The utilization of trees by endangered primate species Javan slow loris (*Nycticebus javanicus*) in shade-grown coffee agroforestry of Central Java

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Abstract. Although human intervention remains high, a shade-grown coffee agroforestry in Kemuning, Central Java still have important roles for biodiversity conservation. Among various fauna, the Javan slow loris (*Nycticebus javanicus*), a critically endangered species, can survive in this agroforestry system. The use of spatial method on shade-grown coffee agroforestry seems unusual. We aim to investigate the utilization of tree and other vegetation by Javan slow lorises in a shade-grown coffee agroforestry ecosystem in Kemuning Forest. We followed two individuals (male and female) of slow lorises from December 2018 until May 2019 using radio collar. We recorded both vertical and horizontal positions of each individual based on their position on trees at two spatial dimensions (vertical and horizontal). To explore whether lorises select certain tree species, we laid 275 plots (20x20m) in their habitat and using Chi-square test for the analysis. Our findings show that both male and female of Javan slow lorises in shade-grown coffee agroforestry use different forest stratum for their activity. The female used 42.11% of their time to do exploratory activity in the outer part of the canopy, regardless the vertical position, and 43.76% in the middle part (vertical position) and the outer part (horizontal position) of the canopy. While the male mostly uses the inner part of the canopy (52.57%) and upper part of the canopy for feeding activity (64.37%). Both male (Chi-square test = 264.05, p < 0.05) and female (Chi-square test = 357.35, p < 0.05) lorises select tree species for their behavior. We provide here evidence of biodiversity conservation services by shade-grown coffee agroforestry practices in Indonesia. The intensity of coffee management under tropical trees seems does not impact significantly to the presence and behavior of slow lorises, however precautionary measures to reduce poaching should be done as this endangered species threatened by illegal activity. Beneficial values from managing shade-grown coffee agroforestry for generating income for locals such as wildlife-friendly coffee production can also be alternative hand in hand to reduce poaching.

Keywords: slow loris, primate conservation, smallholder farmers, habitat used

1. Introduction

Javan slow loris (*Nycticebus javanicus*) is a critically endangered primate species in Indonesia and endemic to the island of Java [1]. This cryptic primate has been considered under serious threat on its wild population due to various factors including habitat loss and fragmentation as well as poaching and illegal trading [2 - 6]. Habitat loss and fragmentation have pushed Javan slow lorises population into small populations in natural forest remnants in Java island. Although the Javan slow loris is adaptive to human-
modified agricultural areas in higher altitude [7, 8], the remained tropical lowland forests still provide alternative habitat for this primate species [9, 10].

Most of the remaining tropical lowland forest in Java island has been part of the state-owned forest company management PERHUTANI, and in collaboration with local communities to establish collaborative forest management / PHBM [11]. In general, the practices of PHBM have been done through the implementation of agroforestry system with various agricultural products and systems [12] [13]. Agroforestry systems have been providing ecosystems and biodiversity services [14 - 16]. Despite concern have been raised to the roles of agroforestry on biodiversity in Java [17], many pieces of research in relation with biodiversity of agroforestry have shown the support for biodiversity conservation [14, 18, 19, 20] and rarely focus on functional ecology of certain species.

Among agroforestry systems, shade-grown coffee agroforestry systems provide support for biodiversity conservation [21] which also serve habitat for Javan slow lorises [9, 10]. Javan slow lorises spend most of their time for climbing the trees, hanging on branches, feeding and other activities [22]. Shade-grown coffee agroforestry inter-cropping practices, combining existing trees and coffee plantation and sometimes replaces existing trees with coffee plantation below canopies. However, the practices of replacing existing trees in the forest were not fully considered in other regions of the world [16]. The tree numbers reduction was commonly practiced for providing indirect sunlight for the coffee plantation.

The reduced number of trees from original tropical lowland forest into shade-grown coffee practices can have a potential influence on the behavior of Javan slow lorises to utilize trees. The existing research on the use of trees by Javan slow lorises mainly limited for agroforestry with main crop products[7, 23] [24]. It seems that it rarely reports behavioral studies of Javan slow lorises that use shade-grown coffee under remained tropical forest in Java, except for occupancy modeling [10] and habitat selection [9]. We aim to investigate the use of trees by Javan slow lorises in a shade-grown coffee agroforestry system in Central Java with emphasis on the spatial use and behavioral of the lorises to utilize the trees.

2. Methods

Kemuning forest is a remained low-land tropical forest in Central Java province under the management of PERUM PERHUTANI, a state-owned forest company in Java. This remained forest has been mixed with a coffee plantation, forming a shade-grown coffee agroforestry system since the 1970s. In the 2000s, both local people and PERUM PERHUTANI agreed to establish Community Collaborative Forest Management (PHBM) and this system has been sustained until the present study. The agroforestry system in this shade-grown coffee consists of forest trees higher stratum and coffee vegetation at lower stratum (Figure 1).
Figure 1. Map of the study area (above) and shade grown-coffee agroforestry condition (below) in Kemuning forest of Temanggung Regency, Central Java -Indonesia. Dots are GPS position of observed individuals.

We followed two individuals (a male and a female) of Javan slow loris, and attached radio collar device (17 grams weight, Biotrack UK) on them. to detect their position, we used Yagi antenna, Biotrack, UK and receiver; R1000, Communication specialist, US. We observed the behavior of loris following Rode-Margono et al. [22] which was divided into social, alert, foraging, feeding, travel, resting and sleeping. The behaviors of loris were recorded every 5 minutes in an ethogram. We calculated the proportion of each behavior and compared among behaviors. We also observed movement postures of the loris, tree species, tree height and vertical position of the loris in trees.
We also collected tree species data and their ecological roles in the shade-grown coffee agroforestry system in Kemuning forest from December 2018 to April 2019. The identification of species was carried out through local people knowledge based on the local name as well as collecting herbarium and checked in Faculty of Forestry, Universitas Gadjah Mada. In each tree used by lorises, we observed the vertical and horizontal position of the loris following the tree stratification for primate that used by Imron et al. [25] and illustrated in Figure 2. We calculated the proportion of each position in the tree to describe the spatial usage of loris. To test whether lorises select tree species during their active time, we compared the frequencies of tree uses using chi-square in R statistics. In addition, we also collected data of trees nearby the selected trees using point centered quarter sample with the center for each sample was tree used by loris. We calculated the important values of each tree species to understand the relative importance of trees in the home range of observed lorises.

![Figure 2](image.png)

**Figure 2.** Tree space used at vertical (Position 1-5) and horizontally (Position A-C) following Imron et al. [25]

3. Results

3.1. Loris behaviors during tree use

In total, we have observed female Javan slow loris for 4,990 minutes (13 observed nights) and male for 3,450 minutes (11 observed nights). Javan slow lorises spent their most time to travel between one place to another (50-55%), followed by foraging (15-26%). We observed that the movement of the lorises during foraging was slower than traveling which sometimes very fast. While lorises also spent a substantial proportion of their daily activities to be alert (15-21%). Alert behavior was observed while lorises open their eyes during they sit on a branch. This behavior has occurred while moving and then stopped and watched us and froze to ensure that we did, not disturb them. A small proportion of social, grooming as well as sleeping has also been observed during our night observation.
Figure 3. Proportion of daily activities between female (a) and male (b) Javan slow loris in the study area

3.2. Tree selection by lorises

We found that both male (Chi-square test = 357.35, p < 0.05) and female (Chi-square test = 264.05, p < 0.05) lorises selected tree species for their daily activities. Lorises spent most of their time to use *Sterculia urceolata* as their feeding behavior and connectivity (Table 1) which also the highest important values of trees in the loris’s habitat. The lorises also only used certain tree species for feeding (*Sterculia urceolata, Ficus sundaica, Artocarpus heterophyllus, Ficus superba, Spondias pinnata, Dysoxylum gaudichaudianum, Aphananthe cuspidata*) and all others for movement activities. The family of feeding trees varies from mainly Moraceae (three species) which produce gum exudates, Malvaceae, Anacardiaceae, Meliaceae, and Cannabaceae. We only found three species of trees (*Artocarpus elasticus, Archidendron pauciflorum, Aphananthe cuspidata*) which have been used by loris for their sleeping sites.
### Table 1. Tree species names, families, important values and activities of Javan slow loris on trees in Kemuning Forest

| No | Scientific and local name                                      | Loris Activity (%) | frequencies and proportion of used tree | Important value (%) |
|----|---------------------------------------------------------------|--------------------|-----------------------------------------|---------------------|
| 1  | Sterculia urceolata Sm./ antap (Malvaceae)                    | C (43.5%), F (55.5%) | 23 (15.23%)                             | 53.56               |
| 2  | Artocarpus elasticus Reinw ex. Blume/bendo (Moraceae)        | S (53.3%), C (46.7%) | 15 (9.93%)                              | 39.00               |
| 3  | Dillenia obovata (Blume) Hoogland/blankan (Dilleniaceae)      | C (100%)           | 12 (7.95%)                              | 17.70               |
| 4  | Crypteronia paniculata Blume/celegan (Crypteroniaceae)       | C (100%)           | 2 (1.32%)                               | 4.21                |
| 5  | Sindora wallichii/Sindora delimas (Fabaceae)                 | C (100%)           | 1 (0.66%)                               | 1.08                |
| 6  | Archidendron pauciflorum (Benth) I.C. Nielsen/ jengkol (Fabaceae) | S (50%), C (50%) | 14 (9.27%)                              | 25.01               |
| 7  | Terminalia bellirica (Gaertn.) Roxb. /joho (Combretaceae)    | C (100%)           | 10 (6.62%)                              | 16.93               |
| 8  | Ficus sundaica Blume/jrakah_welas (Moraceae)                 | C (90%), F (10%)    | 10 (6.62%)                              | 16.93               |
| 9  | Ficus superba Miq./ jrakah lembut (Moraceae)                 | C (66.7%), F (33.3%) | 3 (1.99%)                              | 0.94                |
| 10 | Spondias pinnata (L.f.) Kurz /kedondong hutan (Anacardiaceae)| C (16.7%), F (83.3%) | 6 (3.97%)                              | 3.55                |
| 11 | Cananga odorata (Lam.) Hoo.f. & Thompson/kembang (Annonaceae)| C (100%)           | 4 (2.65%)                               | 5.84                |
| 12 | Garancia celebica L/ kemejin (Clusiaceae)                    | C (100%)           | 2 (1.32%)                               | 1.76                |
| 13 | Horsfieldia glabra (Reinw. ex Blume)/kenangkan (Myristicaceae)| C (100%)           | 1 (0.66%)                               | 0.52                |
| 14 | Syzygium polyanthum (Wight) Walp/ salam (Myrtaceae)          | C (100%)           | 2 (1.32%)                               | 4.22                |
| 15 | Coffea sp./kopi (Rubiaceae)                                  | C (100%)           | 2 (1.32%)                               | -                   |
| 16 | Dyssoxylum gaudichaudianum (Juss.) Miq./krau (Meliaceae)     | C (90%) F (10%)    | 10 (6.62%)                              | 13.47               |
| 17 | Vitex pubescens Vahl/ laban (Lamiaceae)                      | C (100%)           | 3 (1.99%)                               | 1.66                |
| 18 | Lumaea leucocephala (Lam.) de Wit/ lamtoro (Fabaceae)        | C (100%)           | 2 (1.32%)                               | 0.33                |
| 19 | Swietenia macrophylla King/ mahoni (Meliaceae)               | C (100%)           | 10 (6.62%)                              | 2.28                |
| 20 | Allophyla pululata (Blume) Hoogland/putat (Lauraceae)         | C (100%)           | 10 (6.62%)                              | 1.74                |
| 21 | Artocarpus heterophyllus Lam./Nangka (Moraceae)               | F (100%)           | 2 (1.32%)                               | 1.01                |
| 22 | Monina excelsa (Blume) Spreng./ adangdogan (Polygalaceae)    | C (100%)           | 10 (6.62%)                              | 2.45                |
| 23 | Celtis philippensis Blanco/ tajalinan (Cannabaceae)           | C (100%)           | 10 (6.62%)                              | 0.36                |
| 24 | Buchanania arborescens (Blume) Blume/pelem (Anacardiaceae)   | C (100%)           | 10 (6.62%)                              | 0.80                |
| 25 | Litsea velutina (Blume) Hook.f./Pumat (Lauraceae)             | C (100%)           | 10 (6.62%)                              | 1.82                |
| 26 | un-identified/pulutan                                         | C (100%)           | 10 (6.62%)                              | 0.20                |
| 27 | un-identified/pinggung                                        | C (100%)           | 10 (6.62%)                              | 0.35                |
| 28 | Nauclea subdita (Korth.) Steud./pulutan (Rubaceae)            | C (100%)           | 10 (6.62%)                              | 5.57                |
| 29 | Syzygium polyanthum (Wight) Walp/ salam (Myrtaceae)          | C (100%)           | 2 (1.32%)                               | 6.22                |
| 30 | Syzygium microcymum (Koord & Velenon) Ashmoref/ salam_watu (Myrtaceae) | C (100%) | 2 (1.32%) | 3.21 |
| 31 | Albizia chinensis Merr./ sengon_jawa (Fabaceae)                | C (100%)           | 10 (6.62%)                              | 2.42                |
| 32 | Dalbergia latifolia Roxb./ somokeling (Fabaceae)              | C (100%)           | 10 (6.62%)                              | 0.36                |
| 33 | un-identified/senwo                                          | C (100%)           | 10 (6.62%)                              | 0.40                |
| 34 | Allophyla procera (Roxb.) Benth./ wera (Fabaceae)             | C (100%)           | 10 (6.62%)                              | 0.66                |
| 35 | Apkananthus cuspidata (Blume) Planch/wuluhuan (Cannabaceae)  | S (33.3%), F (11.1%) | 9 (6.16%) | 13.65 |
| 36 | Litsea glutosa (Lour.) C.B. Rob./wurubeling (Lauraceae)       | C (100%)           | 2 (1.32%)                               | 4.52                |
| 37 | Gnetum genemon /wuri janggel (Lauraceae)                      | C (100%)           | 2 (1.32%)                               | 3.18                |
| 38 | Litsea sp. / wuri mangkok (Lauraceae)                         | C (100%)           | 2 (1.32%)                               | 2.50                |
| 39 | un-identified/wuri santen (Lauraceae)                         | C (100%)           | 2 (1.32%)                               | 0.33                |

Note: S=sleeping trees; C=connectivity trees; F=feeding trees
Figure 4. Proportion of horizontal space used by the female (a) and male (b) slow loris in the study area

Figure 5. The proportion of vertical space used by female (a) and male (b) slow loris in shade-grown coffee agroforestry in the study area

3.3. Spatial uses on trees

We found a reverse pattern of horizontal space of use on trees for the male and the female lorises. While the female tended to use the periphery part of the canopy, the male tended to be close to trunks (Figure 4). The female used periphery position as the mean of movement between trees. Trunks of trees were mainly used for grooming and feeding by the male. While the middle of trees was used for grooming, resting and moving. We rarely found both the male and the female to feed in the middle position (Figure 4).
The female spent most of her time to use the lower part of tree canopy whereas male in the middle of the canopy. Both rarely use understory, particularly for male which never touched on the ground during our observation (Figure 5). We rarely found both slow loris used coffee plantation for their movement, feeding or sleeping. Only one occasion during our observation we saw the female climbed down and used the coffee trees for connectivity to other trees (Figure 6).

Figure 6. Illustration of the movement of the female Javan slow loris through a coffee tree to connect another tree.

4. Discussion
Javan slow loris is among small primates in Indonesia which are assigned as the 25 most endangered primate species in the world [6]. As habitat loss and fragmentation become critical for the population of this nocturnal primate, our study shows that coffee agroforestry system has important roles for this small primate in Java. We have shown that shade-grown coffee agroforestry is not only suits for the Javan slow loris by providing various tree species, but also provide places for various activities. The primate uses a different part of the tree in the agroforestry system for different activities and supports connectivity for this tree-dwelling primate species.

While conversion of natural forest into coffee and cacao plantation have shown detrimental effect on various countries in the worlds [16], shade-grown coffee agroforestry has been spread around the world which is believed to enhance biodiversity conservation services [16, 26, [27]. In some cases, the biodiversity services can result in an economic benefit [28]. Although similar studies of the presence of Javan slow loris in agroforestry systems have existed [9, 10, 24], our study is the first to investigate behavioral of the loris to use various tree species in a shade-grown coffee. Our findings show that the shade-grown coffee under the remained tropical low-land forest in Java can have a substantial contribution to the habitat of an endangered primate species through the provision of various tree species.

Our findings have shown that Javan slow loris has selected tree species for their habitat. Most of the tree species (Table 1) were used by loris for moving through connectivity. Few species serve as feeding trees which also frequently used by loris. Among those feeding trees, gum tree producers such as Sterculia urceolata (Malvaceae) have been frequently consumed by loris. As Javan slow loris depends on gums as their diet [23] in Taungnya agroforestry in West Java, further investigation on the diet of gums by loris in low-land tropical forests such as in Kemuning forest will improve our understanding the ecology of this species.

Javan slow loris in our study area showed a distinct behavior between male and female on using the spatial structure of trees. The female used more frequent on periphery area than the male (Figure 4). However, both showed similarity in using less of their time in the area between stem and periphery. Javan slow loris is an arboreal primate species, spend most of their time on trees, and have higher flexibility on their motoric aspect to climb trees and hang on them [29]. Our current study has shown both the male and the female used area near to stem in the canopy for foraging, feeding and resting.
(Figure 2). As the previous study showed that Javan slow loris is a *gummivorous* primate [30, [31], they feed gum on the tree stems. Periphery areas of tree canopies help both male and female Javan slow loris to connect between trees for their movement. Liana and small branch were commonly found in the periphery areas of trees which help a lot for the connectivity among trees [4]. Also, this area in the canopy provides young leaves for their diet. Thus, Javan slow loris spends substantial time for staying in this area.

The Female of the Javan slow loris used higher frequency in the lower canopy than male (Figure 5). We have found that slow loris used very rarely forest floor or understory (less than 1% of use). It seems that the loris avoids using the forest floor to avoid predators [32]. Shade-grown coffee production is commonly managed with relatively high human intervention such as pruning, fertilizing, harvesting activities [18, 33, 34], including wildlife harvesting [28]. Therefore, the understory level presents threat for animals [35] and they adapted to avoid this area. To further investigate the possible disturbance of humans in the coffee agroforestry for wildlife, other behaviors such as sleeping patterns of loris [36] may serve as a proxy to investigate the disturbance to this nocturnal mammals during daylights.

Our current study has shows that during their active time, Javan slow loris explores shade-grown coffee agroforestry system in Kemuning for fulfilling their need. The lorises do not show a strange behavior in comparison with other studies and tend to be familiar with the presence of observers/humans. This observation confirms the findings of Nekaris et al. [24] on the co-existence with humans. Since this primate species is also subject to illegal trading [37, 38] the involvement of the local community and increasing their awareness for conservation of this species through various methods including conservation education [39] is urgently needed. A very rare occasion of the use lower part of the agroforestry indicates that this primate species still aware with natural predators [40] or showing spatial response to the disturbance of humans at the lower part of trees. We are aware that our study was only based on the behavioral observation of two individuals loris and was carried ours during relatively short periods. Therefore, we do not generalize our findings. Further study involving more individuals and longer periods of observation will help to develop generalization.

As demands for coffee has shown significant increment in the past years, and at the same time the practices of full-sun coffee plantation have been harmful to biodiversity [16], we promote the application of shade-grown coffee agroforestry system by managing stratum of the trees as we found in our study area. Providing incentives for local communities who practiced shade grown-coffee using wildlife-friendly coffee initiative [41] will enhance the practices. Further promotion of the shade-grown coffee agroforestry system for supporting large mammals conservation for surrounding protected areas [42] is likely to reduce the treatment for protected areas from monocultural practices [43, 44].

5. Conclusion
We have shown that shade-grown coffee agroforestry system which has been practicing in Central Java has a substantial contribution for conserving Javan slow loris, an endangered primate species endemic to Java island. The tree in this agroforestry system provides various resources for lorises to survive from feeding, social activities and also movement. Our current study contributes to the first attempt of studying the behaviors of the Javan slow lorises in this agroforestry system. The agroforestry practices by locals can be further improved into wildlife-friendly coffee initiatives and promoted into larger-scale particularly surrounding protected areas in Java.

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