Disappearing forest species and altered guild composition: bird community responses to land transformation in Jambi, Sumatra, Indonesia

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Abstract

The increasing demand of high-valued agriculture products causes a rapid land use change in the tropics. In Sumatra, Indonesia, the majority of the lowland rainforest has been transformed into agricultural land. Oil palm *Elaeis guineensis* and rubber *Hevea brasiliensis* are two dominant crops in the Jambi province, sharing a significant proportion of land use. Monocultures of both crops dominate, interspersed with rubber agroforests, and a few forest remnants. Here we assess the relative importance of these habitats for birds in the new, human-dominated landscapes of Jambi Province. In two landscapes of the province, we conducted bird point counts in a total of 32 plots within 4 different habitats: lowland rainforest, jungle rubber, monoculture rubber plantation, oil palm plantation. In total, we identified 71 species from 24 families occurring in forest habitats and the anthropogenic landscape. Overall species richness decreased successively from the rainforest, jungle rubber, monoculture rubber, to the oil palm plantation. The habitat change affected avian guild composition. Frugivorous birds disappeared from monoculture rubber and oil palm. In the studied agricultural land use systems jungle rubber plays an important role in harboring forest bird species. Among monocultures, rubber supported a higher number of species compared to oil palm. To protect and maintain the remaining forest cover, including degraded/secondary forest and jungle rubber is thus of utmost importance.

Keywords: Agroforestry; Jungle Rubber; *Hevea brasiliensis*; Oil Palm; Southeast Asia

1. Introduction.

The land use change is inevitable in this growing world. The growing human population, increasing wealth and the development of global markets, lead to increasing demands of nature products, and, in order to fulfill this, land use transformation continues (Schroth 2004). The expansion of agriculture and the change towards modern agricultural practices increase the capacity to provide resources for mankind, but also endanger other species as well as the capacity of the ecosystem to continue deliver services (Foley et al. 2005; Tilman 2001).

The quest for more cropland has put more pressure on tropical regions, which often offer lower production cost and less environmental regulation (Gibbs 2010). Tropical lowland forest is one of biodiversity-richest terrestrial ecosystem, yet it is vulnerable to transformation. Recently, with the continuing expansion of monoculture plantation, the biodiversity in Southeast Asia, in particular, is in a fragile state.

The island of Sumatra is one of the major regions within Southeast Asia where rapid land use change has taken place. Cash crops such as Pará rubber *Hevea brasiliensis* Mull. and oil palm *Elaeis guineensis* Jacq., have been introduced in the early 1900s during the colonization era (Potter & Lee 1998; Feintrenie & Levang 2009). It was not until 1920s that the island experienced a rubber boom. With the high demand of rubber latex, followed by high prices, farmers planted rubber into their swidden cultivation and transformed it into jungle rubber (Gouyon et al. 1993; Feintrenie & Levang 2009). The presence of monoculture rubber plantation appeared since 1950's. In 1980's, alongside with the government transmigration program, oil palm plantations started to take its place in the land use change (Potter & Lee 1998; Feintrenie et al. 2010).

In the recent decades, palm oil, widely used in foods, cosmetics and many other industrial products, has been one of the fastest growing commodities in the world, At present, Indonesia is the top producer for palm oil with 31 million Metric Tons, accounting for 53.4% of the world supply. Together with Malaysia, both countries contribute up to 86% of the world palm oil demand (http://www.fas.usda.gov/oilseeds/Current/; Fitzherbert et al. 2008). A remote sensing study by Koh et. al. (2011) suggests that the total area of 8.3 million ha is occupied by closed canopy oil-palm plantations in Indonesia and Malaysia (Sumatra 3.9 million Ha, Borneo/Kalimantan 2.4 million Ha, and Peninsular Malaysia 2 million Ha). It is also known that in Indonesia itself at least 56% of this transformation was originally from forest (primary, secondary or plantation; Koh & Wilcove 2008). The massive loss of the island's forest recorded during 1990-2000 still continues (Margono et al. 2012). In 2010, 70% of Sumatra forested area has been converted (Margono et al. 2012), while Indonesia's annual forest cover loss was still estimated to be the highest in the world (Hansen et al. 2013; Margono et al. 2014). Plans by the Indonesian government to double its Palm oil production by 2020 suggest this trend will continue (Koh & Ghazoul 2010).

Birds are important components of tropical biodiversity. They are appreciated for their song, appearance and spiritual value by humans, including locals and the wider birdwatching community. Birds exert important functions in the food webs, both in forests and in agricultural crops, including oil palm (Koh 2008; Maas et al. 2013). In general, decreases in bird species richness towards land transformation, especially in the forest species, have been observed (Beukema 2007, Clough et. al. 2009). Recent studies also show that the groups most affected groups by forest transformation are the frugivorous-nectarivorous, insectivorous, and interior forest specialist species (Thiollay 1995; Waltert et al. 2003; Clough et al. 2009).

Here we investigate the effect of dynamic land use change driven by deforestation, and the shift towards monocultures, on the abundance and species richness of the bird community, as well as the abundance of birds of different feeding guilds. We conducted bird point counts in 32 plots of 4 different systems: lowland forest, jungle rubber, rubber plantation and oil palm plantation, which are the main elements of the landscape mosaic in Jambi. We expect that bird species richness is highest in forest and lowest in the structurally simpler, monoculture agricultural land-uses. We also expect a significant change in the species community with some guilds, with most feeding guilds following the overall patterns of abundance and species richness, but with some groups, such as feeding generalists, potentially reaching higher abundances in the monocultures.

***2. Materials and methods*.**

2.1 Study sites

The study sites are located in the surroundings of two forest landscapes in Jambi Province, Sumatera, Indonesia. These are Bukit Duabelas (approximately 60,500 Ha) and Harapan (approx. 46,385 Ha), which are separated by around 50 km. The 32 study plots, 50mx50m in size, with 16 plots per landscape, were established on lowland rainforest and 3 transformed habitats: jungle rubber *Hevea brasiliensis*, monoculture rubber plantation and oil palm *Elaeis guineensis* plantation. The last two habitats together will be referred as plantation afterwards.

Lowland rainforest sites are best described as old-growth forests that have been experiencing some degree of disturbance, but are close to their original state. Jungle rubber is planted rubber with secondary forest re-growth and minimum management practices (Feintrenie & Levang 2009). This land use type has existed since the early 1920’s, when the region experienced a rubber boom (Gouyon et al. 1993; Feintrenie & Levang 2009; Martini et al. 2010). Rubber plantation and oil palm plantation is a form of intensively managed monoculture plantation covering an extensive area in the landscape. According to 2010 government data, in Jambi, rubber (not being distinguished between jungle rubber and monoculture) covers 1.284.003 Ha and Oil palm covers 941.565 Ha, both sums up to more than 45% of anthropogenic land use cover (http://jambiprov.go.id/index.php?letluaswil).

2.2 Bird survey

Bird data was collected using the point count method. The points were located in the center of the 50x 50 m plot and all birds within the radius of 20m-28.18m (depends on its position towards the plot) from the center were recorded. Individuals outside the plot or flying above the canopy were excluded from the analyses. Each plot surveyed during study time June-July 2013, ideally during a clear day. From the total 32 plots, 5 were visited 3 times only, due to bad weather conditions, while all other plots were visited 4 times.

Birds were surveyed between 6.00 to 10.00 h by WEP using *7x42mm* binocular (*Nikon Monarch)*. The counting time spent at each point count was 20 minutes. Species identity, number of individuals, observed behavior, position of vegetation layer utilized, distance towards center of the plot- measured by digital rangefinder (*Nikon Laser 1000AS)*. The timing of bird data collection alternated between early and late morning so that all plot were counted during both portions of the morning to minimize the bias due to the observation time (Ralph et al. 1995, Gregory et al. 2004). Unfamiliar bird calls were collected using a directional microphone coupled to a digital sound recorder. The recording was later compared with the available online voice database (www.xeno-canto.org and www.soundefforts.uni-goettingen.de). Specific behavior of the birds was be noted and used in further discussion. Bird species identification follows Mackinnon, Phillips & van Balen (1998).

2.3. Bird guilds classification

Detected bird species were classified into groups based on the primary diet and habitat preference (forest vs non forest). This classification is primarily based from Thiollay (1995) and Beukema et al. (2007), and field observations.

2.4 Data analysis

To tackle the issue of differing number of visits, we calculated the mean number of individuals detected per visit for abundance data, and expected number of species after three visits (the minimum per site) using the specaccum function (vegan package for R, Oksanen et al. 2013). We fitted a linear model (glm) with first, mean number of individuals detected per visit, and secondly, the expected number of species as a response variable. The categorical explanatory variables were land use and landscape, as well as their interaction terms. P-values for the interaction between the two categorical terms, as well as their main effects, were obtained using likelihood-ratio tests based on comparisons between model with and without the term (or interaction) to be tested, with other terms remaining in the model. The full model was assessed using diagnostic plots. Whenever land-use was significant we fitted a model with land use as the only explanatory variable and conducted a Tukey post-hoc test (R package multcomp, function glht, Hothorn et al. 2008).

We only include fully identified individuals to the species level for the data analysis. Aggregate data of two landscapes were analyzed first, and then separated for each landscape. On the feeding guild analysis, we use the abundance data to calculate the relative proportion of each feeding guild, by aggregating abundances for each landscape and then dividing these data with the total abundance on the same landscape. To visualize the bird community composition we did non-metric multidimensional scaling (NMDS) on abundance data in R with package vegan. All analyses were carried out using R software version 3.1.0

3. Results

Based on our counts, we detected a total of 421 individual birds representing 71 species and 24 families. Among them, 11 individuals remained unidentified. There is no significant difference of mean abundance per visit that could be explained by different land-use systems (GLM, LRT test, all P values >0.1). Expected richness after three visits differed significantly between land-uses (GLM, LRT test, P=0.032). The forest differed marginally non-significantly from the plantations (GLM, Tukey posthoc, P values < 0.10, Fig.1)

The species richness declines from forest to the simpler systems, with forest harboring more than twice number of species compared to the oil palm. The highest number of species (leveled at 3rd visits) was detected in forest (36), followed by jungle rubber (25 species), rubber (24) and oil palm plantation (16). Of the 71 species detected, 26 species were found exclusively in the forest, with 24 of them being forest species. Six species were found only in jungle rubber (four of them being forest species), Seven species only found in rubber (two of them forest species), and Six species only found in oil palm (none of them forest species).

3.1 Richness: different landscape trends

On the landscape level, At Harapan, the expected species richness explained by the landuse (GLM; LRT Pr(>Chi)= 0.001), the forest differs significantly with the plantations (Tukey posthoc test, P<0.01), and marginally with jungle rubber (Tukey posthoc test, P<0.1), while that’s not the case for Bukit Duabelas (GLM, LRT Pr(>Chi)= 0.91) (Fig.2a and 2b). In Harapan, the decline of observed richness (leveled at 4th visit) was more pronounced than Bukit Duabelas, with 30 species found at the forest, followed by jungle rubber (18 species), rubber (11 species), oil palm (10 species). While at Bukit Duabelas landscape (leveled at 3rd visit), 20 species found at the forest, 13 species at jungle rubber, 17 species at rubber monoculture and 12 species at oil palm (Fig. 2c and 2d).

3.2 Richness: feeding guilds

Feeding guilds proportions differed between habitats. Even though declining in numbers, some frugivores were still detected in the jungle rubber, but no in the monoculture rubber and oil palm. There is increasing trend of nectarivore in term of feeding guild proportion when we shift from forest to jungle rubber then to rubber, but not on the oil palm plots (Fig.3). Nectarivores peaked in term of abundance and richness on monoculture rubber.

3.3 Community composition

Two dimensional ordination based on abundance data on the study sites (Fig.4, NMDS stress value=0.18) showed the relative position of the bird community on the studied landscape. The forest community well separated from the other. Clear overlap was shown for jungle rubber and monoculture rubber, and slight overlap between monoculture rubber and oil palm.

4. Discussion

Overall species richness decreased towards simpler systems, along with the disappearance of forest species. Feeding guilds affected from land use change, with frugivorous birds being absent from the plantations. The presence of forest and jungle rubber is important for biodiversity.

4.1 Observed richness and fading forest species

As predicted, the bird species richness declined from forest to the transformed habitat. This declining pattern was also observed in other studies (Thiollay 1995; Waltert et al. 2004; Aratrakorn 2006; Beukema 2007). In the studied landscape, the forest sites harbored more than twice number of species compared to the oil palm sites, which were the poorest transformed habitat in terms of bird species richness.

Bird species dependent on forests, are, of course, expected to be scarce in plantations (Beukema 2007; Maas et al. 2009; Sodhi 2010). These are much simplified habitats with a limited diversity of food and resources. As a result, less adapted species was not able to cope up with the change. Nevertheless, species richness does not always reflect the habitat change, and therefore there is a need to look further into species identities such as forest species (Maas et al. 2009). In Sumatra, where endemism is low at 5% of total species (MacKinnon, Phillips & van Balen 1998), other species identities should be weighed higher or deserve more attentions (Beukema et al. 2007). In the studied landscape, species groups that went missing along the transformation of forest are hornbills, trogon, barbets, woodpecker, flycatchers, and some babblers. Jungle rubber was able to maintain less than half number of the forest species in the forest plots. Whereas at the plantations, the number of forest species survived was devastating, summing only six species in monoculture rubber and single species in oil palm. The lack of large canopy trees (for hornbills), standing dead wood (for woodpeckers), understorey growth (for babblers and understorey foragers), might have greatly affected these forest species (Thiollay 1995; Sodhi et al. 2010).

4.2 Landscape variability

The expected species richness in the forest habitat in Harapan differs significantly from richness within the transformed habitats (P value <0.05, Tukey test) and marginally with jungle rubber (P value <0.1, Tukey test), and in general the observed richness declined sharper. In Bukit Duabelas the expected richness is not differ significantly (P value>0.1, LRT test) (Fig.2a; 2b),. Based on the expected richness, forest plots in the Harapan landscape were generally richer in species (mean=8.69) compared to Bukit Duabelas (mean=5), but not significantly differ (t-test, P>0.1). If the forest plots are considered as a source of species flux to the other habitat, then the difference in initial richness may contribute to the differences in trends between the landscapes.

Another possible influencing factor is the distance from the forest fragments, which has already pointed as influencing the bird communities, for example in the

Sulawesi cacao agroecosystems (Clough et al. 2009). In Bukit Duabelas landscape, forest plots are located in the proximity of the transformed plots, except for two plots (BF3&BF4). In contrast, in the Harapan landscape, forest plots are approximately 25km away from the transformed plots.

4.3 The importance of jungle rubber and rubber monoculture plasticity

The result suggests that among the transformed habitat on the study site, jungle rubber still plays a crucial role in maintaining bird species, particularly for forest species that cannot survive in much structurally simpler habitat (Fig.1, Fig.5). The number of forest species encountered in jungle rubber (14 species) was more than twice that encountered in both monoculture plantation habitat types joined together (6 species). As a buffer (Beukema 1998), jungle rubber favors the forest bird species due to its vegetation structural complexity, which resembles secondary forest more than the other types of land-use (Gouyon et al. 1993; Schroth 2004).

Among the plantations, monoculture rubber, with its physical properties such as tree height, canopy structure, and floral sets, still offers certain number of resources to be utilized by bird species. As shown in Bukit Duabelas, where rubber plantation observed to support more species in total compared to jungle rubber (Fig.5). One explanation about the ability of *Hevea brasiliensis* plantations to support numerous species is the temporary food resource that available during the blooming weeks. At this period, coincident with the observation period, large scale nectar source is accessible in the landscape (pers. obs.). Compared to structurally simplified oil palm, the presence of tree structure and branch architecture may also benefit the birds. Lambert (1992), asserted that in the logged forest, there is tendency that several species were able to shift their foraging height in response of the available habitat. Though how far this canopy height reduce could be tolerated is depends on each species requirement, and there would be certain threshold where the species could not pass to lower height.

Despite being perennial habitats, plantations are too simplified in terms of number of species and vegetation to resemble forests, and as observed, only supported few forest species. But keeping it at small scale, accommodating diverse plantation, and favoring plantation with tall trees and undergrowth, might promote its function. However, to what extent is the plantation's capacity to "capture" bird species could not be detangled from the surrounding matrix. And as been asserted in Tscharntke et al. (2011), the existence of forest together with agroforestry is crucial to allow species movements. Further research on the species flux among these habitats is needed.

4.4 Feeding guild dynamics

Frugivores have been identified as one of the taxa most affected by land-use change (Thiollay 1995; Waltert et al. 2004; Clough et al. 2009; Sekercioglu 2012; Chang et al. 2013). On the study site, the proportion of frugivores greatly decreased in jungle rubber plots compared to forest plots, and was reduced to zero in the monoculture plantations. This result was consistent with the findings from Thiollay (1995) in Sumatran agroforest, and Li et al. (2013) in Hainan rubber plantation. The availability of food for these species, which fluctuates strongly between seasons and years even in natural forests, is crucial for maintaining the frugivore species (Laurance & Vasconcelos 2004). In jungle rubber, the presence of fruiting remnant forest trees seems to make a decisive difference (Abrahamcyzk et al. 2008). In contrast, almost all forest tree species are removed from the plantations.

We also found slight increase of nectarivore species from forest to jungle rubber, then to monoculture rubber subsequently, but decreased in oil palm plantation. Sekercioglu (2012) suggested agroforestry with open area integration may result in spillover of nectarivore species. We suggest this increase is mainly due to the *Hevea* blooming weeks on the studied landscape, during the observation time. This increasing trend of nectarivore was also observed by Li et al. (2013) on Hainan rubber plantations.

Relative proportion of insectivore abundance decreased from forest to jungle rubber then to rubber, with some increase on the oil palm plots. Observed richness shows clear decreasing number of insectivore species with oil palm supporting only a third compared to forest plots. Almost all insectivores found in oil palm are open land and common species such as prinias and tailorbirds. Forest-dependent insectivores, such as Grey-chested Jungle-flycatcher *Rhinomyias umbratilis,* Scarlet-rumped

Trogon *Harpactes duvaucelli,* and Banded broadbill *Eurylaimus javanicus* were never found outside the forest sites. At the same time, a large portion of understorey insectivores, such as babblers, were found only in forest and jungle rubber. They could not be found entering the plantations, even when observed in nearby jungle rubber fragments (pers. observation). The absence of undergrowth vegetation on plantation plots seems to be affecting this group greatly. Sekercioglu (2012) suggests that the ability to disperse towards deforested habitat is the key factor affecting the sensitivity of understorey insectivorous species to forest conversion. Bark gleaning insectivores for example woodpeckers and nuthatch, were missing on the oil palm.

In both plantation types, rubber and oil palm, we saw similar composition with omnivore dominating the proportion of feeding guilds. Omnivores were more than twice as abundant in the plantations compared to the forest, but in lower observed richness. Forest omnivores such as leafbirds, fulvettas, and scimitar-babblers, were being replaced by the other species that have adapted well to anthropogenic habitats, such as bulbuls. In summary, our results suggest that there is feeding guild composition change towards less specialized birds on the simpler habitat type such as plantation (Tschartke et al. 2008; Sekercioglu 2012; Maas 2013).

4.6 Conservation Implications

In Jambi, jungle rubber serves an important role as refugia for forest species which not able to survive on much simpler habitat. Monoculture rubber offers temporal resources for the bird species on the landscape mosaic, especially nectarivores. At the landscape scale, improving matrix between the forested natural habitat and transformed habitat is essential for functionally important species (Tscharntke 2008). On the smaller scope, incorporating remnant forest trees on transformed habitat would be the best practice to facilitate biodiversity (Abrahamcyzk 2008)

The future of land use development in Jambi as foreseen by Feintrenie & Levang (2009), will likely incorporate combination of jungle rubber, as form of agroforestry, along with monoculture plantations. Smallholders will maintain their jungle rubber agroforestry due to the minimum management cost and limited owned capital, while oil palm offers new opportunity in gaining direct profit in short term (Feintrenie et al. 2010; Lee et al. 2014). The true challenge for conservation in the study area is the change toward homogenized landscape dominated by large scale monoculture plantation, at the expense of forest and jungle rubber. Between 2000 and 2010, private companies were responsible for eight times forest cover loss (including secondary and jungle rubber) compared to the oil palm expansion by smallholders (Lee et al. 2014).

Policies which supports smallholders in the maintaining the heterogeneity within the landscape mosaic are needed. Better recognition of the rubber produced from biodiversity-friendly practices such as jungle rubber would help. Favoring jungle rubber and diversified plantation, along with practices which maintain structural complexity of the plantation will benefit more for the environment. Meanwhile, to protect and maintain the remaining forest cover is still of the utmost importance.

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Figures Legends

Figure 1.Boxplot of estimated bird species richness throughout habitat in Jambi, Sumatra. Horizontal lines represent the mean, and the vertical lines represent the variation, dots represent the outliers. GLM indicated that the forest differ marginally non-significantly from the plantations (GLM, Tukey posthoc, P values < 0.10).

Figure 2. (a and b) Boxplot of estimated bird species richness throughout habitat in 2 studied landscapes in Jambi, Sumatra. Horizontal lines represent the mean, and the vertical lines represent the variation, dots represent the outliers. GLM indicated that the forest differs significantly from the transformed habitat at Harapan(left; Pr(>Chi)= 0.001,Tukey test), and not differs significantly in Bukit Duabelas (Right; Pr(>Chi)= 0.91, Tukey test).
(c)Line graph comparing total species richness and forest species richness in Harapan landscape based on 4 visits. (d) Line graph comparing total species richness and forest species richness in Bukit Duabelas landscape based on 3 visits.

Figure 3.Feeding guild precentage in different habitat on Jambi, Sumatra.
Based on the abundance data per habitat on both studied landscapes.

Figure 4. Non Metric Dimensional Scaling of bird communities in different habitat on Jambi, Sumatra. Based on abundance data on both of studied landscapes.

Fig.1

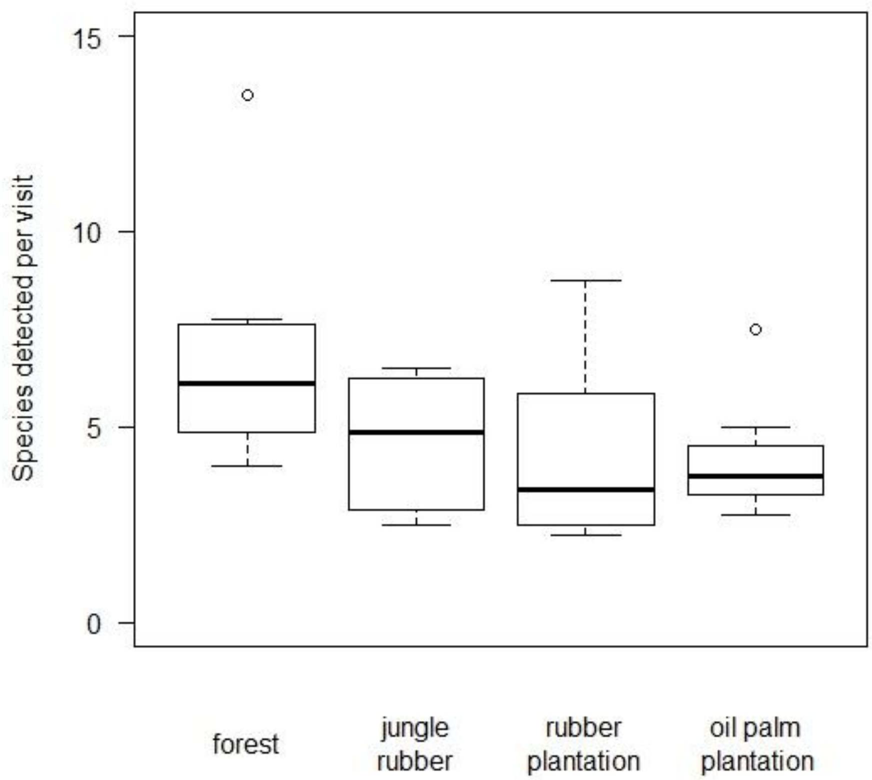

Species detected per visit
15
10
5
0
forest
jungle rubber
rubber plantation
oil palm plantation

Fig.2

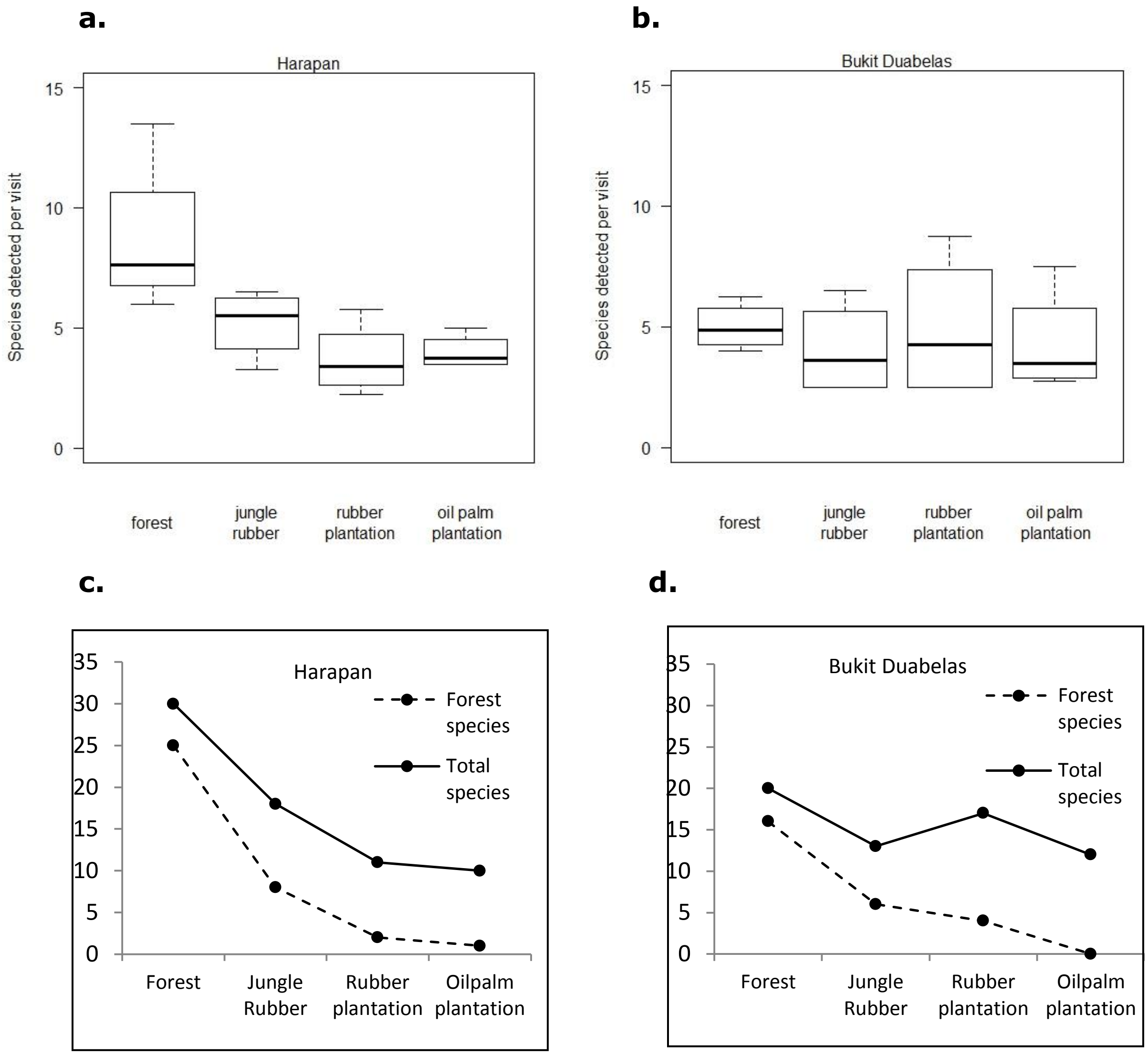

a.
Harapan
Species detected per visit
15
10
5
0
forest
jungle rubber
rubber plantation
oil palm plantation
b.
Bukit Duabelas
Species detected per visit
15
10
5
0
forest
jungle rubber
rubber plantation
oil palm plantation
c.
Harapan
Forest species
Total species
35
30
25
20
15
10
5
0
Forest
Jungle Rubber
Rubber plantation
Oilpalm plantation
d.
Bukit Duabelas
Forest species
Total species
35
30
25
20
15
10
5
0
Forest
Jungle Rubber
Rubber plantation
Oilpalm plantation

Fig.3

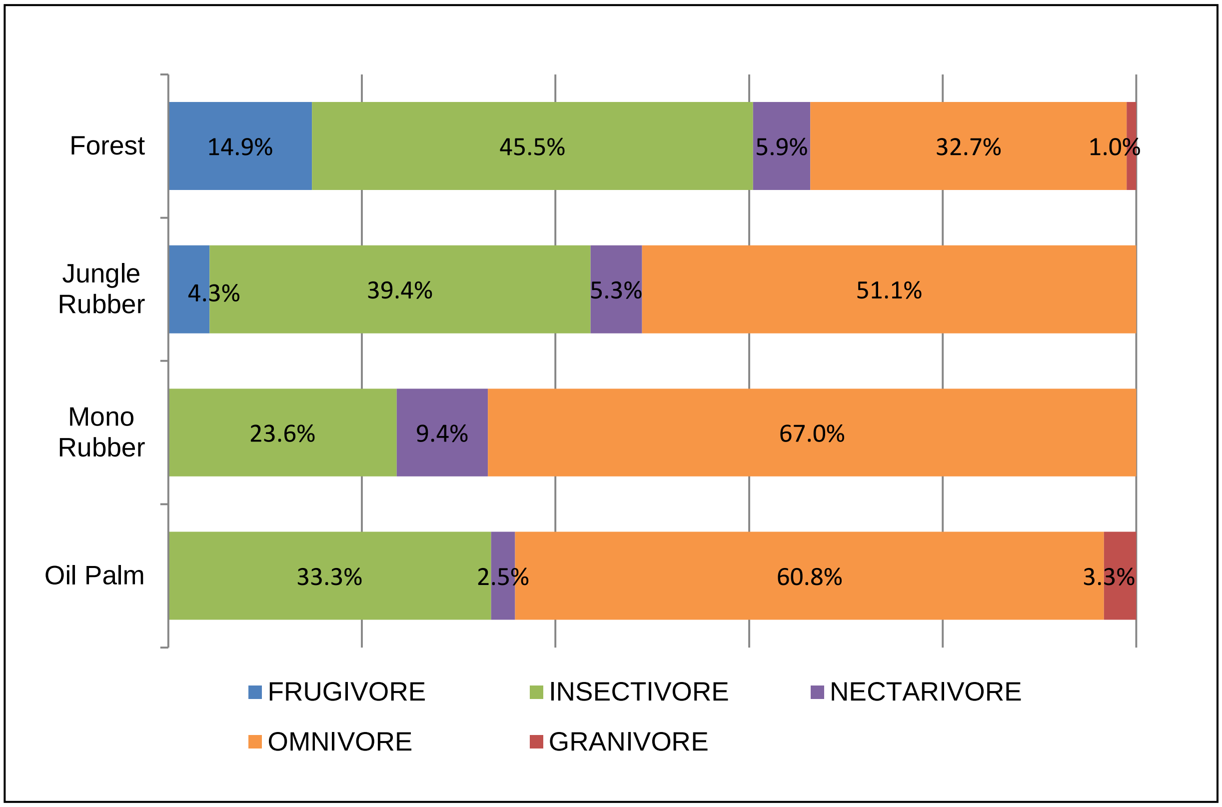
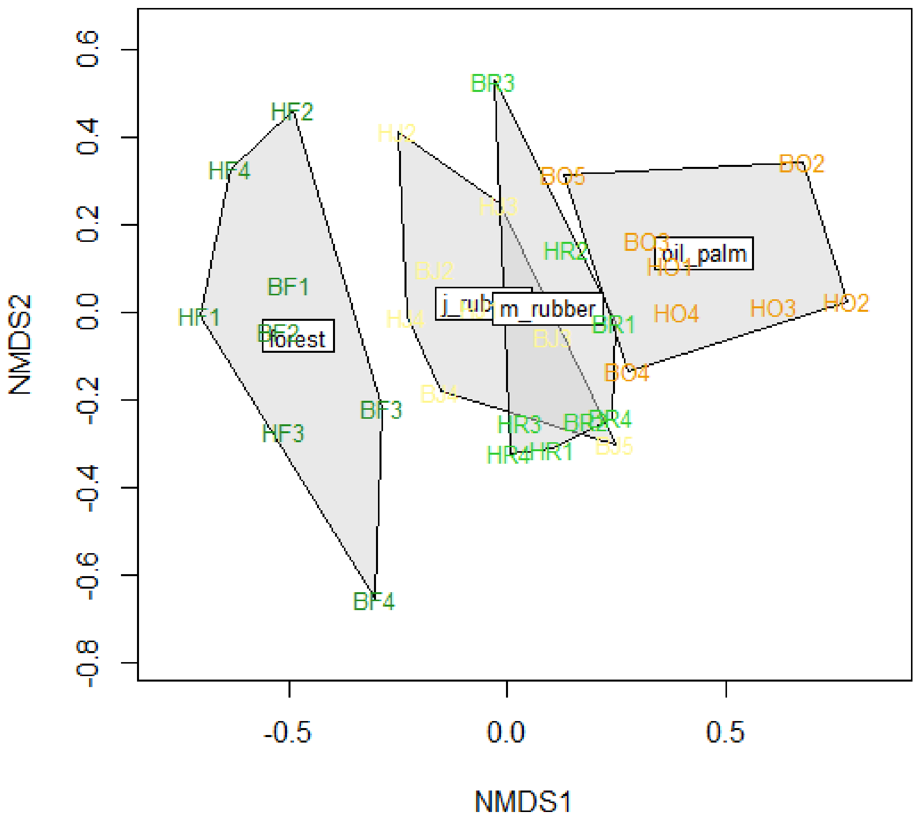

Forest
Jungle Rubber
Mono Rubber
Oil Palm
14.9%
45.5%
5.9%
32.7%
1.0%
4.3%
39.4%
5.3%
51.1%
23.6%
9.4%
67.0%
33.3%
2.5%
60.8%
3.3%
FRUGIVORE
INSECTIVORE
NECTARIVORE
OMNIVORE
GRANIVORE

Fig. 4


NMDS2
NMDS1
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-0.5
0.0
0.5
forest
j_rub
m_rubber
oil_palm
HF1
HF2
HF3
HF4
BF1
BF2
BF3
BF4
BR1
BR2
BR3
BR4
HR1
HR2
HR3
HR4
BO2
BO3
BO4
BO5
HO1
HO2
HO3
HO4

Appendix 1. Species list with mean detection number on each land use and feeding guild.

Scientific name	English name	Forest	Jungle rubber	Mono rubber	Oilpalm	Feeding Guild
Aceros corrugatus	Wrinkled Hornbill	0.03	0.00	0.00	0.00	FR
Aceros undulatus	Wreathed Hornbill	0.03	0.00	0.00	0.00	FR
Aegithina viridissima	Green Iora	0.03	0.03	0.09	0.00	OM
Aethopygia siparaja	Crimson Sunbird	0.00	0.00	0.00	0.03	NE
Alcippe brunneicauda	Brown Fulvetta	0.03	0.00	0.00	0.00	OM
Alophoixus phaeocephalus	Yellow-bellied Bulbul	0.03	0.00	0.00	0.00	OM
Anthracoceros malayanus	Black Hornbill	0.00	0.03	0.00	0.00	FR
Anthreptes malacensis	Brown-throated Sunbird	0.00	0.00	0.03	0.03	NE
Anthreptes rhodolaema	Red-throated Sunbird	0.00	0.03	0.03	0.00	NE
Anthreptes singalensis	Ruby-cheeked Sunbird	0.00	0.00	0.03	0.00	NE
Arachnotera affinis	Grey-breasted Spiderhunter	0.07	0.00	0.00	0.00	NE
Arachnotera chrysogenys	Yellow-eared Spiderhunter	0.00	0.03	0.00	0.00	NE
Cacomantis merulinus	Plaintative Cuckoo	0.00	0.03	0.03	0.00	IN
Cacomantis sepulcralis	Rusty-breasted Cuckoo	0.00	0.03	0.00	0.00	IN
Centropus bengalensis	Lesser Coucal	0.00	0.00	0.00	0.03	IN
Chalcophaps indica	Emerald Dove	0.03	0.00	0.00	0.00	GR
Chloropsis cyanopogon	Lesser Green Leafbird	0.03	0.00	0.00	0.00	OM
Chloropsis sonnerati	Greater Green Leafbird	0.03	0.00	0.00	0.00	OM
Dicaeum concolor	Plain Flowerpecker	0.07	0.10	0.03	0.00	OM
Dicaeum trigonostigma	Orange-bellied Flowerpecker	0.10	0.67	0.72	0.35	OM
Dicrurus paradiseus	Greater Racket-tailed Drongo	0.03	0.07	0.00	0.03	IN
Eurylaimus javanicus	Banded Broadbill	0.03	0.00	0.00	0.00	IN
Gerygone sulphurea	Golden-bellied Gerygone	0.00	0.00	0.03	0.00	IN
Gracula religiosa	Hill Myna	0.07	0.00	0.00	0.00	FR
Halcyon smyrnensis	White-throated Kingfisher	0.00	0.00	0.06	0.00	IN
Harpactes duvaucelli	Scarlet-rumped Trogon	0.13	0.00	0.00	0.00	IN
Hemiprocne longipennis	Grey-rumped Treeswift	0.03	0.00	0.03	0.00	IN
Hemipus hirundinaceus	Black-winged Hemipus	0.00	0.00	0.06	0.00	IN
Hypothymis azurea	Black-naped Monarch	0.00	0.00	0.03	0.00	IN
Lonchura punctulata	Scaly-breasted Munia	0.00	0.00	0.00	0.03	GR
Loriculus galgulus	Blue-crowned Hanging-parrot	0.00	0.03	0.00	0.00	FR
Macronous gularis	Striped Tit-babbler	0.03	0.07	0.03	0.00	IN
Malacocincla malaccense	Short-tailed Babbler	0.07	0.17	0.00	0.00	IN
Malacopteron cinereum	Scaly-crowned Babbler	0.03	0.00	0.00	0.00	IN
Malacopteron magnirostre	Moustached Babbler	0.13	0.07	0.00	0.00	IN
Malacopteron magnum	Rufous-crowned Babbler	0.13	0.03	0.00	0.00	IN
Megalaima australis	Blue-eared Barbet	0.17	0.00	0.00	0.00	FR
Megalaima chrysopogon	Gold-whiskered Barbet	0.10	0.00	0.00	0.00	FR
Napothera macrodactyla	Large Wren-babbler	0.00	0.03	0.00	0.00	IN
Nectarinia sperata	Purple-throated Sunbird	0.00	0.07	0.06	0.00	NE
Nyctyornis amictus	Red-bearded Bee-eater	0.03	0.00	0.00	0.00	IN

Appendix 1 continued

Scientific name	English name	Forest	Jungle rubber	Mono rubber	Oilpalm	Feeding Guild
Orthotomus atrogularis	Dark-necked Tailorbird	0.00	0.23	0.03	0.03	IN
Orthotomus ruficeps	Ashy Tailorbird	0.00	0.03	0.06	0.26	IN
Orthotomus sericeus	Rufous-tailed Tailorbird	0.03	0.07	0.06	0.03	IN
Pellorneum capistratum	Black-capped Babbler	0.03	0.03	0.00	0.00	IN
Phaenicophaeus sumatranus	Chestnut-bellied Malkoha	0.03	0.00	0.00	0.00	IN
Philentoma phyropterum	Rufous-winged Philentoma	0.03	0.00	0.00	0.00	IN
Picus puniceus	Crimson-winged Woodpecker	0.03	0.00	0.00	0.00	IN
Picoides moluccensis	Sunda Woodpecker	0.00	0.00	0.03	0.00	IN
Pomatorhinus montanus	Chestnut-backed Scimitar-Babbler	0.03	0.00	0.00	0.00	OM
Prinia familiaris	Bar-winged Prinia	0.00	0.00	0.00	0.23	IN
Prinia flaviventris	Yellow-bellied Prinia	0.00	0.00	0.00	0.03	IN
Prionochilus maculatus	Yellow-breasted Flowerpecker	0.00	0.00	0.03	0.00	OM
Prionochilus percussus	Crimson-breasted Flowerpecker	0.17	0.03	0.00	0.00	OM
Pycnonotus aurigaster	Black-capped Bulbul	0.00	0.00	0.09	0.06	OM
Pycnonotus brunneus	Red-eyed Bulbul	0.00	0.07	0.03	0.03	OM
Pycnonotus goiavier	Yellow-vented Bulbul	0.00	0.03	0.19	0.84	OM
Pycnonotus melanicterus	Black-crested Bulbul	0.00	0.17	0.22	0.06	OM
Pycnonotus plumosus	Olive-winged Bulbul	0.00	0.00	0.00	0.06	OM
Pycnonotus simplex	Cream-vented Bulbul	0.27	0.03	0.03	0.00	OM
Rhinomyias umbratilis	Grey-chested Flycatcher	0.10	0.00	0.00	0.00	IN
Rhinoplax vigil	Helmeted Hornbill	0.03	0.00	0.00	0.00	FR
Sitta frontalis	Velvet-fronted Nuthatch	0.00	0.03	0.00	0.00	IN
Stachyris erythroptera	Chesnut-winged Babbler	0.03	0.00	0.00	0.00	IN
Stachyris maculata	Chesnut-rumped Babbler	0.17	0.00	0.00	0.00	IN
Stachyris poliocephala	Grey-headed Babbler	0.03	0.00	0.00	0.00	IN
Streptopelia chinensis	Spotted Dove	0.00	0.00	0.00	0.10	GR
Todiramphus chloris	Collared Kingfisher	0.00	0.00	0.09	0.03	IN
Trichastoma bicolor	Ferruginous Babbler	0.10	0.10	0.00	0.00	IN
Trichixos pyrrhopygus	Rufous-tailed Shama	0.03	0.00	0.00	0.00	IN
Tricholestes criniger	Hairy-backed Bulbul	0.13	0.00	0.00	0.00	OM

Appendix 2. R Script used for the data analysis

```
colorscale=data.frame(landuse=c("forest","j_rubber","m_rubber","oil_palm"),color=c("forestgreen","kh
aki1","limegreen","orange2"))
linktable0=read.table("D:/JAMBI CRC/codesFm.csv",header=T,sep=",")
linktable=merge(linktable0,colorscale)
counts0=read.table("D:/JAMBI CRC/cleanEST.csv",sep=",",header=T)
counts1=subset(merge(counts0,linktable),select=-c(localcode,SEcode))
abund2=aggregate(indv~Plot+landuse+Landscape+color+Rep,counts1,sum)
abund3=aggregate(indv~Plot+landuse+Landscape+color,abund2,mean)

glmAb0=glm(indv~landuse*Landscape,data=abund3)
glmAb1=glm(indv~landuse+Landscape,data=abund3)
glmAb2=glm(indv~landuse,data=abund3)
glmAb3=glm(indv~1,data=abund3)
anova(glmAb0,glmAb1,test="LRT")
anova(glmAb1,glmAb2,test="LRT")
anova(glmAb2,glmAb3,test="LRT")
plot(glmAb0)
summary(glmAb2)
glmAb2_Tukey<-glht(glmAb2, linfct = mcp(landuse = "Tukey"))
summary(glmAb2_Tukey)

counts20=read.table("D:/JAMBI CRC/cleanEST_addnosight_incomplete.csv",sep=",",header=T)
counts21=subset(merge(counts20,linktable),select=-c(localcode,SEcode))

library(reshape)
specmat<-cast(counts21,Plot+Rep~Species,value="indv")
specmat<-specmat[,-which(names(specmat)=="N/A")]
dat<-data.frame(Plot=levels(counts21$Plot))
dat$spec3v<-0
nplots<-length(levels(counts21$Plot))

for (i in 1:nplots)
{dat$spec3v[i]<-specaccum(specmat[specmat$Plot==dat$Plot[i],][,-c(1:2)])$richness[3]}
dat2<-merge(dat,linktable,by="Plot")
dat2$Landscape=factor(rep(c("B","H"),each=16))

glm1<-glm(spec3v~landuse*Landscape,data=dat2)
anova(glm1,test="F") #marginally non-sig
anova(glm1,test="LRT")
plot(glm1);summary(glm1)

library(multcomp)
glm2<-glm(spec3v~landuse,data=dat2)
glm2_Tukey<-glht(glm2, linfct = mcp(landuse = "Tukey"))
summary(glm2_Tukey)
summary(glm2)
```