The impact of sustainable forest management on plant and bird diversity in East Kalimantan, Indonesia

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General Introduction

Introduction

Since tropical rain forests harbor most of the world's biodiversity, tropical deforestation has become the major cause of global species extinctions (Pimm & Raven, 2000). Activities of logging are often the starting point for a cascade of interactions leading to forest destruction and habitat loss (Laurance, 1998; Meijaard *et al.*, 2005). Logging directly affects the forest by creating a more open canopy and by producing logging debris (dead wood and other dead plant material on the forest floor) which may lead to the displacement of forest floor habitats by new habitats. A more open canopy leads to increased evaporation and desiccation during dry periods, and to additional structural changes by stimulating the development of a dense undergrowth of lianas, herbs and young trees (Slik *et al.*, 2002). Apart from these direct effects, logging may also lead to an increase of local human populations and subsequent increased exploitation of the forest (Kartawinata & Vayda, 1984) and other destructive human activities such as illegal logging, poaching, and agricultural expansion (Laurance, 1998; Curran *et al.*, 2004).

Among the impacts of logging on primary forest are the mortality of canopy trees (Laurance *et al.*, 2000), recruitment failure resulting from over-predation of seeds (Curran *et al.*, 1999), reduced seedling establishment and plant growth (Slik, 2001; Bruna *et al.*, 2002; Bruna, 2003), local extinction of plants (Benitez-Malvido & Martinez-Ramos, 2003), decline in butterfly abundance and/or diversity (Cleary, 2002), decline in bird abundance and/or diversity (Boulinier *et al.*, 2001; Beier *et al.*, 2002; Slik & Van Balen, 2006), and decreased pollination (Ashworth *et al.*, 2004). Apart from ecological processes, harmful human activities, such as illegal logging and hunting, could also cause the remaining forest fragments to become less biodiverse (Laurance, 1998; Hartshorn & Bynum, 2001; Curran *et al.*, 2004).

Selectively logged forest areas may act as buffer zones and serve as a habitat for forest plants and animals displaced from destroyed primary forest areas (Brearley *et al.*, 2004; Meijaard *et al.*, 2005). Selectively logged forest areas may also act as reservoirs for recolonization and as corridors between remaining primary forest fragments. As succession proceeds, selectively logged forest areas are expected to regenerate to a stage in which they are similar in structure and composition to primary forest, as long as they are left untouched for a sufficiently long period. The time required for a disturbed forest to regenerate through succession to forest resembling primary rainforest has been estimated at 50 years (Kochummen, 1966), 50–80 years (Brown & Lugo, 1990), 73 years (Hughes *et al.*, 1999), 150–200 years (Richards, 1952; Knight, 1975), 150–500 years (Riswan *et al.*, 1985), 250–500 years (Kartawinata, 1994) and 'centuries' (Whitmore, 1991). The actual time needed to revert secondary forest to primary forest will depend on several factors, including initial environmental conditions, intensity and scale of the disturbance, length of time of abandonment, surface of forest remaining in the surrounding landscape and the distance from the seed sources of primary forest species (Brearley *et al.*, 2004; Meijaard *et al.*, 2005).

The Forest Stewardship Council (FSC)

Forest certification schemes have been introduced during the past decades in order to reduce the negative impact of logging. Sustainable Forest Management (SFM) has become an important alternative for conventional logging and is supported by international development organizations, donor agencies, and governments (Poore e*t al.*, 1989; CIFOR, 1993; FAO, 1993; ITTO, 1994; Lanly, 1995). So far, Van Kuijk *et al.* (2009) suggested that there is no quantitative evidence of an impact of FSC-certified logging on biodiversity in tropical forests.

The certification of forest management and labeling of forest products is recognized as a useful tool for promoting sustainable forest management (ITTO, 2004). Forests that have recently been certified under the four largest certification schemes cover 230 million hectares (NN, 2005). The impressive progress in the implementation of certification schemes worldwide has so far mostly been achieved in developed temperate countries of either North America or Europe, which currently account for more than 95% of the certified forest areas (Amha, 2005). The Forest Stewardship Council (FSC) reported that the demand for certified tropical hardwoods exceeds the supply by at least 12.6% logs round wood (FSC, 2014).

The major driving forces of SFM are the emerging interest of the public sector, efforts to minimize commercial risks associated with illegal timber trade, and procurement requirements established by trade associations (Oliver, 2005). Certification for SFM induces increased management costs of conventional and consequently a relatively small sample size (Van der Hoeven *et al.*, 2000; Van Kuijk *et al.*, 2009). The cost for logs is defined as the difference between the price of the certified log and the price of the same log prior to the adoption of certification (Varangis *et al.*, 1995).

Some authors claim that consumers in Europe and in the USA are willing to pay between 2% and 30% more for sustainably produced, certified tropical timber (Baharuddin & Simula, 1994; Baharuddin, 1995; Varangis *et al.*, 1995; Simula & Baharuddin, 1996; Oliver, 2005; NN, 2005). Varangis *et al.* (1995) estimated that in view of the market share of certified tropical timber on the US and European markets, the incremental revenue from the markets assumed to be willing to pay more for certified timber would amount to 62 million USD. Other authors doubt or flatly deny that the majority of consumers are willing to pay a premium for certified logs (Freris & Laschefski, 2001).

Objectively verifiable, quantitative evidence of these claims are rare as it is difficult to retrieve reliable sources of log prices, particularly in the tropics. Baharuddin and Simula (1994) conclude that "there is not yet convincing evidence of an existing price premium for sustainably produced, certified timber and timber products in the market", and after ten years, this statement still holds. Furthermore, most studies dealing with the subject are based on willingness-to-pay inquiries investigating whether or not consumers in Europe or the USA would be ready to pay a price premium. The crucial question whether or not such a premium will benefit in terms of biodiverisity to the producers of certified timber, who also bear the higher costs of sustainable forest management, is usually omitted.

Indicators for sustainable forest management

Sound management demands clear and achievable goals in which practical biodiversity conservation priorities could be achieved by reduced impact logging (Sheil, 2001). Most national conservation plans provide priorities for biodiversity conservation, such as maintaining natural vegetation cover, preventing conversion of protected areas to other land uses and protecting high-profile taxa. These are priority goals that need to be supported both locally and nationally (Sheil, 2002). However, in order to translate such strategies into real action, there is a need to develop suitable biological indicators of sustainable forest management at the forest management unit level (Ghazoul & Hellier 2000; De Iongh & Van Weerd, 2006; De Iongh & Persoon, 2010), which could be used as a monitoring tool to generate spatial and temporal data. A decision support approach using the concept of conventional based utility functions is proposed for formulating forest land use strategies to improve sustainability (De Iongh & Persoon, 2010).

In disturbed forests, species richness may even increase due to an increased number of common edge species (Johns, 1996). Species richness alone may therefore not be a good indicator of the impact of logging on forest biodiversity (Ghazoul & Hellier, 2000). Table 1.1 summarizes the conventional biological indicators/verifiers used in a number of certification systems for sustainable forest management.

Table 1.1
Target criteria used by several organizations and NGO's.

	CIFOR	ACT	ATO	ITTO	TFS	FSC	PEFC	FAO/UNEF	Smartwood	World Bank	Malaysia	Neth. Min. Req.
Species richness*	×			×	×	×	×	×		×	×	×
Species abundance	×					×					×	
Genetic diversity	×				×	×		×		×	×	
Keystone species				×	×						×	
Rare and endangered species	×	×	×	×	×	×	×	×	×		×	
Guild diversity/ abundance	×	×		×								
Population dynamic	×							×				
Hunting										×		
Invasive species	×									×		

* Often described as the number of forest depended species or species list.
Acronyms: CIFOR: Center for International Forestry Research, ACT: Amazon Cooperation Treaty, ATO: African Timber Organisation, ITTO: International Tropical Timber Organisation, TFS: Tropical Forestry Services, FAO: Food and Agriculture Organisation, FSC: Forest Stewardship Council, UNEP: United Nations Environment Program, Malaysia: Malaysian criteria and indicators for forest management, PEFC: Promoting Sustainable Forest Management, Neth. Min Req.: Netherlands criteria and indicators for forest management 'BRL'. Source: De Iongh *et al.*, 2006

This table shows that most certification systems use "species richness" as an indicator/verifier, while some use "genetic diversity", "keystone species" or "rare and endangered" species as additional indicator/verifier. It would seem that long-term recovery data will always be scarce, and this gap will only be filled by further field work (Gazhoul & Hellier, 2003).

An indicator is defined as any variable or component of the forest ecosystem or relevant management system that is used to infer attributes of the sustainability of utilization of the resource (Ghazoul & Hellier, 2000). Preventing extinctions and maintaining or enhancing the level of genetic variation among individuals, populations, and species, requires conserving or managing the dynamic forces of evolution largely at the species level (Namkoong *et al.*, 1996). At the end of the first phase of a CIFOR project, Prabhu *et al.* (1996) reported a lack of suitable indicators for assessing impacts of logging on biodiversity, at all levels of the hierarchy, and stressed the urgent need to address this weakness. They also suggest that a tool-box approach for developing and using criteria and indicators for sustainable forest management would have the highest utility for potential user groups (Gazhoul & Hellier, 2003; De Iongh *et al.*, 2006).

Ghazoul and Hellier (2000) suggest a biological protocol based on five indicators: 1. forest structure; 2. bird community structure; 3. butterfly species richness; 4. mammal species richness; 5. forest disturbance (dead wood and decomposition). Species richness alone may not be a good indicator for the recovery of forest biodiversity and for the impact of logging (Landers *et al.*, 2004; Azevedo-Ramos *et al.*, 2002; Sheil *et al.*, 2004). Some species of vascular plants (*Mallotus* spp. and *Macaranga* spp.) have been used as indicators for forest disturbance (Kessler, 1999; Slik, 2001). While the use of butterflies has been extensively covered by Cleary (2002), mammal species richness is generally more difficult to monitor due to their more extensive ranging patterns (Meijaard *et al.*, 2005). I will therefore use the present research to further investigate the use of three types of indicators: 1) forest structure (plant composition); 2) bird communities and 3) forest disturbance.

Plant composition

Plant and tree diversity in primary lowland tropical forest is impacted by logging, especially in Southeast Asia (Slik *et al.*, 2002). The surface area of primary forests in Indonesia is already surpassed by the surface area of secondary forest as a result of legal/illegal logging operations and agricultural development (Manokaran, 1992; Murali & Hedge, 1997; Sayer *et al.*, 2000; Brooks *et al.*, 2001).

Among the direct effects of logging disturbance, increased tree mortality in the forest overstorey (diameter at breast height (dbh) ≥ 10 cm) has been mentioned (Slik *et al.*, 2002). This is especially relevant in relation to the formation and persistence of forested corridors between remaining patches of undisturbed forest (Rijksen & Meijaard, 1999; Meijaard *et al.*, 2005). However, the ecological quality of secondary forests can vary considerably, depending on the kind and severity of disturbance, the time elapsed since logging took place, and the vicinity of primary forest (Brown & Lugo, 1990; Whitmore, 1991; Corlett, 1994; Chazdon, 2003). In tropical rainforests, the long-term effects of large-scale disturbances such as logging have rarely been studied (e.g. Finegan, 1996).

Mortality of trees by logging reduces the number of tree species per surface area while it increases the light levels in the forest understorey, leading to the development of dense shrubs in the undergrowth (Kartawinata *et al.,* 1981; Woods, 1989; Cannon *et al.,* 1998; Uuttera *et al.,* 2000; Slik *et al.*, 2002). Forest tree mortality is usually more pronounced in commercially logged forest, with tree mortality in conventionally logged forest suggested to be at least 2–3 times lower, and to occur mostly near and on skid trails (Woods, 1989; Webb, 1998; Pinard *et al.,* 2000; Uuttera *et al.,* 2000; Slik *et al.*, 2002). The increased light levels in the forest understorey after selective logging, usually stimulates the establishment of herbaceous and woody pioneer species (Woods, 1989; Nykvist, 1996; Pinard *et al.,* 1996; Cochrane & Schultze, 1999; Fredericksen & Mostacedo, 2000). Such pioneers could therefore be useful for detecting and quantifying tropical forest disturbance (Slik *et al.,* 2002, 2003). Slik *et al.* (2001) describe a clear pattern of increasing pioneer dominance of the genera *Mallotus* and *Macaranga* with an increasing level of disturbance (Table 1.2), thus confirming their potential importance as indicators of disturbance. Since the understorey plays an important role in the regeneration of the forest overstorey, it is likely that at least part of these pioneer species will eventually grow into forest overstorey vegetation, thus affecting the tree species composition and structure of subsequent forest stages (Riswan *et al.,* 1985; Finegan, 1996; Cochrane & Schultze, 1998; Newbery *et al.*, 2000). The abundance of pioneer species is expected to reflect the scale and severity of the disturbance that took place in a forest (Primack & Lee, 1991; Davies *et al.,* 1998; Slik *et al.*, 2002), and as such could be useful to monitor forest development after logging.

Table 1.2
The relation between pioneer and non-pioneer abundance (n per 0.3 ha plot) and disturbance type (time since disturbance between brackets). Sources: Slik *et al.* (2002).

Disturbance type	Pioneers (n ± S.D.)	Non-pioneers (n ± S.D.)	Pioneers (%)	Pioneer range (min.–max.)	Non-pioneer range (min.–max.)
Undisturbed	23.5 ± 36.4a	250.8 ± 143.4a	8.6	1–151	6–465
Logged (21) and thinning (12)	11.6 ± 9.6a	51.8 ± 37.5bc	18.3	4–27	26–113
Logged (20–30)	35.3 ± 21.6b	82.3 ± 69.9bc	30.0	19–78	2–180
Logged (10–20)	58.4 ± 44.4bc	80.3 ± 110.9bc	42.1	20–142	10–324
Logged (0–10)	138.4 ± 130.0cd	110.0 ± 78.8ab	55.7	42–376	5–196
Once burned (15)	168.2 ± 82.1de	45.6 ± 20.0bcd	78.7	82–269	15–68
Once burned (3)	507.0 ± 273.8ef	57.0 ± 39.7abcd	89.9	241–788	15–94
Once burned (1)	476.0 ± 229.3ef	16.2 ± 12.6cde	96.7	249–798	1–34
Thrice burned (3)	1124.6 ± 662.0f	35.0 ± 29.2bcd	97.0	611–2269	6–74
Twice burned (3)	1671.7 ± 1275.3f	8.3 ± 4.9de	99.5	612–3087	5–14
Logged (15) and burned (1)	1264.2 ± 866.3f	6.0 ± 7.3e	99.5	173–2191	0–17
d.f.	70	70			
F-ratio	24.9	7.0			
P	<0.0001	<0.0001			

Disturbance types are ordered according to increasing dominance of pioneers. Significant differences in pioneer and non-pioneer numbers (log transformed) between disturbance types (indicated with different characters) were tested using a general linear model with a Fishers' least significant difference test.

Since changes in forest structure and tree species composition after logging has become such a common and recurrent phenomenon in the lowland forests of East Kalimantan and in Southeast Asia in general (Slik & Eichhorn, 2003; Meijaard *et al.*, 2005), but very little is known regarding the effectiveness of commonly used SFM tools, I examined how forest structure as well as plant and bird species diversity are influenced by selective logging.

However, the discrimination between pioneer and climax species is not always that clear, since they each represent the extremes of a continuous life history gradient (Swaine & Whitmore, 1988; Slik *et al.*, 2003). In addition, the successional status of most species in selectively logged forest (in the process of being certified) is still largely unavailable, since the collection and management of such ecological data requires a lot of time and effort, and is therefore very expensive (Sheil, 1998).

Bird communities

Although logging forms a major threat to the last remaining patches of primary tropical lowland rainforest in Southeast Asia (Siegert *et al.*, 2001; Laurance, 2004), very few studies have thoroughly investigated the impact of logging on tropical bird communities in FSC certified forest concessions (Kinnaird & O'Brien, 1998; Haugaasen *et al.*, 2003; Barlow & Peres, 2004a), and our current understanding of bird community responses to logging is strongly geographically biased (Van der Hoeven *et al.*, 2000; De Iongh & Van Weerd, 2006). To be able to adapt bird conservation strategies to the growing expanses of secondary tropical lowland forest in Southeast Asia, more information about the impact of selectively logged forest on tropical bird communities is therefore urgently needed.

Bird species richness has been found to decline in response to logging (Johns, 1991; Thiollay, 1997; Marsden, 1998) but also to increase (Kofron & Chapman, 1995; Johns, 1996). Ghazoul and Hellier (2000) summarize bird species richness and abundance in primary forests (Table 1.3). After logging, avifaunal assemblages became increasingly dissimilar to primary forest and contained a higher abundance of species associated with second-growth habitats (Barlow & Peres, 2004a).

Table 1.3
Abundance of bird guilds (insectivore, frugivore and nectarivore) as a percentage of undisturbed forest values. Source: Ghazoul and Hellier (2000).

Site (Disturbance)	Insectivore	Frugivore	Nectarivore	References
Amazon (1-10 years)	7-28	47-63	65-90 n.s.	Thiollay, 1997
	25-66	58-67	57-100 n.s.	
Colombia (edges)	75	79	131	Restrepo & Gomez, 1998
Sabah (6-12 years)	72-105	100	100-129	Johns, 1996
	22-60	228	123	
Amazon (fragment)	–	–	267	Stouffer & Bierregaard, 1995
	42	61	137	
Amazon (11 years)	96	92	125	Johns, 1991
Uganda (5-40 years)	77	300	146	Owiunji & Plumptre, 1998
Sabah (8 years)	83	132	245	Lambert, 1992

These changes in avifaunal assemblages were strongly associated with changes in habitat structure, such as canopy cover and regeneration (Barlow & Peres, 2004b). In the Amazon region, most understorey insectivorous guilds declined, while arboreal nectarivores, granivores and frugivores became more abundant after the disturbance (Barlow & Peres, 2004a). A literature review by de Iongh

& Van Weerd (2006) confirmed that understorey insectivores were commonly affected by logging.

Overall, differences in bird species composition between secondary forests and primary forests are more pronounced when individual guilds are examined (Ghazoul & Hellier, 2000). The abundance of insectivorous birds, for example, generally declines in secondary habitats, while nectarivore abundance and species richness increases (Mason, 1996; Canaday, 1997). Thinning operations in particular, which are often carried out over large forest areas, cause considerable changes in the vegetation structure and the distribution of understorey insectivores (Waltert, 2000). In terms of SFM, avian guilds are therefore believed to provide an adequate measure for the long term conservation of forest habitats and their biodiversity (Parren & De Graaf, 1995).

Bird species diversity appears to be related to forest disturbance in a similar way, with a higher species diversity in logged forest and disturbed forest as compared to primary forest (Thiollay, 1992). Changes in bird diversity are most often due to loss of specialized bird species, which are replaced with more individuals of fewer (or more) generalist species (Devictor *et al.*, 2008; Kofron & Chapman, 1995). One of the characteristics of avian communities in tropical areas is the high number of species classified as endemics (Anderson, 1994; Stattersfield *et al.*, 1998; Boer, 2006). Endemic avian species diversity is highly sensitive to forest disturbance, such as logging (MacArthur & MacArthur, 1961; Henle *et al.*, 2004; Meijaard *et al.*, 2005). Meijaard *et al.* (2005) believe that there is an evolutionary explanation for the sensitivity of endemic bird species in Borneo to disturbance of forests, as these species have evolved in rainforest refugia during multiple ice-age cycles.

The various aspects of post-logging concession development have different impacts on habitats and the life-cycle of endemic bird species. As a group, birds are useful for evaluating the effects of logging on fauna, due to their well-established taxonomy and straightforward field identification characteristics, the availability of biological and ecological information on most bird families and many species, their apparent sensitivity to specific changes in forest structure, microclimate, composition and ecological role (e.g., pollination, seed dispersal and seed predation) (Fimbel *et al.*, 2001; Meijaard *et al.*, 2005). Meijaard *et al.* (2005) reported that birds typical of the canopy appeared to be more resilient, with the exception of the highly specialized Green Broadbill (*Calyptomena viridis*); i.e. frugivorous and nectarivorous species seldomly declined in logged forests. Groups that were affected by logging comprised of: 1) some extreme lowland specialist species, because logging in these forests is most intense (Black Hornbill *Anthracoceros* *malayanus*, Crestless Fireback *Lophura erythrophthalma*); 2) nomadic species or species requiring large areas (hornbills, raptors); 3) primary forest species, intolerant to logging disturbance (Great Argus *Argusianus argus*, some trogons (*Harpactes* spp.), some woodpeckers (Picidae), some babblers (*Kenopia striata* and *Napothera* spp.) and some flycatchers (*Cyornis* spp. and *Ficedula* spp.); and 4) species that require large tree cavities for nesting. Among the most frequently used criteria for conservation priorities are so called hot spots of endemism; areas which are rich in range-restricted bird species that are threatened with extinction (Balmford, 2002; Myers *et al.*, 2000; Reid, 1998; Stattersfield *et al.*, 1998; Meijaard *et al.*, 2005). Meijaard *et al.* (2005) suggest that endemic species can provide a useful tool to monitor the effects of logging, due to their vulnerability to disturbance. It is therefore important to consider possible changes in the number of individuals of each endemic bird species, as well as their relative representations.

The impact of logging and forest fires in East Kalimantan

Mechanized logging and additional destructive activities have created large areas of secondary forest in Kalimantan (Slik *et al.*, 2002; Meijaard *et al.*, 2005). Pressure on the forests by mechanized logging and massive transmigration has strongly increased in East Kalimantan during the past decades (Kartawinata & Vayda, 1984; MacKinnon *et al.*, 1996). Before 1970, human impacts on the forest ecosystem in Kalimantan had been relatively limited. Shifting cultivation was practiced around the villages at a sustainable level due to low human population densities, and because technical equipment, such as chain saws, was often insufficient or had not yet been implemented for large-scale operations (Slik *et al.*, 2002). This situation changed with the introduction of mechanized logging and the arrival of transmigrants from Sulawesi and Java in the late 1960s and 1970s (Kartawinata & Vayda, 1984). Forest destruction by human activities was no longer compensated for by forest recovery, while activities of logging companies further intensified and the immigration of people continued. This gradual degradation of the forests was aggravated by the dramatic events of 1982–1983 and 1997–1998, when large tracks of forest burnt down as a result of “El-Niño” (Eichorn, 2003; Meijaard *et al.*, 2005), a significant periodical change in the warm ocean current, which had caused an exceptional drought in East Kalimantan. At that time, mechanized logging and additional destructive activities had created large areas of degraded rainforest which were highly susceptible to fire during dry periods (Cleary, 2002; Slik & Eichorn, 2003; Meijaard *et al.*, 2005; Eichorn *et al.*, 2006). These fires were repeated during the recent drought in 2015 as a result of severe drought caused by the El Niño Southern Oscillation (Marlier *et al.*, 2015).

Main aim and research questions of the thesis

The main aim of my research is to identify and analyze the impact of logging on plant and avian communities in East Kalimantan, Indonesia, in a forest concession which is in the process of FSC certification in Berau and two external sites (Sungai Wain and Pusrehut). Until now, no quantitative evidence on plant and bird communities has been assumed in the absence of sufficient quantitative scientific data (Van Kuijk *et al.*, 2009). My research covers plant and bird diversity and abundance in the selectively logged forest with different logging histories in the Berau district, the Sungai Wain protected forest and the Pusrehut forest. I defined the following research questions:

1 What are the differences in vegetation structure and composition in selectively logged forest sites in comparison to primary forest? (Chapter 2)
2 What are the differences in plant species diversity by diameter class and plant functional type between selectively logged forest sites in comparison to primary forest? (Chapter 3)
3 What are the differences in avian community composition and species abundance between selectively logged forest sites in comparison to primary forests? (Chapter 4)
4 What are the differences in endemic avian species diversity and abundance between selectively logged forest sites in comparison to primary forests? (Chapter 5)
5 What indicators could be identified for monitoring purposes?
6 Does the process of FSC certification contribute to biodiversity conservation?

Research location

Geographical location

The Province of East Kalimantan in Indonesia is part of the island of Borneo (Figure 1.1). It covers approximately 21,144 million ha, which is about 14% of the total Indonesian land surface. Geologically, East Kalimantan consists mainly of tertiary sedimentary rocks (Mantel *et al.*, 2002). The soils are Alisols, but in the extensive limestone areas North of Sangkulirang, they are classified as Luvisols (Van Bremen *et al.,* 1990). Local patches of coarse sandy soils (podzols) are found, covered with heath forest (Kerangas). The province of East Kalimantan encompasses a variety of forest types comprising primary forest, secondary forest, mangrove forest, swamp forest, peat swamp forest, logged over forest and heath forest, stretching from sea-level up to 3,000 m elevation (Whitemore, 1984). Most of the remnant primary forest is characterized by an elevation up to 1,000 m above sea-level, although some mountainous ranges located above 1500 m can be found in the western part of the province. This combination of forest types has been well described for the Bornean provinces of Sarawak and Sabah (Whitemore, 1984).

The botanical diversity of Borneo is illustrated by the 84 families and 370 genera comprising at least one big tree species each (defined as either 35 cm dbh or over 20 m tall) listed by Whitmore *et al.* (1990). Ashton (1989) gives an estimate of 10,000-15,000 species of higher plants (spermatophytes) and states that the flora of Borneo and especially the province of Kalimantan is still under-collected. The botanic taxonomical surveys for Borneo by Sidiyasa *et al.* (1999) since 1991 up to April 1999 have added 181 families, 888 genera and 1,911 species to the collections of Kalimantan. These collections comprise mainly trees from the Balikpapan-Samarinda area.

Study sites

My research was carried out in three main study sites (Figure 1.1): 1) In the district of Berau in selectively logged forest sites, in PT. Hutansangam Labanan Lestari (PT.HLL), East Kalimantan. The largest share of the new company area belongs to the state-owned logging company of PT. Inhutani I, a forest concession in the process of FSC certification, 2) in the district of Balikpapan in the Sungai Wain protected forest, and 3) in the district of Kutai Kartanegara in the Pusrehut forest ex-logging concession. These study sites were each divided into different forest types as follows: i) In the district of Berau four sites were established; in primary forest (1 site) and selectively logged forest (3 sites), ii) in the district of Balikpapan in Sungai Wain protected forest only primary forest was sampled (1 site), and iii) in the district of Kutai Kartanegara I sampled an ex logging concession in the Pusrehut forest (1 site). These are the areas where semi-permanent plots had been surveyed for plant and bird diversities.

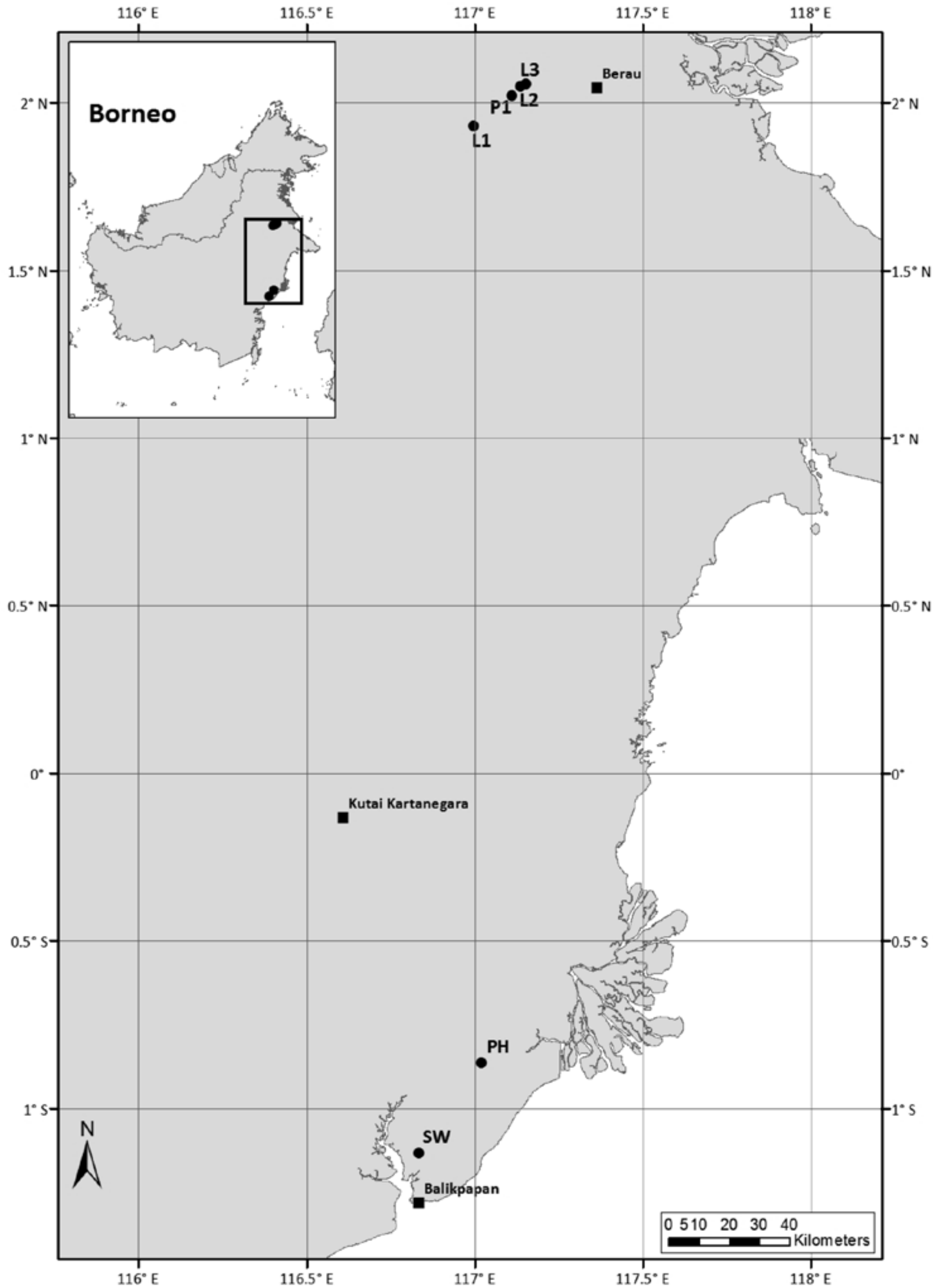

Figure 1.1
Map of East Kalimantan with the location of sampling points. P1 = primary forest site, L1 = logged in 2011, L2 = logged in 2007, L3 = logged in 2003, SW = Sungai Wain protected forest site (primary forest), PH = Pusrehut forest site (disturbed forest).

Berau district

The Berau District is located in the northeastern part of East Kalimantan Province. It covers approximately 2,558,205 ha. The location is between 1°45'- 2°10'north latitude and 116°55'- 117°20'east longitude (Fauzi, 2001). The total human population size of the Berau District is 179,444. The Berau District is divided into 13 sub-districts (http://id.wikipedia.org/wiki/Templat:Kabupaten_Berau). The study area is located in a lowland forest within the forest concession of PT. Hutansanggam Labanan Lestari (HLL) Labanan, East Kalimantan. The largest share of the new company area belongs to the state-owned logging company of PT. Inhutani I, which is one of the logging companies which have obtained FSC Certification for some concessions. PT. Inhutani I, Berau, East Kalimantan, is another one the process of FSC Certification (http://mutucertification.com/en /10-perusahaan-kehutanan-daftar-proses-sertifikasi-fsc).

Logging concession in Labanan

As mentioned, my study area is in the process of FSC certification. During the actual certification process, the logging concession in Labanan Forest Management Unit (FMU) is still a part of PT. Inhutani I (see Figure 1.1) is a government enterprise that is owned by the Ministry of Finance (Wardana, 2002). PT. Inhutani I obtained the concession, comprising a total area of 2.2 million hectares in 1976. In 1995, after a first concession period of about 20 years the Ministry of Forestry (MoF) extended the concession for the second period and the area was reduced to 1,185,249 hectares. The concession was divided into two units: Unit I Balikpapan area, which covers 444,133 ha and Unit II Tarakan area, which covers 741,116 ha. The Balikpapan Unit I was a controlled forest management unit with six plots, one of which (Labanan) covered 83,240 ha (Purbawiyatna, 2002). In April 2000, the director of PT. Inhutani I established the Labanan forest management unit as a self-managed unit. Within this unit, the effective area for timber production is about 63% of the total area; the remaining area was excluded from production, in consideration of other purposes. This excluded area consists of a transmigration area (1,978 ha), a community forest (7,122 ha) and a protection area (15,945 ha) according to Kuswandari (2004).

In the Labanan FMU several forest research projects have been carried out during the past decades, either by local institutions or under inter-governmental-collaboration, e.g. with the International Technological Center-ITC in Enschede, The Netherlands (Kuswandari, 2004). From 1989 until 1996, the STREK programme (Silvicultural Techniques for the Regeneration of logged over forest in East Kalimantan) focused on the development of sylvicultural and management rules leading to sustained productivity of the forest in East Kalimantan. The project was carried out under the authority of MoF through the Forestry Research and Development Agency and PT. Inhutani I with the assistance of CIRAD-forest (Fauzi, 2001). From 1996 to 2003, the Berau Forest Management Project (BFMP), led by MoF and the European Union aimed at developing, testing and promoting a replicable example of sustainable forest management at operational level. To support this project, the Ministry of Forestry and Estates designated the Labanan FMU as a special status area under decree No. 866/Kpts-II/1999 (Kuswandari, 2004).

Sungai Wain protected forest

The Sungai Wain protected primary forest (116.49 E, 1.06 S) is a water catchment area for the city of Balikpapan (Fredriksson & De Kam, 1999). It originally comprised c. 10,000 ha of Mixed Dipterocarp Forest (MDF). About half of the total area was burnt during the first half of 1998, while a central core area was protected from fire by the establishment of firebreaks. In this reserve, plant diversity was studied in unburnt and once-burnt forest (following Eichhorn *et al.*, 2006). The unburnt forest site was located in the central core area and had a very similar tree composition as other MDF in this region (Van Nieuwstadt, 2002; Slik *et al.*, 2003; Eichhorn *et al.*, 2006). The once-burnt forest site is located in the north-western part of the reserve. It was heavily damaged by the fires over most of its area, as could be concluded from the very few stems that survived the fires (Van Nieuwstadt *et al.*, 2001). This study site was therefore classified as having total fire damage, the most severely affected category of burnt forests (Siegert *et al.*, 2001). Despite being heavily affected, the area has been strictly protected since 2001, which allowed the forest to restore considerably, especially in the core area.

Pusrehut forest

The Tropical Rain Forest Research Center (Pusat Studi Reboisasi Hutan Tropika Humida; PUSREHUT) has become a center for studies on forest rehabilitation for many scientists from several countries, with a field station where students from multiple nationalities have conducted their academic studies. Mulawarman University (Universitas Mulawarman; UNMUL) at Samarinda, the capital of East Kalimantan, is one of the National Public Universities which was founded in the early 1970s. A priority in research at this university is research on the rehabilitation of tropical rainforest. As a result of the involvement of the Japan International Cooperation Agency (JICA), in 1979 the Tropical Rain Forest Research Center was jointly established in East Kalimantan. Most of the Research

Center's forest consists of planted trees of *Dipterocarpaceae pp*. species and fruit tree species.

Thesis outline

The thesis comprises six chapters as follows: Chapter 1 provides a general introduction and review of the study topic. It presents the research questions to be addressed and describes the study sites. Chapter 2 deals with structure, composition and diversity of plant communities in FSC-candidate, selectively logged forests of different ages compared to primary rainforest. In this Chapter I examine the structure and composition of forest plots under different logging regimes by assigning species to life forms. Chapter 3 discusses plant communities in FSC-candidate, selectively logged forests compared to primary forest in relation to stem diameter and plant functional types. In Chapter 4 I elaborate on the response of avian communities to FSC-candidate logging in East Kalimantan. Chapter 5 specifies the impacts of FSC-candidate logging in tropical lowland rainforest on endemic Bornean avian species. Chapter 6 provides a general discussion and conclusive remarks on my findings and other available plant and bird data from FSC-candidate selectively logged forest sites of different regime histories. I further formulate recommendations on how these data could be applied to future efforts in the field of plant and bird conservation.

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