangir have a long history with the first one being established in 1916 as the site of Goodyear's first rubber plantation. In 2005, the Dolok Merangir and Aek Tarum rubber plantations were sold to Bridgestone, a tire company based in Japan.