Working Paper

Tree diversity and carbon stock in three districts of Kutai Timur, Pasir and Berau, East Kalimantan

Subekti Rahayu and Sidiq Pambudi

World Agroforestry Centre

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Abstract

East Kalimantan is known as rich of natural resources, both renewable product of high value timber and non-renewable of mineral fuels and coal. Forest degradation occurred in the area due to timber extraction and followed by repeated forest fire. Nowadays, monoculture plantation and coal mining as particular threat for forest cover in East Kalimantan, even in the protected area for economic development reason. Environmental friendly land use planning is an important strategy to achieve sustainable development. Tree diversity and carbon stock as environmental indicator is part of component should be assessed as land use planning input. Amount of 71 plots of 20 x 100 m in 22 land use systems in Berau, Kutai Timur and Pasir were set up to observe tree diversity composition and carbon stock estimation. Higher tree species richness and diversity found in natural ecosystems such as undisturbed forest, logged-over forest, except mangrove that only few species owing to specific characteristic on the ecosystem where allowed limited species to grow. Monoculture systems commonly hold less tree species in the systems depend on the management. Low intensive management contains higher tree species richness and diversity. Natural ecosystems of undisturbed forest, logged-over forest and low intensive management of fruit-based agroforest consist of higher carbon stock than monoculture systems.

Keywords

East Kalimantan, carbon stock, sustainable development, tree diversity

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1. Introduction

East Kalimantan province is known as high potential of natural resources in Indonesia. Lowland tropical forest in East Kalimantan was also known as the richest tree species (Kartawinata et al 2008) and habitat of high value timber from Dipterocarp and ulin (Delmy 2001). Logging concession was the main factor removing most of forest cover in the area. Since the collapse of its timber industry in the 1990s, the provincial economy has been heavily dependent on the mining sector. Charcoal mining is another natural resources option in East Kalimatan. Mining industry not only operates in non forest area, but also in the forested land, even in protected forest. The dependency on nonrenewable resources has not produced sustainable growth, which East Kalimantan are experiencing the real impacts of deforestation.

Major forest fires of 1982/1983 and 1997/1998 in East Kalimantan was multiplier effect of forest degradation, deforestation and long drought period due to El Nino, then direct affect to tree stand and biodiversity loss. Furthermore, environmental services, such as carbon sequestration, hydrological regulation will also loss. Land uses change to settlement, infrastructures development, monoculture plantation established by private companies and smallholder widely spread due to political changes situation.

Land-based economic activities are major source of economic welfare in Indonesia (GE-LAMA-I 2016), and increase significantly after autonomy era. Conversely, natural land cover conversion, mostly forest, through land use, land-use change including burning peat land were the causes of around 60% of Indonesia greenhouse gas emission in 2000 (GE-LAMA-I 2016; Harris et al 2012). However, with the existing economic development targets, Indonesia has committed to reduce greenhouse gas emission by 26% unilaterally or by 41% with international support from business as usual levels by 2020.

East Kalimantan Provincial Government has declared a plan to transform its economy into a green economy through reducing emissions while achieving economic development target. It aims to raise the share of renewable energy, create more value in the region through green industrial zones, and increase the contribution of innovative low-emission economic activities. Expected outcomes are greater prosperity for its people and the conservation of its nature. Landscape management planning is a concern for balancing social-economic needs with environmental sustainability. Therefore, an assessment of socio-economic and environment characteristics is needed for planning.

Green Economy and Locally-Appropriate Mitigation Actions in Indonesia (GE-LAMA-I) is an initiative for building local government capacities in low emission development planning and developing locally and/or nationally appropriate mitigation actions. Related to low emission development planning, baseline data of current and the past land cover condition, carbon stock in various land use systems and tree biodiversity as environment indicators are part of the input of planning development. The aims of the assessment: (1) to inventory tree diversity across land use system and (b) to estimate the carbon stock in various tree-based systems.

2. Methods

2.1 Study Site

The assessment was covered in three districts of Kutai Timur (June 2015), Pasir (November 2015) and Berau (August 2016), East Kalimantan (Figure 1). Amount of 71 plots were set up in 23 selected land use systems where available in those three districts (Figure 2), 28 plots in Kutai Timur, 26 plots in Pasir and 17 plots in Berau.

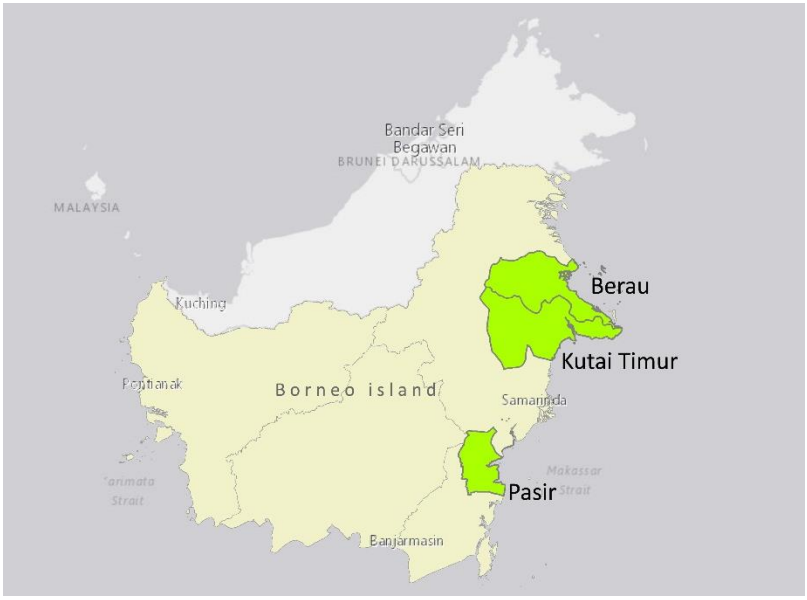
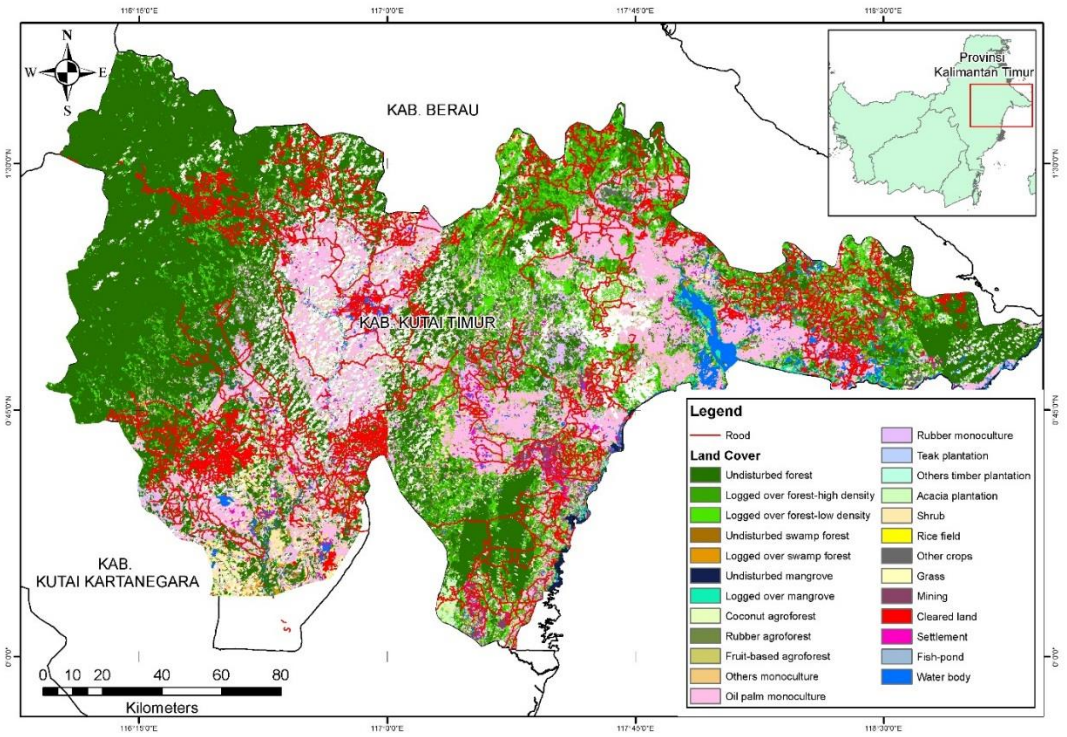


Figure 1. Study site (bright green area)



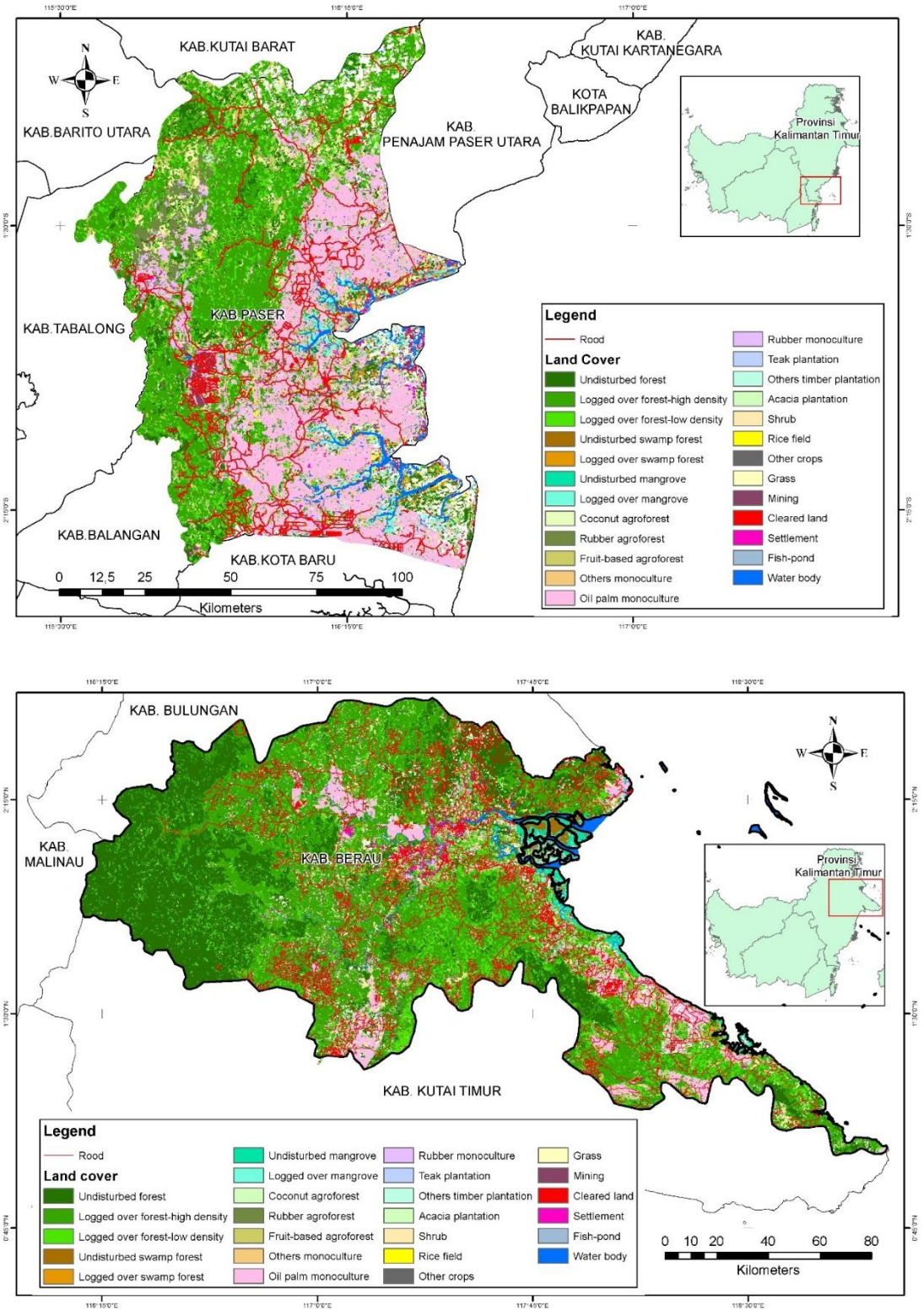


Figure 2. Land uses systems in three district of Kutai Timur (1), Pasir (2) and Berau (3)

2.2 Sampling Methods

Tree diversity sampling was done in the same plot of carbon stock. Modified plot size to 5 x 20 x 20 meters with nested of smaller plot (Figure 3) used to sampling tree diversity. Carbon stock estimation

use method as described in Hairiah et al (2011). The 2000 m^2 plot of 20 x 100 meters was placed in the targeted land cover (Figure 4).

2.2.1 Tree diversity

Four stages of vegetation growth, they are seedling (< 2 m height), sapling (> 2 m height, < 5 cm stem diameter), pole (5 – 10 cm diameter) and tree (> 10 cm diameter) included in the analysis. Sampling was done in nested plot of 2 m x 2 m for seedling, 5 m x 5 m for sampling, 10 m x 10 m for pole and 20 x 20 m for tree.

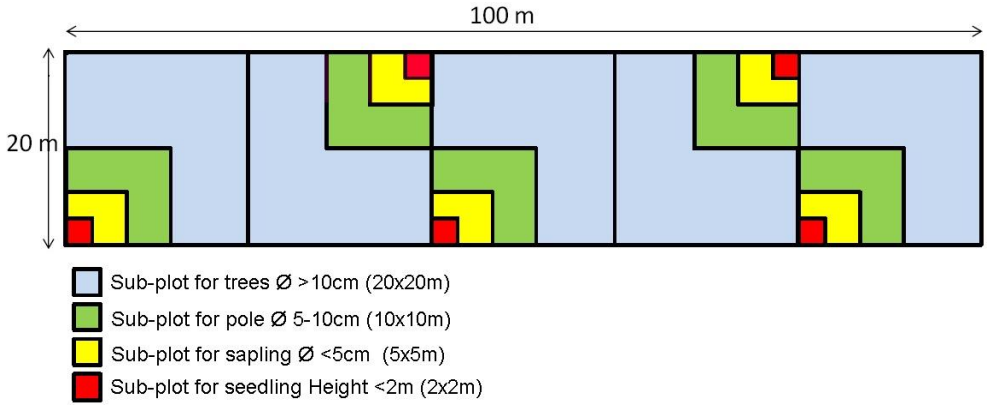


Figure 3. Plot design for tree diversity analysis

All seedling and sapling included in the plot samples were enumerated and each species was identified. All diameter stem of pole and tree in the plot samples were measured at breast height (1.3 meters above ground surface/DBH) and identified. Leaves specimens of all species were collected and identified in Herbarium Bogoriense.

2.2.2 Above-Carbon stock

Four carbon pools, they are: tree biomass, understorey, tree necromass and litter included in the assessment. Biomass estimation for large living and dead trees above 30 cm were measured in 20 x 100 m^2 plot, while the smaller living and dead trees 5-30 cm diameter were measured in 40 x 5 m^2 (Figure 4) through measuring DBH. Decomposition factor of dead tree were estimated based on visual performance.

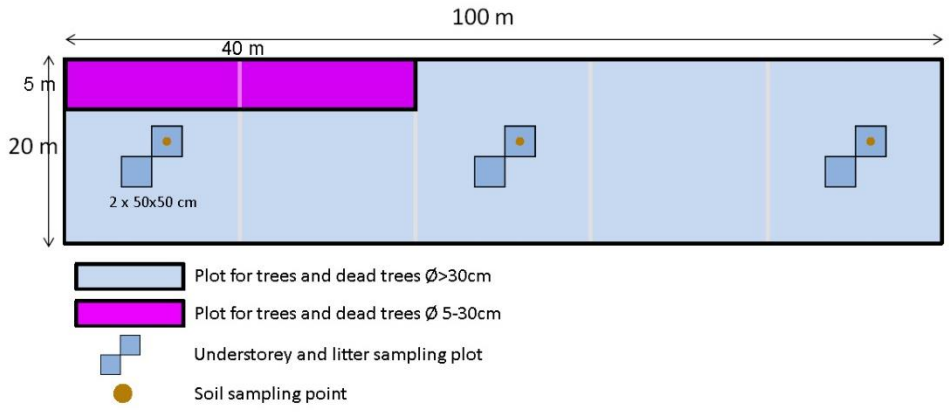


Figure 4. Plot design for carbon stock estimation analysis

Understorey and litter sampling were conducted in a set quadrant 2 x 0.5 x 0.5 m^2 where placed randomly inside 20 m x 100 m plot, minimum 3 replications in each plot. Fresh and dry weights of undertorey and litter samples were used in this analysis.

2.3 Data Analysis

2.3.1 Tree Diversity Analysis

Species richness, important value index (IVI), similarity index using Bray–Curtis dissimilarity and Shannon's diversity index used as tree diversity analysis. Species richness is number of different species represented in an ecological community, landscape or region (Colwell 2009). Important Value Index (IVI) expressed dominance species in the unit area that calculate based on relative frequency, relative density and relative dominance (Curtis & McIntosh 1950):

$$IVI = Relative\ Frequency + Relative\ Density + Relative\ Dominance$$

a. Relative frequency: $Frequency\ of\ species\ i = \frac{Number\ of\ quadrats\ species\ i}{Total\ number\ of\ quadrat\ sampled}$

$$Relative\ Frequency = \frac{Frequency\ of\ species\ i}{Total\ Frequency}$$

b. Relative density: $Density\ of\ species\ i = \frac{Number\ of\ species\ i}{Area\ of\ quadrat\ sampled}$

$$Relative\ Density = \frac{Density\ of\ species\ i}{Total\ density}$$

c. Relative dominance: $Dominance\ (Basal\ area\ of\ species\ i) = \frac{\pi * (Diameter\ of\ species\ i)^2}{4}$

$$Relative\ Dominance\ = \frac{Basal\ area\ of\ species\ i}{Total\ basal\ area}$$

The Bray–Curtis dissimilarity (B) is a statistic used to quantify the compositional dissimilarity between two different sites, based on counts at each site. Bray–Curtis dissimilarity were using the individual number as parameter in the calculation, so that both of species and individual parameters affecting the degree of similarity of two compared sites.

$$Bray\text{–}Curtis\ similarity\ (1 - B) = 1 - \frac{\sum_{i=1}^{S} |(n_{1i} - n_{2i})|}{\sum_{i=1}^{S} (n_{1i} + n_{2i})}$$

Where:

B = Bray–Curtis dissimilarity

S = total species number in land use 1 and land use 2

n_1 = number of individual species i in land use 1

n_2 = number of individual species i in land use 2

Shannon-Wiener diversity index (H') is one of popular index that use in ecological studies. It represents how species heterogeneity of a site that incorporates species richness and evenness. The value of Shannon-Wiener index varied between 0-3.5, rarely surpass 4.5.

$$H' = -\sum pi\ (ln\ pi)$$

Where, *pi = proportion of individual number of each species to total species i*

The value of H' represents species heterogeneity that classified into: low (H' <1.5), medium (1.5-3.5) and high (H'>3.5).

2.3.2 Carbon stock analysis

Aboveground tree biomass of general species was calculated using allometric equation developed by Chave et al (2005) for humid/moist topical forest stand with precipitation between 1500mm-4000mm/year:

$$Above - Ground\ Biomass_{est}(kg) = \rho * esp(-1.499 + 2.148\ ln(D) + 0.207(ln(D))^2 - 0.0281(ln(D))^3)$$

However, for specific species we use allometric equations developed by various researchers compiled in Hairiah et al. (2011) (Table 1).

Table 1. Allometric equations for biomass estimation of specific species

Tree species	Allometric Equation	Source
Coffee regularly pruned	(AGB)est = 0.281 $D^{2.06}$	Arifin 2001
Cacao	(AGB)est = 0.1208 $D^{1.98}$	Yuliasmara 2008
Oil palm	(AGB)est = 0.0976 H + 0.0706	ICRAF 2009
Palm	(AGB)est = exp{-2.134 + 2.530 x ln(D)}	Brown 1997
Palm	(AGB)est = 4.5 + 7.7 x H	Frangi and Lugo 1985
Bamboo	(AGB)est = 0.131 $D^{2.28}$	Priyadarsini 2000
Banana	(AGB)est = 0.030 $D^{2.13}$	Arifin 2001

Note: (AGB)est = estimation aboveground tree biomass, kg/tree; D = DBH, diameter at breast height, cm; H = tree height, m; ρ = Wood density, gcm^{-3} (available from: http://db.worldagroforestry.org/wd).

3 Results

3.1 Land use characteristics

Amount total of 71 plots from 22 land cover system had been surveyed across of the three districts in East Kalimantan (Table 2).

Table 2. Number of sampled plot in each land cover systems of Berau, Kutai Timur and Pasir District, East Kalimantan in 2015-2016

No	Land cover	District			Total
		Berau	Kutai Timur	Pasir	
1	Undisturbed mangrove	2	3	2	7
2	Disturbed mangrove	1		3	4
3	Undisturbed forest	2		2	4
4	Logged-over forest high density	3		1	4
5	Logged-over forest low density		2	1	3
6	Logged-over swamp forest			2	2
7	Fruit-based agroforest	11	4	2	17

No	Land cover	District			Total
		Berau	Kutai Timur	Pasir	
1	Undisturbed mangrove	2	3	2	7
8	Coconut monoculture		3		3
9	Coconut agroforest	1			1
10	Rubber monoculture		3	1	4
11	Rubber agroforest			1	1
12	Pepper monoculture				
13	Pepper agroforest	2	1		2
14	Cacao agroforest				
15	Citrus monoculture		4		4
16	Teak agroforest	1	1		2
17	Teak monoculture	1		1	2
18	Home garden			1	1
19	Sengon monoculture			1	1
20	Acacia monoculture			1	1
21	Gmelina plantation	3	2	1	1
22	Gaharu agroforest	1			1
	Total	**28**	**26**	**17**	**71**

3.1.1 Undisturbed mangrove

Three plots of undisturbed mangrove were set up in Sangkima Village, Sangatta Selatan, Kutai Timur district with coordinate location at 0.399848° and 117.561372°, 0.405800° and 117.557013°, and 0.404474° and 117.556688°. Plots were located in estuarine area with mud as dominant substrate. *Rhizophora* sp. is the most dominant species, while *Sonneratia* sp. also found. Tree > 10 cm is very common, a few sapling and pole and understorey species is absent.

Figure 5. Undisturbed mangrove in Kutai Timur

Two plots of undisturbed mangrove set up in Pondong Baru Village, Kuaro, Pasir District at -1.79848° and 116.22731°, -1.80072° and 116.22688°. *Rhizophora* sp. is the common species, while *Xylocarpus* sp. also found. Tree > 10 cm is very common, while seedling found in open canopy area. Land conversion to fish and shrimp pond is widely occurred by migrants people, mostly from Sulawesi. Undisturbed mangrove mostly found at coastline or river banks at about 100 meters wide, while in the middle area mostly had been cleared off, an access road has built to connect between the area and village.

Figure 6. Undisturbed mangrove in Pasir

Two plots of undisturbed mangrove set up in Teluk Sulaiman Village, Biduk-biduk, Berau District at 1.16056°, 118.75881° and 1.16152°, 118.76328°. Mangrove forest covering approximately 47.941 ha or about 3% of total land area of Berau District. Mangrove forest spread over the coastal area and small islands. Undisturbed mangrove is quite extensive both in Berau (Figure 7). At the coastline, mangrove species dominated by *Rhizophora* and *Sonneratia* species, depends on substrate type. There are many trees > 10 cm diameter as well as seedlings. *Rhizophora apiculata* dominated the muddy soil area, while *Sonneratia alba* and *Rhizophora apiculata* on the mixed of sand and mud soil.

Figure 7. Undisturbed mangrove in Berau

3.1.2 Disturbed mangrove

Three plots of disturbed mangrove located at Sangkima Village, Sangatta Selatan, Kutai Timur at 0.397062° and 117.563628°, 0.393145° and 117.564875°, 0.388656° and 117.564193°. Conversion to ponds, firewood or building materials is the common reason causes mangrove degradation, particularly where located near the settlement. Fewer large tree > 10 cm diameter available in disturbed mangrove. The most dominant species in disturbed mangrove of the area are *Cerios tagal* and *Lumnitzera littorea*.

Figure 8. Disturbed mangrove

A plot of disturbed mangrove was set up in sandy soil substrate of Teluk Sulaiman Village, Biduk-biduk, Berau at 1.20132° and 118.76485°. *Sonneratia alba* is dominant species. There is no seedlings, sapling and pole in the sampled plot although the mature tree are remain, however the tree stand has been old, with this condition the mangrove on the sampled plot is threatened due to no regeneration (Figure 9).

Figure 9. Disturbed mangrove in Berau

3.1.3 Undisturbed forest

Two plots of undisturbed forest set up in Muluy Hamlet, Long Sayo Village, Muara Komam, Pasir at -1.447469° and 115.920857°, -1.434324° and 115.974248° where located in Gunung Lumut protected forest. The topography of the area mostly at sloping ground with altitude around 200-400 m asl. Many trees > 30 cm diameter are available in the area (Figure 10).

Figure 10. Undisturbed forest in Gunung Lumut protected forest of Pasir

Two plots of undisturbed forest set up in Sungai Lesan Protected Forest (HLSL) at 1.61102°, 117.16323° and 1.61112°, 117.16665°. All of growth stage available in the forest, understory rarely found, but quite plenty of seedling and sapling (Figure 11).

Figure 11. Undisturbed forest of Sungai Lesan protected forest, Berau

HLSL is protected forest located at Kelay and covering four villages with total area 11,342.61 ha at elevation between 40 to 430 meters above sea level. Tree composition dominated by Dipterocarpaceae family.

3.1.4 Logged-over forest high density

A plot of logged-over forest high density surveyed at Petangis Village, Batu Engau, Pasir at -2.062294° and 116.095009° where located in the former coal mining. Currently the area is being established as recreational area and part of Taman Hutan Raya Lati Petangis. A block of remnant forest (Figure 12) found between Acacia plantation for reclaim degraded land after mining activities.

Figure 12. Logged-over forest high density

Three plots of logged-over forest were set up in Berau, two plots in Hutan Lindung Sungai Lesan at 1.65344°, 117.08634° and 1.65240°, 117.08749° and one plot in Hutan Lindung Dumaring at 1.39003° and 118.09079°. Visually, species composition in logged-over forest of Sungai Lesan is similar to undisturbed forest, but lower density of large trees. Logging activity and decaying old tree creating the gap and causes amount of seedling and sapling regenerated in. Logging activity at HLSL was occurred in the past, but forest recovery is in good progress. Land conversion is the main threat of Hutan Lindung Dumaring forest, particularly in the border area of protected forest. Canopy closure in the area is medium, while the understory is composed by seedlings, saplings and shrub species (Figure 13).

Figure 13. Logged-over forest high density in Hutan Lindung Sungai Lesan (left) and Hutan Lindung Dumaring (right), Berau

3.1.5 Logged-over forest low density

Two plots of logged-over forest low density set up in Miau Baru village, Kutai Timur at 0.397062° and 117.563628°, 0.393145° and 117.564875°. Cleared land was done by Dayak Kayan since 1978 to grow crop, mostly rice using slash and burn method. Secondary forest from medium to large tree diameter and shrub available in the area, depend on fallow period left by land manager. Pioneer species such as *Vitex pubescens* commonly grow in recently burnt land (Figure 14).

Figure 14. Logged-over forest low density in Kutai Timur

A plot of logged-over forest low density set up in Jone Village, Tanah Grogot, Pasir at -1.878129° and116.203313°. Abandoned land as shrub very common in Tanah Grogot (Figure 14).

Figure 15. Logged-over forest low density in Pasir.

3.1.6 Logged-over swamp forest

Two plots of logged-over swamp forest were set up in Jone Village at -1.90005° and 116.25122° and Rantau Panjang Village, Tanah Grogot, Pasir. Mixed tree species with shrubs and lianas commonly found, but gelam (*Melaleuca* sp.) found in Rantau Panjang (Figure 16). Local people collect its wood

and bark for building materials. Swamp forest in both of Jone and Rantau Panjang are inundated during rainy season.

Figure 16. Heterogenous logged-over swamp forest in Jone (left), homogenous logged-over swamp forest in Rantau Panjang (right), Pasir

3.1.7 Fruit-based agroforestri

Two plots were set up in Miau Baru village, Kongbeng, Kutai Timur at 1.192935° and 116.940951°, 1.193625° and 116.941848° and two plots in Sangatta, Kutai Timur at 0.487950° and 117.489270°, 0.467312° and 117.481275°. A fruit-based agroforestry system integrated with livestock herding area is found in Miau Baru Village, particularly along the river. *Lansium domesticum* as main fruit trees mixed with other wild fruit trees of *Artocarpus* sp. and *Syzigium* sp. without management systems. The fruit-based agroforest where close to the settlement consist of mango, cacao, coconut, rambutan and durian used for daily utilization (Figure 17).

Figure 17. Fruit-based agroforestry in Miau Baru (left), and rambutan plantation in Sangatta (right)

An intensive of 15 years durian plantation established by private sector found in Mulyo Sari hamlet, Padang Pangrapat Village, Tanah Grogot, Pasir at -1.84802° and 116.24375°. The durian trees were planted in 10 m distance and pruned (Figure 18). Another type of fruit based agroforest plot was set up in Kasungai Village, Batu Sopang, Pasir at -1.803542° and 115.916174°. A various type of fruit trees planted within the area consists of rambutan, coconut, jackfruit, durian, *Lansium domesticum* etc. Low management implemented characterized with flourish of understorey (Figure 18). Rubber is very common in this area while fruit-based agroforest is rarely found in large area. People tend to plant fruit trees around the settlement for daily consumption.

Figure 18. Durian plantation (left), fruit-based agroforest (right) in Pasir

Figure 19. Various types of fruit-base agroforestry in Berau

In Berau, several types of mix garden are established based on environment and sosio-economic factor (Figure 19). Fruit-based agroforest found in Lesan Dayak Village, Kelay. Langsat (*Lansium domesticum*) and *Caryota* are dominant species with coffee and other species intercropped in. Fruit-based agroforest in Gunung Tabur, where cultivated by migrant people from Java and South Sulawesi used rambutan as main commodity such as in Birang village. In Teluk Bayur Dayak tribe and migrant people from Melayu, Java and South Sulawesi cultivate cacao inside the systems. In Talisayan home garden of local people, consists of areca nut, candle nut, durian and *langsat.*

3.1.8 Coconut monoculture

Three plots of coconut monoculture set up in Sangkima Village, Sangatta Selatan, Kutai Timur at 0.397479° and 117.564020°, 0.392691° and 117.565629°, 0.394349° and 117.565425°. Migrant people from South Sulawesi live in the area and plant coconut in 8 x 10 m distance around the home yard for additional income since they settle at the location since about 40 years ago (Figure 20).

Figure 20. Coconut monoculture in Sangatta, Kutai Timur

3.1.9 Coconut agroforest

Coconut plantation, both monoculture and agroforest, mostly concentrated on coastal region. Monoculture system established at near shore while agroforest system sometimes established at higher elevation in mixed garden as intercrop. A plot of coconut agroforest was set up in Teluk Sulaiman village, Biduk-Biduk, Berau at 1.18885° and 118.76799°. The plantation has been established since 1970, some coconut stand has been replaced by new trees in 10 x 10 meters spacing. Some fruit trees found among the coconut stand, such as mango, star fruit and jackfruit (Figure 21).

Figure 21. Coconut agroforest in Berau

3.1.10 Rubber monoculture

Three plots of rubber monoculture were set up in Miau Baru Village, Kongbeng, Kutai Timur at 1.294320° and 117.070321°, 1.208958° and 116.966148°, 1.194603° and 116.945928° that covered of different plantation age: 3-4 years, over 10 years and old rubber monoculture. Young rubber monoculture planted in 5 meters distance, semi intensive management is implemented in the system. Middle aged rubber monoculture applied 6 or 7 meters distance. The canopy cover is not tight so the farmer plant pineapple as intercropping. At old rubber monoculture cacao planted as intercrop, some understorey seedling has presence, another pioneer species also found such as *Macaranga triloba* (Figure 20).

Figure 22. Rubber monoculture in Kutai Timur, Young rubber 3 - 4 years (left), > 10 years (center), old rubber (right).

A plot of 8 years orubber monoculture was set up in Mulyo Sari, Padang Pangrapat, Tanah Grogot, Pasir at 1.84802° and 116.24375° (Figure 23).

Figure 23. Rubber monoculture in Pasir

3.1.11 Rubber agroforest

A plot of old rubber agroforest established in 1985 was set up in Pasir Belengkong Village, Pasir Belengkong, Pasir at -2.001627° and 116.210386°. Semi intensive management implemented characterized by flourish of understorey and many tree seedlings, the canopy cover is medium to high. The trees are planted in random pattern. Mostly tree seedling or sapling are cut off, only fruit trees that can be utilized or which can be sold are allowed to grow, such as jack fruit and lai (*Durio kutejensis*) (Figure 24).

Figure 24. Rubber agroforest in Pasir

3.1.12 Pepper monoculture

A plot of pepper monoculture set up in Miau Baru Village, Kongbeng, Kutai Timur at 1.293984° and 117.071173°. Paper planted at 2 m distance with wood block of ulin and *Gliciridia sepium* as shading trees (Figure 25).

Figure 25. Pepper monoculture in Kutai Timur

3.1.13 Pepper agroforest

Basically, there are two types of pepper systems in East Kalimantan, they are: 1) pepper with *Gliricidia sepium* as stake, and 2) pepper with ulin wood block (*Eusideroxylon zwageri*) as stake at 1.5 x 1.5 meters or 2 x 2 meters spacing. Farmer plant pepper with monoculture system or mixed with another species, mostly with *Gliricidia sepium*, *Leucaena leucocephala* or *Moringa oleifera* as shading trees for young pepper. Pruning for shading tree implemented depends on climate, usually conducted at rainy season where sunlight penetration is less. Weed management using herbicide to control weed population and fertilize regularly done. A plot of pepper agroforest set up in Birang Village, Gunung Tabur at 2.20956° and 117.46076° and a plot in Dumaring Village, Talisayan, Berau at 1.57425° and 118.20133° (Figure 26).

Figure 26. Pepper plantation (left: wood stake; right: *Gmelina* stake) in Berau

3.1.14 Cacao agroforest

Three plots of cacao agroforest set up in Miau Baru Village, Kongbeng, Kutai Timur at 1.208735° and 116.954033°, 1.190844° and 116.940618°, 1.191328° and 116.941833°. Cacao was planted at 3 m distance and was pruned at about 1 to 2 meters height. Some fruit trees such as *Nephelium lappaceum, Durio zibethinus, Mangifera indica, Artocarpus champeden* or *Dimocarpus longan* and wild species such as *Piper aduncum* and *Vitex pubescens* found in the system (Figure 27).

Figure 27. Cacao agroforest in Kutai Timur

3.1.15 Citrus monoculture

A plot of citrus monoculture set up in Miau Baru Village, Kongbeng, Kutai Timur at 1.191179° and 116.940165°. Citrus planted at about 4 meters distance (Figure 28).

Figure 28. Citrus monoculture in Kutai Timur

3.1.16 Teak agroforest

A plot of teak agroforest was set up in Miau Baru Village, Kongbeng, Kutai Timur at 1.193214° and 116.941215° (Figure 29).

Figure 29. Teak agroforest in Kutai Timur

A plot of teak agroforest were sampled in Birang Village, Gunung Tabur, Berau at 2.20875° and 117.46035°. Semi intensive management were implemented with weeding activity and using herbicides. Teak was planted in 5 x 5 meters distance. Coffee and cacao were interspersed between teak (Figure 30).

Figure 30. Teak agroforest in Berau

3.1.17 Teak monoculture

A plot of teak monoculture was set up in Kerang Dayo Village, Batu Engau, Pasir at -2.304956° and 116.03844° (Figure 31).

Figure 31. Teak monoculture in Pasir

A plot of teak monoculture was set up in Birang Village, Gunung Tabur, Berau at 2.20717° and 117.47246°. The plantation established by migrant from South Sulawesi in 3 x 3 m distance (Figure 32). Seeds were obtained from government program. Semi-intensive land management was implemented by weeding and fertilizing.

Figure 32. Teak monoculture in Berau

3.1.18 Home garden

A plot of home garden was set up Pasir Jaya Hamlet, Padang Pangrapat Village, Tanah Grogot, Pasir in at -1.84271° and 116.23861°. The home garden found in almost home yard among the village, mostly planted with coconut trees, other fruit trees or cassava (Figure 33).

Figure 33. Home garden in Pasir

3.1.19 Sengon monoculture

A plot of sengon monoculture was set up in Petangis Village, Batu Engau, Pasir at - 2.077236° and 116.099164°. Sengon (*Paraserianthes falcataria*) is part of reclamation activity after coal mining operation (Figure 34).

Figure 34. Sengon monoculture in Pasir

A plot of sengon plantation set up in Campursari village, Batu Putih, Berau at 1.48967° and 118.27122° (Figure 35).

Figure 35. Sengon monoculture in Berau

3.1.20 Acacia monoculture

A plot of acacia monoculture was set up in Petangis Village, Batu Engau, Pasir at -2.071441° and 116.099323°. Similar to sengon monoculture in Petangis, *Acacia auriculiformis* is also part of reclamation activity after coal mining.

3.1.21 Gmelina plantation

Two plots of gmelina plantion set up at km 14 Sangatta Selatan, Kutai Timur at 0.437751° and 117.476844° (Figure 33).

Figure 36. Gmelina plantation in Kutai Timur

A plot of gmelina plantation was set up in Swan Slutung Village, Muara Komam, Pasir at -1.419038° and 115.884606°. Gmelina planted at 2003 in 2.5 distances (Figure 37).

Figure 37. Gmelina plantation in Pasir

A plot of abandoned *Gmelina* plantation set up in Biatan, Berau at 1.61700° and 118.14799°. Gmelina planted in 5 x 5 meters distance. Another plot of *Gmelina* plantation was set up in PT. Sumalindo Alam Lestari which is established in 1985 at 1.42594° and 118.33547° (Figure 38).

Figure 38. Gmelina plantation in Biatan (left) and in PT Sumalindo Alam Lestari (right), Berau

3.1.22 Gaharu agroforest

A plots of gaharu agroforest was set up in Muara Lesan Village, Kelay, Berau at 1.71591° and 117.17607°. Gaharu, *Aquilaria microcarpa* and *Gyrinops* sp from wild seedlings domesticated in the mixed system with rubber (Figure 39).

Figure 39. Gaharu agroforest in Berau

3.2 Tree Species Composition

3.2.1 Species Richness

Generally, tree species richness in three districts of Kutai Timur, Pasir and Berau have different characteristic depend on the management applied in the systems (Table 3). Natural regeneration with limited management such as undisturbed forest and logged-over forest hold high species richness for all growth stages. Logged-over forest high density in Berau and undisturbed forest in Pasir has highest species richness, 116 species in 3 plots and 107 species in 2 plots, respectively. However, disturbed and undisturbed mangrove in Berau tends to be occupied by certain species.

Low intensive management of fruit-based agroforest provides habitat for tree species, both cultivated economically and wild of naturally regeneration. Species richness of fruit-based agroforestry in Kutai Timur is higher than logged-over forest low density, in Pasir is similar, but in Berau even higher than undisturbed forest.

Species richness in agroforestry systems such as cacao, teak and rubber tend to lower species richness than the low management of fruit-based agroforest, but higher than the monoculture systems. Interestingly, gmelina plantation in three district samples of East Kalimantan consists of 15 – 24 species richness for all growth stages.

Table 3.Tree species richness in various land use types of Kutai Timur, Pasir and Berau District, East Kalimantan

	Land cover	No. of plot	Number of species				
			Seedling	Sapling	Pole	Tree	All growth stages
Kutai Timur	Logged-over forest low density	2	10	16	18	21	37
	Undisturbed mangrove	3	2	3	1	3	3
	Disturbed mangrove	3	8	9	6	9	12
	Fruit-based agroforest	4	29	20	12	61	85
	Teak agroforest	1	8	4	0	13	20
	Rubber agroforest	1	7	3	1	2	8
	Rubber monoculture	2	2	2	1	1	3
	Coconut monoculture	3	3	2	3	3	5
	Cacao agroforest	3	8	3	4	19	22
	Citrus monoculture	1	3	3	3	4	8
	Pepper agroforest	1	0	0	0	2	2
	Gmelina plantation	2	9	5	3	8	15
Pasir	Undisturbed forest	2	31	23	24	69	107
	Logged-over forest high density	1	8	12	9	46	60
	Logged-over forest low density	1	6	4	9	19	27
	Logged-over swamp forest	2	7	7	12	23	36
	Fruit-based agroforest	2	11	3	4	13	25
	Undisturbed mangrove	2	4	2	4	2	4
	Home garden	1	0	1	3	13	14
	Rubber agroforest	1	16	3	3	6	21
	Rubber monoculture	1	3	2	1	1	3
	Teak monoculture	1	2	0	1	1	2
	Acacia monoculture	1	0	0	1	2	2
	Sengon monoculture	1	7	4	2	2	11
	Gmelina plantation	1	5	7	8	9	15
Berau	Undisturbed forest	2	14	22	22	41	57
	Logged-over forest high density	3	36	26	23	82	116
	Undisturbed mangrove	2	2	2	1	2	2
	Disturbed mangrove	1	1	0	1	1	1
	Fruit-based agroforest	11	23	12	14	37	56
	Gaharu agroforest	1	2	0	3	5	7
	Coconut agroforest	1	2	0	0	5	7
	Pepper agroforest	2	6	3	6	2	10
	Teak agroforest	1	4	2	2	2	7
	Teak monoculture	1	3	0	1	1	3
	Gmelina plantation	3	12	9	7	5	24

3.2.2 Dominance Species

Important Value Index (IVI) used to express dominance species in the sampled plot which is represented species composition in the land use system. High IVI species indicate dominant species (Table 4).

Table 4. Three highest IVI species of all growth stages in various land cover systems in Kutai Timur, Pasir and Berau District, East Kalimantan

Land cover	Seedling	Sapling	Pole	Tree
KUTAI TIMUR				
Logged-over forest low density	*Millettia sericea* *Tetracera scandens* *Endospermum diadenum*	*Millettia sericea* *Vitex pubescens* *Endospermum diadenum*	*Vitex pubescens* *Macaranga triloba* *Endospermum diadenum*	*Vitex pubescens* *Endospermum diadenum* *Macaranga triloba*
Undisturbed mangrove	*Rhizophora apiculata* *Rhizophora mucronata* -	*Rhizophora apiculata* *Rhizophora mucronata* *Rhizophora stylosa*	*Rhizophora apiculata* - -	*Rhizophora apiculata* *Rhizophora stylosa* *Rhizophora mucronata*
Disturbed mangrove	*Ceriops tagal* *Lumnitzera littorea* *Rhizophora apiculata*	*Ceriops tagal* *Rhizophora apiculata* *Bruguiera gymnorrhiza*	*Ceriops tagal* *Thespesia populnea* *Lumnitzera littorea*	*Lumnitzera littorea* *Ceriops tagal* *Thespesia populnea*
Fruit-based agroforest	*Millettia sericea* *Vitex pubescens* *Endospermum diadenum*	*Sarcotheca diversifolia* *Endospermum diadenum* *Vitex pubescens*	*Theobroma cacao* *Mangifera indica* *Endospermum diadenum*	*Nephelium lappaceum* *Mangifera indica* *Artocarpus champeden*
Teak agroforest	*Ficus septica* *Hibiscus tiliaceus* *Nephelium lappaceum*	*Cratoxylum formosum* *Hibiscus tiliaceus* *Tectona grandis*	- - -	*Tectona grandis* *Albizia chinensis* *Hibiscus tiliaceus*
Rubber agroforest	*Fagraea racemosa* *Macaranga triloba* *Macaranga tanarius*	*Ardisia sanguinolenta* *Leucaena leucocephala* *Macaranga tanarius*	*Hevea brasiliensis* - -	*Hevea brasiliensis* *Leucaena leucocephala* -
Rubber monoculture	*Fagraea racemosa* *Hevea brasiliensis*	*Hevea brasiliensis* *Alstonia scholaris*	*Hevea brasiliensis* -	*Hevea brasiliensis* --
Coconut monoculture	*Leucaena leucocephala* *Homalanthus populneus* *Cocos nucifera*	*Cocos nucifera* *Leucaena leucocephala* -	*Leucaena leucocephala* *Acacia auriculiformis* *Artocarpus heterophyllus*	*Cocos nucifera* *Leucaena leucocephala* *Artocarpus heterophyllus*
Cacao monoculture	*Anacardium occidentale* *Hevea brasiliensis* *Theobroma cacao*	*Theobroma cacao* *Durio zibethinus* *Homalanthus populneus*	*Theobroma cacao* *Artocarpus champeden* *Piper aduncum*	*Theobroma cacao* *Durio zibethinus* *Leucaena leucocephala*
Citrus monoculture	*Homalanthus populneus* *Gliricidia sepium* *Citrus aurantifolia*	*Citrus aurantifolia* *Gliricidia sepium* *Lansium domesticum*	*Citrus aurantifolia* *Theobroma cacao* *Artocarpus champeden*	*Citrus aurantifolia* *Artocarpus elasticus* *Durio zibethinus*
Pepper agroforest	- -	- -	- -	*Gliricidia sepium* *Nephelium lappaceum*-
Gmelina plantation	*Hibiscus tiliaceus* *Vitex pubescens* *Hevea brasiliensis*	*Hevea brasiliensis* *Vitex pubescens* *Dillenia indica*	*Gmelina arborea* *Hevea brasiliensis* *Mallotus macrostachyus*	*Gmelina arborea* *Artocarpus heterophyllus* *Vitex pubescens*
PASIR				
Undisturbed forest	*Shorea acuminata* *Shorea platyclados* *Fabaceae sp.1*	*Shorea acuminata* *Heritiera javanica* *Polyalthia glauca*	*Sageraea elliptica* *Polyalthia glauca* *Baccaurea stipulata*	*Heritiera javanica* *Dipterocarpus sp.* *Shorea acuminata*
Logged-over forest high density	*Rhodamnia cinerea* *Buchanania arborescens* *Tetracera fagifolia*	*Rhodamnia cinerea* *Aporosa symplocoides* *Glochidion rubrum*	*Memecylon oligoneurum* *Archidendron ellipticum* *Beilschmiedia sp. 1*	*Aporosa lucida* *Artocarpus elasticus* *Cratoxylum sp.*
Logged-over forest low	*Schima wallichii*	*Syzygium claviflorum*	*Schima wallichii*	*Artocarpus integer*

Land cover	Seedling	Sapling	Pole	Tree
density	*Xanthophyllum sp.* *Syzygium claviflorum*	*Barringtonia lanceolata* *Macaranga triloba*	*Rhodamnia cinerea* *Syzygium acuminatissimum*	*Parartocarpus sp.1* *Xanthophyllum sp.*
Logged-over swamp forest	*Macaranga triloba* *Homalanthus giganteus* *Elaeocarpus stipularis*	*Peronema canescens* *Alstonia spatulata* *Melaleuca leucadendra*	*Melaleuca leucadendra* *Peronema canescens* *Vitex pinnata*	*Melaleuca leucadendra* *Vitex pinnata* *Gardenia tubifera*
Fruit-based agroforest	*Nephelium lappaceum* *Melastoma malabathricum* *Micromelum pubescens*	*Vitex pinnata* *Dolichandrone spathacea* *Macaranga hypoleuca*	*Mangifera indica* *Syzygium aqueum* *Dolichandrone spathacea*	*Durio zibethinus* *Nephelium lappaceum* *Lansium domesticum*
Undisturbed mangrove	*Rhizophora apiculata* *Ceriops tagal* *Bruguiera parviflora*	*Rhizophora apiculata* *Bruguiera parviflora* -	*Rhizophora apiculata* *Bruguiera parviflora* *Ceriops tagal*	*Rhizophora apiculata* *Bruguiera parviflora* -
Home garden	- - -	*Aquilaria malaccensis* - -	*Cinnamomum porrectum* *Nephelium lappaceum* *Syzygium aqueum*	*Cocos nucifera* *Nephelium lappaceum* *Parkia speciosa*
Rubber agroforest	*Hevea brasiliensis* *Psychotria viridiflora* *Artocarpus integer*	*Hevea brasiliensis* *Nephelium lappaceum* *Rhodamnia cinerea*	*Hevea brasiliensis* *Artocarpus integer* *Artocarpus rigidus*	*Hevea brasiliensis* *Artocarpus integer* *Ixonanthes petiolaris*
Rubber monoculture	*Hevea brasiliensis* *Elaeocarpus stipularis* *Ilex sp.1*	*Hevea brasiliensis* *Elaeocarpus stipularis* -	*Hevea brasiliensis* - -	*Hevea brasiliensis* - -
Teak monoculture	*Tectona grandis* *Palaquium sp.1-*	- -	*Tectona grandis* -	*Tectona grandis* -
Acacia monoculture	- -	- -	*Acacia auriculiformis* -	*Acacia auriculiformis* *Vitex pinnata-*
Sengon monoculture	*Vitex pinnata* *Clausena excavata* *Aporosa lucida*	*Artocarpus dadah* *Clausena excavata* *Rhodamnia cinerea*	*Albizia chinensis* *Artocarpus dadah* -	*Albizia chinensis* *Acacia auriculiformis* -
Gmelina plantation	*Macaranga sp.* *Gmelina arborea* *Mallotus paniculatus*	*Mallotus paniculatus* *Macaranga sp.* *Macaranga gigantea*	*Peronema canescens* *Buchanania sessilifolia* *Macaranga sp.*	*Gmelina arborea* *Peronema canescens* *Dyera costulata*
BERAU				
Undisturbed forest	*Coccoceras borneense* *Koilodepas brevipes* *Shorea sp. 4*	*Koilodepas brevipes* *Polyalthia lateriflora* *Antidesma coriaceum*	*Polyalthia lateriflora* *Nephelium uncinatum* *Baccaurea sumatrana*	*Polyalthia lateriflora* *Elateriospermum tapos* *Harpullia arborea*
Logged-over forest high density	*Pentace adenophora* *Polyalthia lateriflora* *Eusideroxylon zwageri*	*Polyalthia lateriflora* *Macaranga hypoleuca* *Pentace adenophora*	*Baccaurea stipulata* *Polyalthia lateriflora* *Microcos crassifolia*	*Eusideroxylon zwageri* *Shorea cf. leprosula* *Baccaurea stipulata*
Undisturbed mangrove	*Rhizophora apiculata* *Sonneratia alba* -	*Rhizophora apiculata* *Sonneratia alba* -	*Rhizophora apiculata* - -	*Rhizophora apiculata* *Sonneratia alba*
Disturbed mangrove	*Sonneratia alba*	-	*Sonneratia alba*	*Sonneratia alba*
Fruit-based agroforest	*Coffea canephora* *Theobroma cacao* *Nephelium lappaceum*	*Theobroma cacao* *Coffea canephora* *Hevea brasiliensis*	*Theobroma cacao* *Hevea brasiliensis* *Nephelium lappaceum*	*Theobroma cacao* *Lansium domesticum* *Nephelium lappaceum*
Gaharu	*Gliricidia sepium*	-	*Gyrinops sp.*	*Aquilaria microcarpa*

Land cover	Seedling	Sapling	Pole	Tree
agroforest	*Mallotus sp. 2*	-	*Hevea brasiliensis*	*Hevea brasiliensis*
	-	-	*Aquilaria microcarpa*	*Gyrinops sp.*
Coconut agroforest	*Homalanthus populneus*	-	-	*Cocos nucifera*
	Annona muricata	-	-	*Mangifera indica*
	-	-	-	*Averrhoa bilimbi*
Pepper agroforest	*Leucaena leucocephala*	*Gliricidia sepium*	*Gliricidia sepium*	*Gliricidia sepium*
	Vitex pinnata	*Leucaena leucocephala*	*Leucaena leucocephala*	*Leucaena leucocephala*
	-	*Moringa oleifera*	*Moringa oleifera*	-
Teak agroforest	*Coffea canephora*	*Coffea canephora*	*Nephelium lappaceum*	*Tectona grandis*
	Macaranga triloba	*Macaranga hypoleuca*	*Psidium guajava*	*Nephelium lappaceum*
	Tectona grandis	-	-	-
Teak Monoculture	*Vitex pinnata*	-	-	*Tectona grandis*
	Senna siamea	-	-	-
	Tectona grandis	-	-	-
Gmelina plantation	*Homalanthus populneus*	*Gmelina arborea*	*Gmelina arborea*	*Gmelina arborea*
	Macaranga hypoleuca	*Coffea canephora*	*Piper aduncum*	*Falcataria mollucana*
	Piper aduncum	*Leea indica*	*Nauclea sp.*	*Harpullia arborea*

Shorea and *Dipterocarpus*, high value timber production from Dipterocarpaceae are dominant in undisturbed forest of Pasir and Berau. Logged-over forest in Kutai Timur and Pasir dominated by pioneer and sub-climax species, while in Berau is dominated by climax species. Logged-over forest plot in Berau is part of remnant forest which is protected by local government as part of Forest Park for ecotourism purposes. *Rhizophora* that consist of *apiculata*, *mucronata* and *stylosa* are dominant species in undisturbed mangrove of Kutai Timur, Pasir and Berau. *Ceriops* tagal and *Lutmnitzera littorea* dominant in disturbed mangrove of Kutai Timur, but *Sonneratia* sp. in Berau.

Rambutan (*Nephelium lappaceum*), durian (*Durio zibethinus*) and duku (*Lansium domesticum*) are the common dominant species is fruit-based agroforestry systems in East Kalimantan.

3.2.3 Similarity Species among Land cover

A similarity index determines how closely the current vegetation community resembles either the potential natural community or some other reference community. Similarity index among land use system in three districts of Kutai Timur, Pasir and Berau varied depend on the land use comparison (Table 5, 6 and 7).

Table 5. Similarity matrix of species among land uses systems in each growth stage in Kutai Timur

Land cover	CA	CiM	CoM	DM	FA	GP	TA	LOF	PM	RA	RM	UM
Seedling												
Cacao agroforest (CA)	1	0.14	0.10	0	0.17	0.09	0.07	0	0	0.03	0.04	0
Citrus monoculture (CiM)		1	0.23	0	0.10	0.08	0	0	0	0	0	0
Coconut monoculture (CoM)			1	0	0.08	0.05	0	0	0	0	0	0
Disturbed mangrove (DM)				1	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)					1	0.11	0.10	**0.26**	0	0.02	0.03	0.04
Gmelina plantation (GP)						1	0.08	0.05	0	0.15	0.22	0
Teak agroforest (TA)							1	0.06	0	0	0	0
Logged-over forest (LOF)								1	0	0	0	0

Land cover	CA	CiM	CoM	DM	FA	GP	TA	LOF	PM	RA	RM	UM
Pepper monoculture (PM)									1	0	0	0
Rubber agroforest (RA)										1	**0.31**	0
Rubber monoculture (RM)											1	0
Undisturbed mangrove (UM)												1
Sapling												
Cacao agroforest (CA)	1	0	0	0	0	0.08	0	0	0	0	0	0
Citrus monoculture (CiM)		1	0	0	0.05	0	0	0	0	0	0	0
Coconut monoculture (CoM)			1	0	0	0	0	0	0	0.2	0	0
Disturbed mangrove (DM)				1	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)					1	0.08	0.10	0.25	0	0	0.05	0
Gmelina plantation (GP)						1	0	0.10	0	0	**0.29**	0
Teak agroforest (TA)							1	0.08	0	0	0	0
Logged-over forest (LOF)								1	0	0	0	0
Pepper monoculture (PM)									1	0	0	0
Rubber agroforest (RA)										1	0	0
Rubber monoculture (RM)											1	0
Undisturbed mangrove (UM)												1
Pole												
Cacao agroforest (CA)	1	0.05	0	0	0.11	0	0	0	0	0	0	0
Citrus monoculture (CiM)		1	0	0	0.15	0	0	0	0	0	0	0
Coconut monoculture (CoM)			1	0	0	0	0	0	0	0	0	0
Disturbed mangrove (DM)				1	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)					1	0	0	0.12	0	0	0	0
Gmelina plantation (GP)						1	0	0	0	**0.57**	0.36	0
Teak agroforest (TA)							1	0	0	0	0	0
Logged-over forest (LOF)								1	0	0	0	0
Pepper monoculture (PM)									1	0	0	0
Rubber agroforest (RA)										1	**0.59**	0
Rubber monoculture (RM)											1	0
Undisturbed mangrove (UM)												1
Tree												
Cacao agroforest (CA)	1	0.01	0.00	0	0.14	0.01	0.01	0.00	0.01	0.03	0.02	0
Citrus monoculture (CiM)		1	0	0	0.02	0	0.03	0.01	0	0	0	0
Coconut monoculture (CoM)			1	0	0.01	0.01	0	0	0	0.01	0	0
Disturbed mangrove (DM)				1	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)					1	0.02	0.07	0.10	0.01	0	0	0
Gmelina plantation (GP)						1	0.01	0.01	0	0.01	0.01	0
Teak agroforest (TA)							1	0	0	0	0	0
Logged-over forest (LOF)								1	0	0	0	0
Pepper monoculture (PM)									1	0	0	0
Rubber agroforest (RA)										1	**0.77**	0
Rubber monoculture (RM)											1	0
Undisturbed mangrove (UM)												1
All growth stage												
Cacao agroforest (CA)	1	0.04	0.03	0	0.14	0.06	0.02	0.01	0.00	0.08	0.07	0
Citrus monoculture (CiM)		1	0.04	0	0.05	0.01	0.07	0	0.14	0	0	0
Coconut monoculture (CoM)			1	0.01	0.03	0.02	0.01	0	0	0.01	0	0
Disturbed mangrove (DM)				1	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)					1	0.05	0.09	0.21	0.01	0.01	0.01	0.01

Land cover	CA	CiM	CoM	DM	FA	GP	TA	LOF	PM	RA	RM	UM
Gmelina plantation (GP)						1	0.04	0.03	0	0.10	0.08	0
Teak agroforest (TA)							1	0.02	0.02	0	0	0
Logged-over forest (LOF)								1	0	0.01	0	0
Pepper monoculture (PM)									1	0	0	0
Rubber agroforest (RA)										1	**0.71**	0
Rubber monoculture (RM)											1	0
Undisturbed mangrove (UM)												1

Basically, species composition among land use systems in Kutai Timur significantly different each other, expressed by low similarity index, even totally dissimilar. Highest similarity found between rubber monoculture and rubber agroforest at seedling, pole and tree stage. Relatively high similarity occurred between rubber agroforest and gmelina plantation for pole stage.

Table 6. Similarity matrix of species among land uses systems in each growth stage in Pasir

Land cover	AM	FB	GP	HG	LFH	LFL	LsF	RA	RM	SM	TM	UF	UM
Seedling													
Acacia monoculture (AM)	1	0	0	0	0	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)		1	0	0	0.02	0	0.02	0	0	0.07	0	0	0
Gmelina plantation (GP)			1	0	0	0	0	0	0	0	0	0	0
Home garden (HG)				1	0	0	0	0	0	0	0	0	0
LOF high density (LFD)					1	0	0.06	0.12	0	0.06	0	0.02	0
LOF low density (FLD)						1	0	0.04	0.11	0	0	0	0
LOF swamp (LOS)							1	0	0.08	0	0	0	0
Rubber agroforest (RA)								1	0.28	0	0	0	0
Rubber monoculture (RM)									1	0	0	0	0
Sengon monoculture (SM)										1	0	0	0
Teak monoculture (TM)											1	0	0
Undisturbed forest (UF)												1	0
Undisturbed mangrove (UM)													1
Sapling													
Acacia monoculture (AM)	1	0	0	0	0	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)		1	0	0	0	0	0	0	0	0	0	0	0
Gmelina plantation (GP)			1	0	0	0	0	0	0	0	0	0	0
Home garden (HG)				1	0	0	0	0	0	0	0	0	0
LOF high density (LFD)					1	0.09	0	0.09	0	0.08	0	0	0
LOF low density (FLD)						1	0	0	0	0	0	0	0
LOF swamp (LOS)							1	0	0.13	0	0	0	0
Rubber agroforest (RA)								1	0.33	0.17	0	0	0
Rubber monoculture (RM)									1	0	0	0	0
Sengon monoculture (SM)										1	0	0	0
Teak monoculture (TM)											1	0	0
Undisturbed forest (UF)												1	0
Undisturbed mangrove (UM)													1
Pole													
Acacia monoculture (AM)	1	0	0	0	0	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)		1	0	**0.44**	0	0	0	0	0	0	0	0	0
Gmelina plantation (GP)			1	0	0	0	0.19	0	0	0	0	0.04	0
Home garden (HG)				1	0	0	0	0	0	0	0	0	0

Land cover	AM	FB	GP	HG	LFH	LFL	LsF	RA	RM	SM	TM	UF	UM
LOF high density (LFD)					1	0	0.05	0	0	0	0	0	0
LOF low density (FLD)						1	0	0	0	0	0	0.05	0
LOF swamp (LOS)							1	0	0	0	0	0	0
Rubber agroforest (RA)								1	0.24	0	0	0	0
Rubber monoculture (RM)									1	0	0	0	0
Sengon monoculture (SM)										1	0	0	0
Teak monoculture (TM)											1	0	0
Undisturbed forest (UF)												1	0
Undisturbed mangrove (UM)													1
Tree													
Acacia monoculture (AM)	1	0	0	0	0.03	0	0.02	0	0	0.16	0	0	0
Fruit-based agroforest (FA)		1	0	0.27	0	0	0	0.01	0	0	0	0.01	0
Gmelina plantation (GP)			1	0	0	0	0.01	0	0	0	0	0.02	0
Home garden (HG)				1	0.01	0	0	0.01	0	0	0.01	0.01	0
LOF high density (LFD)					1	0.03	0.07	0	0	0	0	0.11	0
LOF low density (FLD)						1	0.01	0.06	0	0	0	0.02	0
LOF swamp (LOS)							1	0	0	0	0	0.01	0
Rubber agroforest (RA)								1	**0.49**	0	0	0.01	0
Rubber monoculture (RM)									1	0	0	0	0
Sengon monoculture (SM)										1	0	0	0
Teak monoculture (TM)											1	0	0
Undisturbed forest (UF)												1	0
Undisturbed mangrove (UM)													1
All growth stage													
Acacia monoculture (AM)	1	0.02	0	0	0.03	0	0.02	0	0	0.16	0	0	0
Fruit-based agroforest (FA)		1	0	**0.20**	0.02	0.01	0.04	0.01	0	0.02	0	0.01	0
Gmelina plantation (GP)			1	0	0.01	0.01	0.06	0	0	0	0	0.02	0
Home garden (HG)				1	0.01	0	0	0.02	0	0	0.01	0.00	0
LOF high density (LFD)					1	0.10	0.07	0.03	0	0.03	0	0.08	0
LOF low density (FLD)						1	0.04	0.08	0.02	0.02	0	0.01	0
LOF swamp (LOS)							1	0	0.01	0.02	0	0.01	0
Rubber agroforest (RA)								1	**0.63**	0.00	0	0.01	0
Rubber monoculture (RM)									1	0	0	0	0
Sengon monoculture (SM)										1	0	0.00	0
Teak monoculture (TM)											1	0	0
Undisturbed forest (UF)												1	0
Undisturbed mangrove (UM)													1

Similarity index among land use systems in Pasir indicate dissimilar, except between rubber agroforest and rubber monoculture, even the similarity index is less than 0.5 for seedling, sapling, pole and tree stage. Tend to similar occurred between home garden and fruit-based systems.

Table 7. Similarity matrix of species among land uses systems in each growth stage in Berau

Land cover	CoA	DM	FA	GA	LHD	GP	PM	TA	TM	UF	UM
Seedling											
Coconut agroforest (CoA)	1	0	0.01	0	0	0.11	0	0	0	0	0
Disturbed mangrove (DM)		1	0	0	0	0	0	0	0	0	0.20
Fruit-based agroforest (FA)			1	0.03	0.04	0.16	0.04	0.05	0.03	0.00	0
Gaharu agroforest (GA)				1	0	0.04	0.22	0	0	0	0
Logged-over forest high density (LHD)					1	0.07	0	0.02	0	0.16	0
Gmelina plantation (GP)						1	0.03	0.07	0	0	0
Pepper monoculture (PM)							1	0	0.24	0	0
Teak agroforest (TA)								1	0.14	0	0
Teak monoculture (TM)									1	0	0
Undisturbed forest (UF)										1	0
Undisturbed mangrove (UM)											1
Sapling											
Coconut agroforest (CoA)	1	0	0	0	0	0	0	0	0	0	0
Disturbed mangrove (DM)		1	0	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)			1	0	0	0.15	0.07	0.38	0	0	0
Gaharu agroforest (GA)				1	0	0	0	0	0	0	0
Logged-over forest high density (LHD)					1	0.04	0	0.04	0	0.15	0
Gmelina plantation (GP)						1	0	0.29	0	0	0
Pepper monoculture (PM)							1	0	0	0	0
Teak agroforest (TA)								1	0	0	0
Teak monoculture (TM)									1	0	0
Undisturbed forest (UF)										1	0
Undisturbed mangrove (UM)											1
Pole											
Coconut agroforest (CoA)	1	0	0	0	0	0	0	0	0	0	0
Disturbed mangrove (DM)		1	0	0	0	0	0	0	0	0	0
Fruit-based agroforest (FA)			1	0.07	0	0	0	0.07	0	0.02	0
Gaharu agroforest (GA)				1	0	0	0	0	0	0	0
Logged-over forest high density (LHD)					1	0	0	0	0	0.18	0
Gmelina plantation (GP)						1	0	0	0	0	0
Pepper monoculture (PM)							1	0	0	0	0
Teak agroforest (TA)								1	0	0	0
Teak monoculture (TM)									1	0	0
Undisturbed forest (UF)										1	0
Undisturbed mangrove (UM)											1
Tree											
Coconut agroforest (CoA)	1	0	0.03	0.01	0	0	0	0	0	0	0
Disturbed mangrove (DM)		1	0	0	0	0	0	0	0	0	0.35
Fruit-based agroforest (FA)			1	0.07	0.01	0.01	0.01	0.05	0.05	0.01	0
Gaharu agroforest (GA)				1	0	0	0	0	0	0	0
Logged-over forest high density (LHD)					1	0.01	0	0.01	0	**0.36**	0
Gmelina plantation (GP)						1	0	0	0	0.01	0
Pepper monoculture (PM)							1	0	0	0	0
Teak agroforest (TA)								1	**0.76**	0	0
Teak monoculture (TM)									1	0	0
Undisturbed forest (UF)										1	0
Undisturbed mangrove (UM)											1
All growth stage											
Coconut agroforest (CoA)	1	0	0.02	0.01	0	0.02	0.01	0	0	0	0
Disturbed mangrove (DM)		1	0	0	0	0	0	0	0	0	0.36
Fruit-based agroforest (FA)			1	0.06	0.02	0.03	0.01	0.07	0.04	0.01	0
Gaharu agroforest (GA)				1	0.00	0.00	0.01	0	0	0	0
Logged-over forest high density (LHD)					1	0.04	0	0.01	0	**0.37**	0
Gmelina plantation (GP)						1	0.02	0.03	0.01	0.01	0
Pepper monoculture (PM)							1	0	0.01	0.00	0
Teak agroforest (TA)								1	**0.66**	0.00	0

Land cover	CoA	DM	FA	GA	LHD	GP	PM	TA	TM	UF	UM
Teak monoculture (TM)									1	0.00	0
Undisturbed forest (UF)										1	0
Undisturbed mangrove (UM)											1

High similarity at tree stage found between teak agroforest and teak monoculture in Berau. Even at low index in tree stage, some species of undisturbed forest in Berau still found in logged-over forest. The same trend occurred between undisturbed mangrove and disturbed mangrove where low similarity found at seedling and tree stage.

3.2.4 Tree diversity

Tree diversity index in certain ecosystems express the complexity of species and population. Shannon-Wiener index used to express complexity species in various land use systems of Kutai Timur, Pasir and Berau (Table 8). High tree diversity index found in fruit-based agroforestry (Kutai Timur), undisturbed forest and logged-over forest (Pasir and Berau) above 3. Agroforestry systems in three districts commonly have medium tree diversity index at 1 – 3, mostly less than 2 and monoculture systems categorized low tree diversity less than 1.

Tree diversity index of vegetation growth stage express horizontal vertical composition of the ecosystem and indicate establishment period of the system and management practices applied in the systems. Tree diversity index among growth stage in fruit-based agroforestry is relatively constant. Low and medium intensive management such as rubber, cacao, teak, sengon and gmelina mostly have higher diversity at lower stages, but higher diversity index at higher growth stage found in undisturbed forest. Logged-over forest has various composition depend on the period after logging and logging practiced.

Table 8. Shannon-Wiener diversity index in various land cover systems for all growth stages in Kutai Timur, Pasir and Berau

District	Land cover	No. of plot	Seedling	Sapling	Pole	Tree	All growth stage
Kutai Timur	Logged-over forest low density	2	1.63	2.45	2.46	1.84	2.44
	Undisturbed mangrove	3	0.60	0.82	0	0.25	0.36
	Disturbed mangrove	3	0.84	1.51	1.06	1.79	1.45
	Fruit-based agroforest	4	3.09	2.86	2.38	3.09	**3.56**
	Teak agroforest	1	2.08	1.33	0	1.48	1.92
	Rubber agroforest	1	1.85	1.10	0	0.06	0.56
	Rubber monoculture	2	0.69	0.56	0	0	0.06
	Coconut monoculture	3	0.68	0.68	1.01	0.09	0.71
	Cacao monoculture	3	1.43	0.90	0.34	0.93	1.20
	Citrus monoculture	1	0.97	1.10	0.38	1.07	1.26
	Pepper agroforest	1	0	0	0	0.23	0.23
	Gmelina plantation	2	1.98	1.36	0.88	0.28	0.93
Pasir	Undisturbed forest	2	2.42	2.59	3.09	3.82	**3.83**
	Logged-over forest high density	1	1.71	2.39	2.20	3.47	**3.73**
	Logged-over forest low density	1	1.73	1.33	2.14	2.63	**3.03**
	Logged-over swamp forest	2	1.77	1.91	2.06	1.80	2.30
	Fruit-based agroforest	2	1.84	1.04	1.33	1.84	2.49
	Undisturbed mangrove	2	0.95	0.69	0.92	0.55	0.78

District	Land cover	No. of plot	Seedling	Sapling	Pole	Tree	All growth stage
	Home garden	1	0	0	1.10	1.65	1.80
	Rubber agroforest	1	2.29	1.05	0.88	0.78	1.26
	Rubber monoculture	1	0.64	0.41	0	0	0.12
	Teak monoculture	1	0.56	0	0	0	0.04
	Acacia monoculture	1	0	0	0	0.13	0.13
	Sengon monoculture	1	1.84	1.28	0.41	0.37	0.85
	Gmelina plantation	1	1.31	1.78	1.89	0.71	1.26
Berau	Undisturbed forest	2	2.54	2.89	2.74	3.25	**3.47**
	Logged-over forest high density	3	3.39	3.19	2.91	4.04	**4.20**
	Undisturbed mangrove	2	0.45	0.45	0	0.60	0.56
	Disturbed mangrove	1	0	0	0	0	0
	Fruit-based agroforest	11	2.88	2.40	1.42	2.10	2.48
	Gaharu agroforest	1	0.69	0	1.05	0.94	1.03
	Coconut agroforest	1	0.64	0	0	0.92	1.23
	Pepper agroforest	2	1.73	0.80	0.64	0.45	0.72
	Teak agroforest	1	1.33	0.56	0.64	0.07	0.72
	Teak monoculture	1	1.04	0	0	0	0.24
	Gmelina plantation	3	2.32	2.11	1.62	0.69	1.59

3.2.5 Above-ground carbon stock

Similar to the other sample area, undisturbed forest of low land forest in Berau and Pasir has highest carbon stock above 200 Mg ha^{-1}, followed by undisturbed mangrove about 180 Mg ha^{-1}. Logged-over forest has low density and high density has about 60 Mg ha^{-1} and 180 Mg ha^{-1}, respectively. Man-made ecosystems, both monoculture and agroforest has various value of carbon stock depend on the species integrated in the system (Tabel 9).

Table 9. Above-ground carbon stock of four carbon pool and total carbon stock in various land use types in Kutai Timur, Pasir and Berau District

District	Land cover	Number of plot	Carbon stock (Mg ha^{-1})				
			Tree	Necromass	Understorey	Litter	Total
Kutai Timur	Logged-over forest low density	2	37.0	0.9	1.7	20.4	60.0
	Undisturbed mangrove	3	167.7	5.6	0	0	173.3
	Disturbed mangrove	3	16.2	14.4	0.5	1.7	32.7
	Fruit-based agroforest	4	86.8	14.0	3.1	11.1	114.9
	Teak agroforest	1	127.6	0	0	0	127.6
	Rubber monoculture	3	54.8	3.8	2.0	13.8	74.3
	Coconut monoculture	3	49.9	0	3.0	3.7	56.7
	Cacao monoculture	3	34.1	1.3	0.8	19.1	55.2
	Citrus monoculture	1	6.3	0.1	5.1	0	11.5
	Pepper agroforest*	1	38.2	0	0.2	3.3	41.7
	Gmelina plantation	2	43.1	10.9	11.8	13.8	79.6
Pasir	Undisturbed forest	2	277.9	46.1	5.3	0.3	329.5
	Logged-over forest high density	1	166.6	18.2	12.5	0.1	197.4
	Logged-over forest low density	1	44.7	13.4	4.9	0.3	63.4
	Logged-over swamp forest	2	61.3	2.3	2.6	1.6	67.8
	Fruit-based agroforest	2	76.2	0	8.4	0.3	84.8
	Undisturbed mangrove	1	161.7	16.7	1.9	0.8	181.1
	Home garden	1	21.6	3.7	7.5	2.7	35.6

District	Land cover	Number of plot	Carbon stock (Mg ha^{-1})				
			Tree	Necromass	Understorey	Litter	Total
	Rubber agroforest	1	101.2	8.3	7.5	0.3	117.4
	Rubber monoculture (young age)	1	8.8	0	2.2	0.2	11.2
	Teak monoculture	1	48.7	0	2.6	0.3	51.7
	Acacia monoculture	1	71.2	0.4	1.3	0	72.9
	Gmelina plantation	1	50.6	0	1.6	0	52.2
Berau	Undisturbed forest	2	192.3	2.3	0.1	15.3	210.5
	Logged-over forest high density	3	143.6	1.6	0.6	12.2	158.0
	Undisturbed mangrove	3	187.3	0.3	0	0	187.6
	Fruit-based agroforest	11	58.9	2.1	0.3	6.8	68.1
	Coconut agroforest	1	45.7	0	0.4	2.1	48.21
	Pepper agroforest	2	29.4	0	1.3	2.1	32.7
	Teak agroforest	2	62.9	0	0.3	7.4	70.7
	Gmelina plantation	2	33.6	0	0.2	3.4	37.2
	Sengon monoculture	1	24.3	1.1	1.0	4.5	30.9

4 Discussions

4.1 Tree species component

More intensive management and establishment period of the systems affect to species richness significantly. However, the real monoculture system with single species in smallholder, both plot and landscape level is very rare. In the beginning, monoculture systems developed for single species, such as rubber, teak, gmelina, sengon and acacia but wild species regenerated in system due to irregularly management or even planted by the owner. Improved diversity in such situations is attributed to species resilience to regenerate or to other factors such as canopy gap formation that increased light to the forest floor (Senbeta et al 2002) led the fast growing species to grow.

Fruit-based agroforestry, a traditional systems practiced by local community, such as Dayak tribe consist high species richness for all growth stage. This is indicates that this systems was established for long period where some species grow up to tree level and low management to be implemented. Low management practiced, such as irregular weeding or even no weeding provides some tree species regenerated naturally and affect to constant diversity index for seedling and sapling. Low disturbance may occur in fruit-based agroforestry system managed by local community, since they have other land-based livelihood option such as rubber monoculture and annual crop.

Low species richness and diversity in mangrove, both undisturbed and disturbed because of specific land character that only certain species can adapt to the typical land cover. Mangrove tree species is determined by the type of substrate and the zonation of the mangrove ecosystem that usually harbouring only few tree species (Alongi 2012).

The lower species richness and diversity at younger growth stage occurred in undisturbed forest due to canopy closure that only certain species can adapt. In the logged-over forest, lower species richness and diversity at sapling and pole stages assumed caused by clearing for pathway or impact of logging activity. The factor also can be caused by species specific character in the way of sprouting its seeds but some species cannot survive until sapling stage. While in man-made land cover, the proportion of

seedling and sapling tends to be influenced by land management. More intensive management availability of seedling and sapling is low.

Dominance of Dipterocarpaceae such as Shorea and Dipterocarpus in undisturbed forest of Pasir District where located in Hutan Lindung Gunung Lumut indicate that the area is well protected. As well as, dominance of ulin (*Eusideroxylon zwageri*) in logged-over forest of Berau where located in ecotourism area of forest park. Both, Dipterocarp timber and ulin are high value timber. Dominance pioneer species in logged-over forest low density indicates that forest disturbance may occur at less than 10 years, but sub-climax species dominated logged-over forest high density shown that the ecosystems disturbance occurred, but in low level.

Dominance species is an indicator of composition in a certain habitat (Lohbeck et al 2014), that refers to its relative importance in its habitat ecologically (Chase et al 2003). In the natural regeneration, dominance species may useful to identify the disturbance level, both of frequency and intensity. In the man-made ecosystems, dominance of certain species can be used to identify or classify the ecological type, as well as to understand the establishment purposes and management practices. Current dominance species is considerate as basic information to determine land management action.

Typical natural land cover such mangrove tend to dominated by single species due to the characteristic of mangrove zonation. *Sonneratia* and *Avicennia* commonly co-dominant in exposed mangrove zone, whrere grows on the seaward side of mangrove belts and inundated by medium high tides (van Steenis 1958). *Sonneratia alba* and *Avicennia alba* co-dominate in this deeply inundated coastal zone. *Sonneratia alba* tends to dominant on sands, or on corals, while in the muddy substrate tend to dominated by *Rhizophora* species (Giesen et al 2007).

Dominant species in natural ecosystem not exactly similar among growth stage, because in natural ecosystems normally there is no single dominant species (Leigh 2004), hundreds species shared the area each other. In man-made ecosystem, similarity among growth stage is strongly determined by anthropological factor, such as management practices in the systems. Management practiced directly impact to availability natural regeneration species developed in the systems. Low intensive management systems still support natural regeneration species, such as mixed agroforest system like *Shorea* agroforest system in Krui, Lampung (de Foresta et al 2000).

4.2 Above-ground carbon stock

Undisturbed forest in East Kalimantan, generally has high carbon stock above 200 Mg ha^{-1}, due to presence of larger trees. Carbon stock in logged-over forest is ranged 60 – 200 Mg ha^{-1} depend on tree density and presence of larger tree. Larger tree in logged-over forest high density contribute to high carbon content. Logged-over forest low density dominated by shrub and smaller tree less than 10 cm diameter has lower carbon stock. Tree based systems have varied carbon content depend on the main species and establishment period (age of tree), since tree species contribute up to 80% of carbon stock. Capability of trees on absorbing carbon from atmosphere which is substantial amount is stored in mature trees (Meineke et al 2016). Fruit-based agroforestry system practiced by local community has carbon stock similar to logged over forest high density above 100 Mg ha^{-1}. Long establish of this system provides chance to fruit trees species stay in the land, and the owner tend to keep as source of income.

Monoculture systems that develop widely in three districts such as perennial crop of cacao, coconut, pepper and rubber has lower carbon stock about 30 – 70 Mg ha^{-1}, as well as industrial timber such as gmelina, teak and sengon.

5 Conclusions

Higher tree species richness and diversity found in natural ecosystems such as undisturbed forest, logged-over forest, except mangrove that only few species owing to specific characteristic on the ecosystem where allowed limited species to grow. Monoculture systems commonly hold less tree species in the systems depend on the management. Low intensive management contains higher tree species richness and diversity.

In line with species richness and diversity, natural ecosystems of undisturbed forest, logged-over forest and low intensive management of fruit-based agroforest consist of higher carbon stock than monoculture systems.

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