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

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Citation

Arbainsyah, A. (2016, December 6). *The impact of sustainable forest management on plant and bird diversity in East Kalimantan, Indonesia*. Retrieved from <https://hdl.handle.net/1887/44704>

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Issue Date: 2016-12-06



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Synthesis

General discussion

Van Kuijk *et al.* (2009) suggested that there is no quantitative evidence of an impact of FSC-certified logging on biodiversity. In East Kalimantan, primary rainforests are under considerable pressure from both legal and illegal logging activities, which has led to fragmentation and degradation of the remaining tropical rainforests. Additional pressure on these forests arises from landless farmers, who practice shifting cultivation (Slik *et al.*, 2002; Meijaard *et al.*, 2005). The question now arises whether FSC certification standards are helping to conserve the biodiversity which is still contained within these forests or are as detrimental as conventional logging practices. To address this issue, I studied the response of plant and avian communities to logging in selectively logged forest sites as compared to primary forest sites in lowland rainforests of East Kalimantan, with a particular emphasis on plant diversity, forest structure, and avian communities.

One of the characteristics of avian communities in tropical rainforest is the high number of species classified as endemic (Anderson, 1994; Stattersfield *et al.*, 1998; Boer, 2006). Since endemic avian species diversity has been demonstrated to be highly sensitive to disturbance such as logging (MacArthur and MacArthur, 1961; Henle *et al.*, 2004; Meijaard *et al.*, 2005), impact studies using birds could provide valuable information on the status of forest disturbance (Ghazoul & Hellier, 2000; De Iongh & Van Weerd, 2006; De Iongh & Persoon 2010).

Field research

My study was restricted to one forest concession with several logging histories in the Berau district and two external forest sites: one site in the district Balikpapan and one site in the district Kutai Kartanegara, East Kalimantan. This has resulted in a relatively small scale study in a forest concession which was in the

process of FSC certification. Because of the small scale and the fact that full FSC certification was not yet obtained in the Berau concession the conclusions of my study should be handled with care. The secondary forest sites in this concession had been selectively logged in 2003, 2007 and 2011. In addition, I selected one primary forest site in the Berau concession, one primary forest site in the Sungai Wain protected forest in Balikpapan, and one disturbed forest site in the Pusrehut forest, situated in the Kutai Kartanegara region (see Chapter 1 for more details). I realize that these sites were far apart and that the Berau sites were more similar than the other external sites. However all sites were classified as tropical Dipterocarp lowland forest and in that sense belonged to the same habitat type.

Structure, composition and diversity of plant communities

In order to obtain a complete overview of possible changes in forest structure, I sampled all trees, saplings and seedlings in all forest sites (Appendix 1 to 3). Tree densities were significantly lower in the sites logged 1 and 5 years ago, while sapling and seedling densities were not significantly different among all forests sites (Table 2.3, 2.4 and 2.5). Dicot trees accounted for a higher plant diversity in the primary forest site, while the number of species of palm trees was higher in some of the selectively logged forest sites, especially in the forest site logged 10 years ago. Regarding saplings, only treelets accounted for a higher overall plant diversity in the primary forest site, while the number of species of lianas, shrubs and herbaceous plants was higher in the selectively logged forests. Seedlings, palm lianas (rattans) accounted for a higher overall plant diversity in primary forest, while the number of species of monocots (lianas and herbs), dicots (trees, lianas and shrubs), and ferns (trees, lianas and herbs) was higher in the selectively logged forest sites. The enhanced light conditions created by the numerous gaps in the canopy most likely caused this effect; pioneer species especially tend to respond to improved light conditions by growing faster than species of later successional stages (Arbainsyah, pers. obs., Bazzaz & Pickett, 1980; Uhl & Clark, 1983; Swain & Whitmore, 1988; Vazques-Yanes & Orozco-Segovia, 1993; Slik *et al.*, 2002; Eichhorn *et al.*, 2006).

The density of small tree seedlings was highest in the primary forest site in Berau, while the density of liana seedlings was two times higher in the selectively logged forest sites (Figure 2.2). Slik *et al.* (2002) reported similar results. Densities of life forms such as herbs and shrubs were more than two times higher in the selectively logged forest sites (Figure 2.2, Table 2.5). In the selectively logged forest sites, pioneer species were dominant, probably as a result of the dramatic increase of light penetrating to the forest floor after logging. Several studies showed

that pioneer species occur only after disturbance, when the light or temperature levels are raised substantially (Bazzaz & Pickett, 1980; Uhl & Clark, 1983; Swain & Whitmore, 1988; Vazques-Yanes & Orozco-Segovia, 1993; Eichhorn *et al.*, 2006). Particularly the pioneer *Macaranga hypoleuca* was very dominant in the selectively logged forest sites. Similarly, after logging regeneration is generally better when a forest logged previously has been occupied by successional vegetation (Slik *et al.*, 2002; Meijaard *et al.*, 2005). My findings suggest that selectively logged forest could recover, provided that further destruction by landless farmers is strongly reduced. This is also confirmed by the fact that the studied forest sites had been selectively logged, and tree species diversity was found to be higher in the diversity of plants, and to have more or less the same value in the number of species although in a different growth stage (Table 2.2). Previous logging of our forest sites had not resulted in permanent deforestation.

My study further showed that overall tree densities were significantly higher in the primary forest site than in the forest sites selectively logged 1 and 5 years ago, but approximately similar to that in the forest site logged 10 years ago, which is in accordance with other scientific findings (Slik *et al.*, 2002; Sist *et al.*, 2003), suggesting that the impact of selective logging was similar for the three sites. Although the forest structure was affected in some of the selectively logged forest sites, in the forest site logged 1 and 5 years ago, species numbers were not much lower compared to the primary forest site. In addition, a comparison of vegetation in the four forests sites suggested that in terms of species composition and diversity selective low impact logging largely compensated for the strong negative impact of initial logging. Our results therefore suggest a sufficient level of tree species regeneration, as was observed at several sites in East Kalimantan (e.g. Siegert *et al.*, 2001; Slik *et al.*, 2002; Yassir *et al.*, 2010).

Plant species diversity in relation to stem diameter and plant functional types

Ten years after selective logging, vegetation succession appeared to have reached a stage which was sufficiently developed to study forest recovery based on patterns in forest structure, tree species composition, and tree species diversity in relation to stem diameter and Plant Functional Type. So far, there are few scientific studies reporting on these parameters after logging. 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 intact vegetation structure and the absence of removed tree stems were most pronounced in the primary forest site, whereas in forest sites logged 1 and 5 years ago the number of tree stems was

lower than in the primary forest site (Table 3.1). In addition, my study showed significant differences between the abundance of tree stems in the small diameter class and in tree species richness in the selectively logged forest sites compared to the primary forest site, with higher tree species diversity in the primary forest site (Table 3.2 and 3.3).

The plant functional types (PFT) of the four forest sites (primary forest, forest logged selectively 1, 5 and 10 years ago) were studied by calculating tree numbers as the sum of trees counted in the three PFT classes (light, medium and heavy hardwood: see Chapter 3 for further details). These three classes reflected a high degree of contrasting ecological plant functional types; i.e. most abundant species were often referred to the classes of “light and medium hardwood”, while few species were classified as “heavy hardwood” (Table 3.5). A comparison of the primary forest site and the selectively logged forest sites regarding the PFT showed that the abundant tree stems were largely dominated by pioneer species, while the PFT of tree stems were dominated by light wood (Figure 3.2, Table 3.5). Tree stem densities and tree species abundance of the “heavy hardwood” PFT were significantly lower in forest sites selectively logged 1 and 5 years ago compared to the primary forest site, while tree stem densities in the “light hardwood” PFT and tree species abundance were higher in forest sites logged selectively compared to the primary forest site (Figure 3.2, Table 3.5). This is partly the result of large differences in the classification of PFT among the selectively logged forest sites and the primary forest site. Secondary succession has also been described in terms of replacement of tree stems of different tree density classes (Brown & Lugo, 1990; Verburg & Van Eijk-Bos, 2003).

In the selectively logged forest sites, the species *Shorea parvifolia*, appeared to be one of the few Dipterocarp timber trees which were still present 10 years after selective logging (Table 3.4), thus being able to endure logging pressure and surviving during post logging succession. While many other species were reduced in density by logging, *Shorea parvifolia* is likely to further recover in the selectively logged forest sites. Further regeneration of the PFT classes depends on the available stock of small stems of seedlings and saplings in the selectively logged forest sites (Arbainsyah *et al.*, 2014).

My results show that selective logging mainly affects the smallest tree stems up to 30 cm dbh of the forest understorey and mid-levelstorey as well as the class with stems between 70 and 80 cm of the emergent trees in the upperstorey, due to the negative relation between tree stem diameter and plant functional types. In the selectively logged forest sites, this PFT-related pattern might also result in selective extinction of certain tree species/genera because of differences in

the tree species composition among PFT classes between the primary forest site and secondary forest sites. It is therefore likely that, although tropical rainforests could recover from selective logging to some extent through the process of succession, their species composition will change considerably for a long time after logging. Evidence from my research suggests that it could take at least 10 years for forests to recover from heavy/intermediate logging to primary forest. This finding is confirmed by other authors who reported on tree species composition in tropical rainforest (e.g. Slik *et al.*, 2002; Verburg & Van Eijk-Bos, 2003).

Response of avian communities

Chapter 4 discusses the impact of selective logging on bird communities in secondary forest sites as opposed to a primary forest site. I analyzed the response to logging in terms of species richness, bird abundance and bird diversity (Shannon and Evenness indices) (Jost, 2006). I used point counts to assess bird species presence (Bibby *et al.*, 2000). In total I established 30 point counts, 2×5 in the primary forest, 15 in forest sites logged selectively and 5 in the disturbed forest site (for further details see Table 4.1) and for comparison of bird abundance in total 5 point counts during 8 visits in all sites (see Appendix 4). My aim was to test if I could find quantitative evidence of any impact from the FSC certification process on plant and on avian communities and to compare my results to Van Kuijk *et al.* (2009), who did not find any evidence for this. My study shows a significant difference in the mean abundance of birds observed per visit per site between two groups of forest plots: the primary forest sites had a higher number of individual birds than the secondary forest sites (Table 4.2, Figure 4.2). This difference in abundance is probably related to the fact that the primary forest sites provide more food resources than the non-primary forest sites (Slik & Van Balen, 2006).

The mean abundance of both the terrestrial avian guild and the arboreal guild was significantly higher in the primary forest sites compared to the secondary forest sites (Table 4.3). At the feeding guild level, I found a higher abundance of frugivores/insectivores in the primary forests compared to the secondary forests (Table 4.4, Figure 4.5). Although this finding differs from other studies (e.g. Johns, 1996; Van Hoesen *et al.*, 2000; Pieterse & Wielstra, 2005; Wielstra *et al.*, 2011), it could be an indication of a positive impact of the FSC certification process on bird species diversity

The suggestion that a reduction of the understorey layer could strongly reduce the availability of food sources for certain birds (Karr & Brawn, 1990; Mason,

1996; Pieterse & Wielstra, 2005; Slik & Van Balen, 2006) was supported by my finding that the composition of the frugivorous / insectivorous guild differed between primary and secondary forest sites. Comparisons of both forest types with respect to bird diversity expressed as species richness or as diversity indices (the Shannon index and Evenness index), did not provide any significant differences however, indicating that the impact of selective logging on bird communities was relatively low, as was also suggested by Johns (1996), Van Hoesen *et al.* (2000) and Wielstra *et al.* (2011) in their studies of Bornean bird communities.

Endemic avian Bornean species

The ratio between endemics and all species appeared to be significantly different for the insectivorous guild (Table 5.3). I also found a significantly higher abundance of insectivores in the primary forest sites as compared to the secondary forest sites. The Bornean Ground-cuckoo (*Carpococcyx radiatus*) and Bornean Blue Flycatcher (*Cyornis superbus*) were especially abundant in the primary forest sites. Both species were absent in the secondary forest sites (Table 5.1).

The higher abundance of the insectivorous guild in the primary forest site compared to the secondary forest sites which I found was confirmed by previous studies which demonstrated a negative impact of logging on the insectivorous guild (Mason, 1996; Pieterse & Wielstra, 2005; Slik & Balen, 2006; Arbainsyah *et al.*, 2015). Species richness of endemic avian Bornean species, however, was not affected by logging, indicating a rather low level of disturbance by selective logging.

Conclusions

The following conclusions can be drawn from this study:

What are the differences in vegetation structure and composition in selectively logged forest sites in comparison to primary forest? (Chapter 2)

- 1 As predicted, the sapling vegetation disclosed a high diversity in the selectively logged forest which was in the process of FSC certification, represented by the newly regenerated species *Madhuca malaccensis*. Stems were two times more abundant in the selectively logged forest sites than other species in the forest site logged 5 years ago compared to the primary forest site.
- 2 As ingrowth of seedling vegetation represented by some new pioneer species in the selectively logged forest sites, newly recorded plants, such as *Maca-*

ranga hypoleuca, as it was fast-growing and particularly abundant in the selectively logged forest sites compared to primary forest. I therefore conclude that seedling vegetation will support the species richness regeneration in the selectively logged forests of my study.

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)

- 1 Selective logging mainly affected the smallest tree stems up to 30 cm dbh of the forest understorey and mid-levelstorey, and trees with stems between 70 and 80 cm dbh of the emergent trees in the upperstorey, with a clear negative relation between tree stem diameter and plant functional types.
- 2 Due to the relation between tree stem diameter and plant functional type classes, in the heavy hardwood class tree stem and species richness were more affected in the selectively logged forest sites under process of FSC certification (1 and 5 years ago) compared to the primary forest site. This is partly the result of large differences in the classification of PFT among selectively logged forest sites.
- 3 The species of *Shorea parvifolia* which is one of the main Dipterocarp timber trees was still present 10 years after selective logging under the process of FSC certification. This species contributed for 15.3% to the tree stem abundance in the light wood plant functional type, with a significantly higher tree stem density in the forest sites selectively logged 1 year ago as compared to the primary forest site. This species is one of the main Dipterocarp timber trees that may have been a target species for logging in the past.

What are the differences in avian community composition and species abundance between selectively logged forest sites in comparison to primary forests? (Chapter 4)

- 1 As species richness and mean abundance of birds were not affected by selective logging, I conclude that selective logging will not change species richness and mean abundance of birds in the Berau concession of my study.
- 2 The higher abundance of birds of the terrestrial guild in some foraging layers of the primary forest site as compared to the secondary forest site in my study, suggests a negative impact of selective logging and disturbances on the forest upperstorey.
- 3 As predicted, the abundance of frugivorous / insectivorous birds was significantly lower in the secondary forest sites compared to the primary forest sites. I therefore conclude that primary forest in the Berau concession more effectively supports the existing bird populations compared to forests that are selectively or non-selectively logged.

What are the differences in endemic avian species diversity and abundance between selectively logged forest sites in comparison to primary forests? (Chapter 5)

I found that the endemic insectivorous birds were more abundant in primary forest sites as compared to secondary forest sites, which confirms earlier findings on the impact of logging on avian endemic communities in East Kalimantan.

What indicators could be identified for monitoring purposes?

The process of FSC certification coincides with similar bird species diversity, but lower tree species diversity in secondary forest sites.

Does the process of FSC certification contribute to biodiversity conservation?

The set up of my research does not allow to draw hard conclusion on the impact of the process of FSC certification. However, in terms of plant species and bird species diversity there are no large differences between the Berau concession with different logging histories and the two external sites (Sungai Wain and Pusrehut).

Perspectives for future research

My research showed that most of the original plant and bird species richness had been conserved after selective logging in secondary forests, suggesting logging under a process of FSC certification had no detrimental effects, at least not on most of the species and guilds I studied. Based on this, I could recommend the currently proposed FSC (and LEI) logging strategies as effective SFM. Although some conclusions may be applicable only to the situation in East Kalimantan, they provide a valuable basis for the establishment of indicator-based strategies for biodiversity conservation. Such indicators could include a) Plant abundance; b) Sapling lianas abundance and species richness; c) Fern herb species richness; d) Avian abundance and d) Avian frugivores/insectivores. Studies on other taxa, such as butterflies or mammals as possible indicators of biodiversity loss and these could further enhance our understanding of the impacts of logging practices on tropical rainforests. (Ghazoul & Hellier, 2000; Landers *et al.*, 2004; Azevedo-Ramos *et al.*, 2002; Sheil *et al.*, 2004). Building on my findings, future studies could further elaborate on the underlying processes explaining changes in plant and bird diversity in response to forest disturbances, to formulate recommendations for sustainable forest exploitation. An interesting example of such a study would be one covering the relationships between plant diversity and bird diversity and their response to logging. Van Kuijk *et al.* (2009) concluded that there is no quantitative evidence that FSC-certified logging has an impact on biodiver-

sity conservation. My study detected a relationship between plant diversity and bird diversity.

Another important question which should be further exploited in future studies, is how plant and bird diversity relates to certain patterns in forest recovery and succession. Such studies could provide valuable comparative data, especially when methods are similar to the ones used in my study. To further enhance results acquired from such studies I would however advise to increase the sampling area targeted. My research showed the impact of logging 10 years after logging. At that time, plant diversity was still high in the selectively logged forests, although the forest structure was affected in some of the selectively logged forest sites, especially in the forest site logged 1 and 10 years ago (see Chapter 2 and 3). Bird abundance was higher in the primary forests, although I found a few differences in the feeding guilds composition between primary forests and secondary forests, which confirms earlier findings on the impact of logging on avian endemic communities (see Chapter 3 and 4). My results revealed that secondary forest sites could recover considerably when they were left undisturbed for a period of 10 years, although some species became less abundant during this time span. Recovery time spans longer than ten years may reveal to what extent selective logging leads to long term extinctions, but also how long it would take to reach a stable state of succession and if changes in plant and bird diversity are related to changes in the biodiversity. Ideally, future research should aim to integrate multiple aspects of biodiversity and ecological processes.

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