Fine scale habitat and movement patterns of javan slow loris (Nycticebus javanicus) in Cipaganti, West Java, Indonesia

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Abstract
Today biodiversity is rapidly decreasing and an increasing number of threatened species live in modified and human dominated landscapes. Therefore it is essential to learn more about how species cope with the changes of their habitat. The focus of this study lies on a primate species, the critically endangered Javan slow loris (Nycticebus javanicus), endemic to the densely populated island of Java, Indonesia. In cooperation with the Little fire face project in West Java, I used a step selection function (SSF) framework, to understand how landscape structure affects the movement of Javan slow lorises within a fragmented mountain-agroforest landscape of Cipaganti, West Java.

To investigate the movement and fine scale habitat selection of slow lorises I used one hour locations of 6 radio-collared slow lorises. The habitat and vegetation of observed and random steps was investigated in multiple variables such as presence of food trees and signs of human disturbance. For the analysis I paired observed steps (1h relocations) with 3 random habitat locations and used a conditional logistic regression to parameterize the SSF, which represents the probability of a focal slow loris to select a given step as a function of the habitat and vegetation factors surveyed. In average the slow lorises travelled about 450 m each night and most frequently they used a step length of about 0 – 50 m.

My result reveals that slow lorises fine scale habitat selection is positively influenced by the presence of trees and tree trunk cover (indirect increasing the canopy cover and connectivity). They are also to a high extent positively affected by the presence of a feeding tree species, Calliandra calothyrsus. Surprisingly slow lorises selected steps associated with a higher number of fields (fields may indicate an increased biodiversity within the location). The results also indicate that slow lorises are limited in their movement by the presence of fields or rivers, which indicates that slow lorises are negatively influenced in their movement by a declining ability to move and forage within Cipaganti. I found no significant differences between sexes in their distance travelled.

The recommendation for future conservation of slow lorises in Cipaganti is to prevent further habitat loss and fragmentation through activities that protect or maintain the present suitable slow loris habitat. Further research is needed to increase the knowledge of these primates’ abilities to live in this modified landscape.
**Introduction**

Today there are 504 primate species, of which 60% are threatened or show a decline in their populations. The distribution of primates often overlaps with human dominated areas where primates are forced to stay. A major threat for primates living in these habitats is the habitat destruction where the main pressure comes from the human activities influenced by local or global market demands. These demands often lead to habitat loss through factors such as logging or industrial agriculture etc. (Estrada et al. 2017). The escalation of both tropical deforestation and fragmentation are major threats to the biodiversity in tropical regions; leaving only remnants of the habitat. These remnants offer the only refuge for many primate species and are therefore essential areas to protect (Sharma et al. 2013). In order to preserve these ecosystems and its threatened primates, we need to investigate how primates respond to living in modified and human dominated areas (Isabirye-Basuta & Lawanga 2008).

Primates are essential for ecosystems because they are key features in the food webs but also important pollinators and seed dispersers; thereby influencing the structure, function and resilience of ecosystems (Estrada et al. 2017). Unfortunately, most natural environments for primate populations are not available any more for future conservation. Therefore, more efforts for primate conservation should be put in modified and human disturbed habitats and the goal should be to find ways for coexistence among humans and primates (Hockings et al. 2015).

Interactions between human and primates are common in rural areas. Such areas are defined as mosaic landscapes with remnants of natural habitats, boarded or mixed with farmland and villages, sometimes located in close proximity to protected areas and are for instance called agroforest areas (McLennan et al. 2017). The knowledge about primate’s use of and activity in these anthropogenic habitats is limited, especially how the human-induced pressures and associated risk factors affect the species (Bryson-Morrison et al. 2016).

Modified landscapes probably provide less dense canopy cover and hence influence arboreal primates negatively. If primates use the fields as a stepping stone when moving or for foraging they become more vulnerable to the risk of being a victim to local hunters, domestic dogs, raptors or other predators (Estrada et al. 2012). Encounters with humans in these areas, has the potential to be a negative interaction for the primate due to infrastructures such as roads (crossing them might increase mortality due to collisions with cars or the risk of getting caught by a wildlife-trader) and plantations (change in foraging patterns towards cultivars might upset the farmers) (Bryson-Morrison et al. 2016).

In any heterogeneous landscape, the habitat contains resources that are patchily distributed in both space and time, making it important for an animal to make its foraging effort as energy efficient as possible. For instance, black howler monkeys (*Alouatta pigra*) showed a strategy that favored energy intake and decreased the costs of movement. Their strategy was to choose a preferred tree at each step and to decrease their costs of movement by staying at that location for a longer time compared to locations with less preferred trees. They also seemed to stay in high-quality patches and avoid going back to that or other used locations where the resource already been consumed (Plante et al. 2014).

The movement of an animal in a human modified landscape is likely influenced by multiple factors in its environment and is the result of a trade-off between avoiding human disturbance and the use of resources within the landscape (Fortin et al. 2005). Foraging primates in human modified areas have access not only to their natural food items but also to other potentially attractive food items such as different kind of cultivars. Primates foraging in these areas are influenced by the availability of food items and might increase or decrease their use of certain areas in a fragmented landscape (Bortolamiol et al. 2016).
The habitat preference together with an animal’s movement can give a unique picture on the ecology of the species. It is essential to understand space use patterns of animals in relation to how the animal interacts with its environment. This is important for understanding the effects of habitat change on ecosystem functioning (Potts et al. 2014). These kinds of investigations are useful for future land use plans in areas that are highly disturbed by humans and where it is important to balance conservation of species against human living (Bryson-Morrison et al. 2017).

To increase the knowledge about species habitat preferences through its movement patterns, the concept of an animal’s trajectories can be used. These kinds of studies allow species to be surveyed with high-frequency sampling and are often used together with positioning technology to monitor the movement of wild animals (Calenge et al. 2008). The trajectory can be explained as the curve that describes the animals’ movement. As that the movement is continuous it can be divided into different discrete “steps” that connects successive relocations of an individual (Turchin, 1998). These discrete “steps” taken by the individual can be surveyed and compared to random “steps” (sharing the same start point); making step selection functions (SSF) powerful as models for resource selection studies of animals movement in the landscape (Thurfjell et al. 2014).

Hence, a step selection function (SSF) can be used to investigate the fine scale habitat selection of animals. It allows the researcher to model the animal preferences for different landscape characteristics and provides a more realistic scale of the animal decisions that is built from known movement parameters (Fortin et al. 2005). SSF analyses the segments separating the successive locations and can therefore be used to investigate the probability of an animal to select a given movement step as a function of the landscape variables present (Coulon et al. 2008). Knowledge about how individuals move in both space and time, especially in a disturbed area can give a deeper knowledge about what impact these individual decisions. Therefore these studies have been used to explore not only habitat selection but also conservation issues as human-wildlife interactions, movement corridors, and animal’s abilities to disperse (Thurfjell et al. 2014).

Only a few studies about the trajectories of primates have been done. One study surveyed the trajectories of three sympatric primate species (*Cebus capucinus*, *Alouatta palliata* and *Ateles geoffroyi*) in relation to the canopy structure of the forests at Barro Colorado Island, Panama gaps. For all three species the movement decision was correlated with the height of the canopy and the distance to gaps (Mclean et al. 2016).

The slow loris or the genus *Nycticebus* is a highly adapted arboreal primate group that also is one of the least known primate taxa when it comes to ecology, distribution and systematic (Nekaris & Starr 2015). For primates that are not well known and faces habitat loss (both are true for slow lorises), it is especially important to investigate activity patterns (Arroyo-Rodriguez & Mandujano 2009). The javan slow loris (*Nycticebus javanicus*) is endemic to the island of Java, Indonesia. Java has a long history of deforestation, and is the world’s most densely human populated island. Due to the demographic pressure and massive land conversion only 10 % of the forest remains, often located to isolated volcano areas (Nijman 2013). The destruction of forests, forces this arboreal lowland species towards montane regions were they have to cope with extreme habitat disturbance, due to agricultural practices that are expanding at higher altitudes (Reinhart et al. 2016).

To achieve conservation status of species it is vital to collect data on geographical ranges and evaluate levels of human disturbance (Torn et al. 2009). When slow lorises abundance was surveyed in 14 different areas of Java, the presence of lorises was higher in disturbed and human oriented areas compared to undisturbed areas. Therefore it is of great importance that
more ecological studies are made to see if and how *N. javanicus* can sustain in human disturbed areas,

From past studies on preferences and movement in slow lorises, we know that they use all height available, from ground to the top of the tree and that they prefer substrates where their hands can grasp completely. They also seem to prefer tree trunks with up to or even above 100 cm in diameter (Nekaris 2014). Red slender loris (*Loris tardigradus tardigradus*) in Sri Lanka, showed a preference for a substrate height of 3.5 m and with a branch diameter smaller than 5 cm. Tree species preference was based on food sources present or a high amount of branches (sleep trees); others were only used for passage (Nekaris 2005).

Studies on Mysore Slender Loris (*Loris lydekkerianus lydekkerianus*) show that they use the same sleeping sites every night (these occur in center of their home ranges). From the sleep site they start their nightly movement in dusk, spending their active hours in other part of their home range to forage until they return before dawn to find their sleep site again (Nekaris 2003). Abundance of the javan slow loris are positively correlated with the amount of bamboo in the forest (Voskamp et al. 2014), and bambu patches provides high protection (high cover) and are therefore used both for social activities and for rest or sleep (Rode-Margono et al. 2014). The males have a bigger home range and also use more sleeping sites than females (Nekaris 2014).

Different environmental factors are known to alter the behavior and activity of nocturnal mammals. The insect abundance can for instance influence the foraging behavior of slow lorises. Insect abundance increases at higher altitudes with an increasing humidity. The slow loris responses to this are to be more active at high altitudes in these conditions (Rode-Margono et al. 2015).

To my knowledge no movement analysis investigating trajectories has focused on a nocturnal primate before. Therefore the javan slow loris provides a unique opportunity to explore the fine scale habitat selection and movement patterns of a nocturnal primate. It also provides the opportunity to learn more about arboreal primate species movement. Little is known about how the composition of the landscape matrix affects arboreal primates, but it is believed that surrounding forest fragments are important for their survival (Pozo-Montuy et al. 2011).

If we want to understand primates patch use and behavior in disturbed areas a fine scale approach is necessary to estimate the effects of the disturbance (Bortolamiol et al. 2016). Therefore this study focuses on the fine scale habitat selection and trajectories of slow lorises in an agroforest landscape. The aim is to increase the understanding on how slow lorises move in relation to the landscape and the human disturbance within the landscape. Hopefully the result can provide further knowledge about the species and how to preserve them in the future.

**Study questions**

This study aimed to answer the question: “What is the javan slow loris habitat selection on a fine scale”. The hypothesis was that the javan slow loris, as an arboreal species, prefers areas with a high amount of canopy cover and with a greater biodiversity due to presence of trees for feeding and a higher amount of insects (connected to the amount of bushes)”. Several predictions was also selected such as “The chosen location has higher tree cover than random locations”, “The javan slow loris select forest habitat”, “The javan slow loris select areas with presence of trees observed to be used for foraging, sleeping or moving (different bamboo species, cajeput tree (*Malaleuca leucadendra*), Red Caliandra (*Calliandra calothyrsus*) and Green wattle (*Acacia decurrens*)” and “The javan slow loris selects areas with more bushes”.

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The aim was also to answer another question: “How are Javan slow lorises affected by the fragmented agroforest landscape”. This time the hypothesis made was “The javan slow loris avoids areas that are greatly disturbed by humans”. Several predictions was also selected, these were: “The javan slow loris avoids locations close to agricultural fields”, “The javan slow loris select locations with high tree connectivity” and “The javan slow loris select locations with less road cover”.

Materials and methods

Study area

Research was conducted in an agroforest landscape surrounded by the village of Cipaganti (7°16′44.30″S, 107°46′7.80″E, 1200 m asl), located at Gunung Puntang, close to the nature reserve of the active volcano Mount Papandayan that is part of the Java-Bali montane rainforest ecoregion (Nekaris et al. 2017) (Fig 1). The study area has two defined periods of climate: a wet and a dry season (Cabana et al. 2016). The mean annual precipitation exceeds 2500 mm (Nekaris et al. 2017).

Figure 1 Map of the study area Cipaganti near Garut, west Java (Rode-Margono et al. 2014, with permission from the publisher).

Local people in the area make their livings from cultivated gardens in the mountain (Fig 2) (Reinhardt et al. 2016) were they cultivate crops such as; tea, coffee, beans, chilli, tomato, tobacco, potato, white cabbage, onion and carrot (Rode-Margono 2015 & Nekaris et al. 2017). From my personal observation also crops such as ginger are present. The farmers of the area are known to shift the agricultural crops used depending on the local economic trend (Nekaris et al. 2017).
The habitat around Cipaganti is dominated by a mosaic of cultivated gardens (Fig 3). At the boarders of these gardens you find tall trees planted in rows or even patchily distributed among the different crop types (Nekaris et al. 2017). Slow lorises in the area mainly use specific tree species (they are all non-native) such as: String bamboo (*Gigantochloa atter*), Clumping bamboo (*G. pseudoarundinacea*), Giant bamboo (*Dendrocalamus asper*), cajeput tree (*Malaleuca leucadendra*), Red Caliandra (*Calliandra calothyrsus*), Green wattle (*Acacia decurrens*), Avocado (*Persea americana*), and Indonesian mahogany (*Toona sureni*) (Rode-Margono et al. 2014).

“The species studied” in relation to its movement

In the study area of Cipaganti slow lorises are present at altitudes of 1275 m above sea level (asl) to 1570 m (asl). They are nocturnal and only active between dusk and dawn; during daytime they remain in a sleep tree, often a bamboo stand (Nekaris et al. 2017). These extreme climbers have a body length of about 30 cm and they weigh between 750 and 1150 g as adults (Nekaris 2014) (Fig 4)
The structure of a social unit is two adults of different sex and a varying amount of younger individuals, and the unit is characterized by friendly interaction among members in the group. These stable social groups ("spatial groups") that slow lorises form often have overlap in their home ranges, but these overlap are not present between different social units (Wiens & Zitzmann 2003). The javan slow lorises have a mean home range size of about 6.6 ha (Nekaris et al. 2017), and the males can have slightly larger home range than females (Nekaris 2014), see the home ranges of my focal individuals (Fig 5). The slow lorises are more active in foraging, traveling or feeding compared to resting in habitats with greater connectivity or that show an increase in relative humidity (Nekaris et al. 2017).

During their active hours slow lorises are constantly moving up and down branches or trunks busy in search for food (Nekaris 2014). Slow lorises are exudativorous primates, i.e. they are gum specialist and in the area of Cipaganti slow lorises mainly find this food source from Green wattle (Acacia decurrens). Gum are consumed all year round together with Red Caliandra (Calliandra calothyrsus) nectar (can be limited during dry season) and various insect species (Cabana et al. 2016) taxa that are recorded to be eaten by N. javanicus are adult Lepidoptera, Hymenoptera, Orthoptera and Arachnida (Rode-Margono et al. 2015).
Sometimes slow lorises visit and feed on fruits from Japanese persimmon and Jackfruit, but they are not recognized as a frugivorous species (Rode-Margono et al. 2014).

As already mentioned there are many tree species in the study area. Most of them are used by the lorises during their movements through the canopy and some seem to be more important for the slow lorises than other when foraging or resting. Therefore in this study I focused extra on presence of trees such as string bamboo (*Gigantochloa atter*) and giant bamboo (*Dendrocalamus asper*), cajeput tree (*Malaleuca leucadendra*), Red Caliandra (*Calliandra calothyrsus*), Green wattle (*Acacia decurrens*), Red Caliandra (*Calliandra calothyrsus*), Green wattle (*Acacia decurrens*), this to see if they are positively influencing the step selection of the slow lorises in the area of Cipaganti. All these tree species except cajeput tree are proved to be important trees for the slow loris daily life (Cabana et al. 2016 & Rode-Margono et al. 2014) and was therefore subject of interest. Cajeput trees are used by slow lorises when moving and also for insect foraging (personal observation), why it also seemed to be a positive species for their space use pattern.

The increasing land cultivation makes slow lorises exposed to the human disturbance during daytime (which impacts them even though they are only active during the night). These activities includes clearing of trees and bamboo (Rode-Margono et al. 2014); mainly to find new areas to cultivate crops or for the bamboo constructions used for growing chayote (*Sechium edule*). This crop was suggested to have a positive impact on the slow lorises movement in this fragmented landscape (since it started to be cultivated 2013). These chayote fields has the potential to increase the connectivity between forest patches (it is grown on bamboo frame constructions around 1 - 6 m above ground, and this construction is often attached to trees around the field) (Nekaris et al. 2017). The study site is traversed by a network of trails (Fig 6). These are used by humans to transport their crops from farmland to the villages and towns. Some of these are used by motorbikes and some are used only by foot.

![Figure 6 Map of trails in the study area. In the picture you also clearly can see the mosaic of the study area.](image)

**Field work**

The fieldwork was conducted in 2017 during the dry period between 30 April and August 27, in collaboration with a Non-government Organisation called Little Fire face project (LFP). LFP is working on the protection of slow lorises through research, education and conservation. Their main focus is on the critically endangered *N. javanicus* ([http://www.nocturama.org/en/welcome-little-fireface-project/](http://www.nocturama.org/en/welcome-little-fireface-project/)).
The study focused on a subset of collared lorises; 3 males (Alomah, Fernando & Toyib) and 3 females (Lucu, Shirley & Tereh), fitted with 19-g VHF collars (PIP3, Biotrack, Wareham, UK). The observations were done with the help of local trackers (LFP staff). The trackers located the focal individual using radio tracking equipment; antenna (Lintec flexible, Biotrack, Wareham, UK) and a receiver (Sika receiver, Biotrack, Wareham, UK). Because slow lorises are strictly nocturnal the behavioural observations were collected during the night between 5 pm and 5 am.

Movement data of lorises were collected by different observers using a modified version of the ethogram developed by Rode-Margono (2015). To minimise disturbance during behavioural observations of *N. javanicus*, head torches (HL17 super spot, Clulite, Petersfield, UK) fitted with red filters was used to observe the focal individuals. *N. javanicus* are dichromatic and therefore do not react to the red spectrum (Nekaris et al. 2014). Binoculars were also used when needed.

The trajectories (n = 24) of 6 focal individuals were followed. The trajectory can be explained as the movement path of a slow loris. Each trajectory was recorded from sleep site to sleep site. The path trajectory represents the lorises path of movement during one nightly observation (12 hours). The path was broken down into discrete “steps” (n=12) (which are the straight line segments between locations at 1 hour’s intervals), meaning focal individual was relocated every hour.

The observed locations of the lorises at 1 hour intervals was marked with a GPS point (this location was usually a specific tree) using a handheld GPS (GPS62s, Garmin International, Olathe, KS, USA) and also with yellow bio safe tape in order to go back precisely to the location for habitat surveys. Sometimes the focal individual was not seen at the exact hour during the observational study. When this happened (to avoid losing step data) the next tree where the loris were seen was marked instead, but the position had to be close in time range from the hour observation. The accuracy of the GPS was sometimes not the best and therefore it was sometimes hard to find the actual marked tree during the subsequent vegetation study. In these cases a qualified guess was made, or the trajectory had one less step.

The step selection function was used to investigate the probability of a step to be taken by the focal individual (see Fortin et al. 2005 for details on the method). Each observed “step” (habitat choice) was paired with random locations (n=3 in this study) (Fig 7). The observed locations (n=262) represent the habitat choices of the focal individual. The random locations represent what is available for the animal when moving through the landscape; together they form the strata used later in analysis. Each step in the same strata shared the same starting point, but differed in length and direction. Lengths and turnings angles (i.e., the angle between current step direction and the direction of the previous step (Calenge et al. 2008)) of random steps were drawn from empirical distributions of previous years. The lorises start their nightly activities in dusk when they leave their sleep tree (mainly located in bamboo) and then travel between different trees until they reach their next sleeping site. We considered the step lengths to be the straight line connecting 2 successive locations. The end of these steps lengths were marked, there were thus 12 steps per trajectory. The trajectory ends when the focal individual stays at a new sleep tree at dawn.
Figure 7 The trajectory of a loris with its different step length and turning angles. The trajectory starts at A, often in the sleep tree of a bambu temen. Then the loris moves likely in an un-straight way between trees in the “step lengths” before arriving to the 1-hour locations. This pattern of movement is repeated until the trajectory ends at B in the morning. The loris was followed 12 hours, giving 12 one-hour locations.

**Vegetation and habitat study**

Since my main focus was on how slow lorises interact with their environment, we surveyed the landscape features of each observed and random step. Definitions of these variables you can see in table 1. The focus was on features believed to influence the movement of slow lorises, such as tree species, connectivity or signs of human disturbance. I conducted a habitat and vegetation survey at each observed and random location within a circle with a radius of 5 m. This limit was chosen to catch important variables to habitat selection of the slow loris. I chose this method because it was time effective and gave a more precise picture of the slow loris habitat selection than a larger sized circle would have. A larger radius would catch the habitat selection on a different scale and give us a more general picture. The centre of the circle represented the observed location of the focal individual (GPS point from the nightly observations of the loris position or the GPS point of the random locations position).

<table>
<thead>
<tr>
<th>Measured variables</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>Presence of trees within the location, present or absent. Defined as present if they had their trunk inside the 5 m radius.</td>
</tr>
<tr>
<td>Tree: Tree cover</td>
<td>Tree presence within the location analysed with an interaction term; tree cover. Tree cover represents how much of the actual ground that is covered by tree trunks (estimated percentages cover).</td>
</tr>
<tr>
<td>Connected to other</td>
<td>If the trees present in the location were connected to other trees or not.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Estimation</td>
<td>Estimation over if the loris could move from the tree and further away in the tree tops or not. Two trees in a middle of a field with no other connection were therefore noted as not connected.</td>
</tr>
<tr>
<td>Canopy cover</td>
<td>Estimate of the total canopy cover for each location in percentage. Trees needed to be within the circle with its trunk for the canopy to be used in the study.</td>
</tr>
<tr>
<td>River cover</td>
<td>How much of the location in percentage that was covered by the presence of a river.</td>
</tr>
<tr>
<td>Road</td>
<td>The presence of a road within the location, presence or absence.</td>
</tr>
<tr>
<td>Road: road cover</td>
<td>The presencees of a road with an interaction term of the estimated percentage road cover in the location.</td>
</tr>
<tr>
<td>Labu</td>
<td>When trees within the location was connected to labu, connected or not. Also when it was a field location where labu was totally covering, because then it was likely used as substrate for lorises and provided connection to the border areas with tree rows.</td>
</tr>
<tr>
<td>Field cover</td>
<td>Estimate of how much of the location in percentage that was covered by field.</td>
</tr>
<tr>
<td>Distance to fields</td>
<td>From the centre of the location (the loris position or random point) to the edge of present fields, estimate in meter.</td>
</tr>
<tr>
<td>Number of fields</td>
<td>The total number of different fields within in the location, each different field, even if both had the same crop but was separated by road it became 2 fields instead of 1.</td>
</tr>
<tr>
<td>Bush</td>
<td>The estimation in percentage of how much of the location that was covered in bushes.</td>
</tr>
<tr>
<td>Number of bush species</td>
<td>How many different bush types/species that was present within the location.</td>
</tr>
<tr>
<td>Red Caliandra</td>
<td>The presence of Red caliandra in the location, present or absent.</td>
</tr>
<tr>
<td>Bamboo</td>
<td>The presence of different bamboo species in the location, present or absent.</td>
</tr>
</tbody>
</table>
From the centre of each observed step, a random step length and turning angle was randomly selected and walked using measure tape and the GPS function “sign and go”. The end of the distance walked became the centre of the random location and was always marked by a GPS point. This method was repeated for each of the three random steps per observed individual (Fig 7). The range of the random distances was between 0 and 267 m, these were drawn from the actual distribution of distances and angles found in the population 2016. I excluded distances above 100 m in the method because these were not often observed in the range and due to field work limitations that made these distances harder to study.

At each observed and random location a visual estimation of land cover was conducted. I estimated the cover percentage of different habitat types: river, field, tree, bare ground and human disturbance. All percentage was given in a scale with a score from 0-100 with 10% intervals.

**A statistical analysis of animal movement: A case control study**

To model the environmental factors influencing the movement pattern of the slow lorises, I used a step selection analysis (SSF). The structure of a SSF is explained by this function:

\[ \hat{w}(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \ldots + \beta_p x_p) \]

In this function, \( \beta_1 \) to \( \beta_p \) is the coefficients estimated by the conditional logistic regression and the variables connected to these coefficients are \( x_1 \) to \( x_p \). The function can tell us how likely it is that a slow loris selects a certain step. If the function gives a location a high score for \( \hat{w}(x) \) the probability that a loris will visit that particular location is higher than for a location with a lower score (Fortin et al. 2005). The benefit of this model is that the landscape can be analysed with multiple variables. The model compares these landscape characteristics at random and observed locations at the end point of the steps (Thurfjell et al. 2014). The SSF was analysed using R version 3.4.2 (2017-09-28) with the `clogit` function in the survival package version 2.41-3. The individual variability was taken into account using random coefficients. To determine which model that explained the data best I used Akaike’s information criterion (AIC), where the lowest scored model are picked to explain the data.

To analyse the step length and turning angle distribution of slow lorises R version 3.4.2 (2017-09-28) was used, and a paired t-test conducted to see if there was a statistically significant difference between these factors between the sexes. The paired t-test was used because the data collected was dependent (each focal loris had been followed several times). QGIS Browser 2.12.3 with GRASS 6.4.3 was used for making maps over the field site and home ranges, and for measurement of the field site area.

**RESULTS**

**Distances and angles of the trajectories**

I used 1046 steps in the analysis (262 observed and 784 random). We excluded the last step of each trajectory ending in the sleeping site because the selection or choice of the sleep site by the slow loris is probably not driven by the same reasons as for the steps before (during the active hours of the slow loris). In total the distribution of the trajectories (n=23) was divided...
by females (n=12) and males (n=11). For the males the focal individual Toyib’s last trajectory are missing due to technical issues and time limit, therefore the analysis on males was on only 11 trajectories in total.

The closest estimation of distance travelled by the slow loris we got in our results is the distance between the sleep sites (straight line) and for observed steps this was in average 254 m, with a range of a minimum distance of 3 m and a maximum distance of 726 m) (Fig 8).

![Figure 8](image)

**Figure 8** The distance (straight line) between sleep sites selected by the focal slow lorises. The last sleep tree distance is missing for Toyib.

The trajectories length in total i.e. how long the loris travelled during one night of observation was for observed steps in average 480 m (range 7 – 1260 m) (Fig 9).

![Figure 9](image)

**Figure 9** The total distance of the trajectories of the focal slow lorises, i.e. the cumulative step length per trajectory. Last trajectory distance is missing for Toyib because the data lack the last sleep site for him.

I found no statistically significant difference between sexes in total distance travelled where t = 0.61 and P = 0.55. Females travelled on average 526 m (± 331 SE, range7 – 1260 m). Males travelled on average 430 m (± 238 SE, range 27 – 873 m) (Fig 10).

I found no statistically significant difference between the sexes in distance travelled between sleep sites where t = 0.43 and P = 0.68. Females travelled on average 224 m (± 270 SE, range 3 – 726 m). Males travelled on average 287 m (± 235 SE, range 55 – 615 m) (Fig 10).
The distance difference between sexes in Cipaganti both for the in average total distance and for the distance between sleepsites. Vertical bars show the standard error.

The step length and turning angle distribution (Fig 11) for the focal slow lorises observed “1hour” steps was as shown in the figures below. The step length varied from 0 to 250 m and shorter distances of travelling where used more frequently. The frequency of turning angles was about equal distributed.

As an example of a slow lorises movement pattern, you can see Tereh’s first trajectory plotted below (Fig 12).

Fine scale habitat selection
The results from the AIC model (AIC = 422) are shown in table 2. There is a significant difference between the “steps” made by the slow lorises and the paired random locations. I
got a significant positive effect for trees (P < 0.01), tree trunk cover (P < 0.001), number of fields present (P < 0.001) and for presence of Red Caliandra (P < 0.001). For the variables river (P < 0.01) and field cover (P < 0.001) I got a significantly negative effect. For the variables bush, distance to fields, labu, Bamboo, Cajeput tree and Green wattle there were no significant difference between the locations. In summary, the Javan slow lorises seem to prefer border areas with presence of tree rows and forest patches. They especially preferred areas with presence of the feeding tree Red caliandra. Also a higher amount of fields present seem to have a positive effect on the slow lorises probability to select that location, i.e. an indication of higher biodiversity within the location. A contradicting result to the previous statement is that slow lorises seem to avoid areas with a high field cover; this was true also for a high river cover.

Table 2. Results from the conditional linear regression analysis.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coef</th>
<th>SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree</td>
<td>1.241425</td>
<td>0.438298</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>River cover</td>
<td>-0.035892</td>
<td>0.013188</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>Field cover</td>
<td>-0.027060</td>
<td>0.007815</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Nr. fields</td>
<td>1.170821</td>
<td>0.243717</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Red Caliandra</td>
<td>0.817688</td>
<td>0.259942</td>
<td>P &lt; 0.01</td>
</tr>
<tr>
<td>Tree: tree cover</td>
<td>0.082160</td>
<td>0.018269</td>
<td>P &lt; 0.001</td>
</tr>
</tbody>
</table>

Discussion

Slow loris movement patterns

Although I found no significant difference in distance travelled between males and females, there was a large variation in the trajectory distances of focal slow lorises in Cipaganti. For instance the total length of the trajectories ranged from 7 m (the focal slow loris likely moved a longer distance, discussed further down) up to a distance of 1260 m. Also the range for sleep site distances varied and was between 3 m and up to 726 m. Important to note for these distances is that I only measured the distances travelled between trees and that the lorises most likely moved a greater distance if the vertical distance had been taken into account (slow lorises constantly climbing up and down trees). These distances found in this study seem reasonable for the slow lorises, since their home ranges lie within an area of about 1 km² (Qgis measurement of the field site (QGIS Browser 2.12.3 with GRASS 6.4.3)).

This pattern of variation in distances travelled is reasonable because the movement of an animal in a human modified landscape is likely influenced by multiple factors in its environment, and is the result of a trade-off between avoiding human disturbance and the use of resources within the landscape (Fortin et al. 2005). Therefore, the slow loris likely selects the most preferable location in both space and time. For arboreal primates it is believed that surrounding forest fragments are important for their survival (Pozo-Montuy et al. 2011). The distance the slow loris needs to travel depends on the presence of suitable locations in the surrounding of the previous sleep or foraging site. Therefore a longer step length distance (above 100 m) might be an indication of that the slow loris had to travel a long distance to find a suitable habitat and perhaps that gives us an indication of how fragmented the area is.

In the area of Cipaganti the total distances travelled by slow lorises was in average 480 m and for the sleep site distance it was in average 254 m. To actually be able to say something about these distances and the sleep site distance pattern it is possible a longer study period is needed, especially since it would catch environmental variations over time that might influence slow lorises differently. With my limited sample size (n = 6, I argue it is a
relatively good sample size for a slow loris species) I can only guess what influences these distances and the sleep site distance in general. For instance the shortest distance travelled during a trajectory and for the sleep site distance come from Lucu’s last trajectory. During this night she was seen for the first time with a new born baby and it is interesting to note that during that night she stayed in the same bamboo patch the whole night. Therefore I argue that the relationship between females and their young likely influences the trajectories and movement patterns of females. This female behaviour may be influenced by the state of the home range (structure and distribution of resources, sleep trees and disturbance), the individual fitness (age, experience and health) and perhaps also the age of the young. So this extremely short distance moved might have been a reasonable reaction on the fact that the female had a new born baby to take care of.

What influences slow loris movement?

Behavioural differences are of great interest to analysis of my results and can give important clues about the lives of slow lorises. How individuals move in space and time, especially in a disturbed area can give a deeper understanding about what impact these individual decisions (Thurfjell et al. 2014). What influences the slow loris to move a short or a long distance during a night is therefore very interesting. How suitable the location is might change depending on the slow loris needs and health at that moment in time and space. The slow loris is also likely influenced by resource distribution, structure of the home range, weather factors or time at night. For instance weather factors such as heavy rain or wind and changing temperatures might influence the movement (Reinhardt et al. 2016) and habitat selection of slow lorises such as making the slow loris stay and hide in a bamboo patch (personal observation) instead of moving longer distances to forage elsewhere.

The time of their active hours are probably also influencing the slow loris but this we did not analyse and should therefore be of interest for further research. Another factor of interest should be moon illumination since bright moon light can influence nocturnal primate’s activity patterns in different ways. For instance previous studies in Cipaganti have showed a more active slow loris behaviour during cloudy nights with high humidity. Less moon illumination could favour the movement of slow lorises (easier to hide etc) but according to the authors this increase in activity might be influenced by prey availability (insects) and not by the moon light (Rode-margono & Nekaris 2014). The fact that we did not take moon illumination as a variable could therefore bias our results. Further research should explore slow loris movement in relation to the moon illumination as well.

A possible trade-off difference between the sexes

During my study of slow lorises in Cipaganti the results showed no significant difference in distances travelled between the sexes. This result is not surprising due to my low sample size (n=6) and with 3 individuals per gender I can only speculate about differences among the sexes. The sexual dimorphism among the genders of javan slow lorises is not that great (Nekaris 2014) which may indicate that the genders have similar abilities of movement and foraging. But are their trade-offs the same? A previous study made in Cipaganti actually found differences in activity pattern between females and males. Their results showed that female slow lorises spend more time foraging compared to males and that males spend most of their time on behaviours like traveling, being alert, and being social (Rode-Margono et al. 2014).

One speculation is that differences among gender is usually related to reproductive success (Davies et al. 2012) and for a mature mammal female that is in charge of the parental care (seem like the female is when it comes to the slow lorises) they often invest more energy into the survival of the young (gestation and lactation) than males normally do, and this is energy
costly (Alcock 2013). The interbirth interval for a nycticebus species is around 17-22 months, and the young javan slow loris usually do not disperse until they are 16-18 months (Nekaris 2014) this together with the fact that slow lorises likely are non-seasonal breeders (Wiens & Zitzmann 2003) make the slow loris female to put a lot of energy into the reproduction every year. Therefore a successful female need to actively search for resources that are patchily distributed in the landscape, this implies a longer total distance travelled. My non-statistically significant result show an in average slightly shorter sleep site distances for females and a slightly higher average total distance travelled compared to males. If this is in fact a true pattern only further research can tell.

Then the result that female slow loris in Cipaganti spend more time on foraging than males do (Rode-Margono et al. 2014) is interesting. This movement will probably not be in a straight line (of course also males travel in this way), as my result implies, see Tereh’s movement pattern (Fig 12). Slow lorises females park their young in a tree while foraging (personal observation) and also revisit their young during the night, this behavioural likely increase their movement. One way to reduce her cost of movement and/or decrease the risk for the vulnerable young would be for the female to pick the same or a very close sleep tree.

When it comes to males in Cipaganti they spend most of their time on behaviours like traveling, being alert, and being social (Rode-Margono et al. 2014), which are factors that might increase their reproductive success. I therefore speculate that a male slow loris is successful if he has a good territory/home range (good resources of food and sleeping sites) that can attract a female’s attention. Females home ranges seem to be almost exclusively within the home range of the male (Wiens & Zitzmann 2003), and this pattern could be seen in my result, where for instance Alomah and Shirley form a spatial group (Fig 5). A social behaviour could influence his bond to the female and give him a better chance of reproducing later. Traveling and being alert seem to be behaviours that could help the male keep his home range.

Slow lorises males have been seen urine mark substrate during locomotion (Wiens & Zitzmann 2003), and this olfactory sent may keep other males away. If males choose sleep trees that are further apart (as my non-significant results indicate) it may be a way for the male to cover a larger area of his range during the night. Males are also known to have more sleeping sites in use than females (Nekaris et al. 2014). Perhaps the use of more sleeping sites that are distributed in different areas of their home range are energy effective since it would help him revisit different part of his home range more often. This behaviour could influence males to travel longer distances between their sleeping sites.

Therefore, it would be interesting to see if a larger sample size and/or a longer study period would reveal statistically significant differences between sexes if present. Of course a bigger sample size is always to be preferred, but it was for logistic reasons (time limitation, schedule issues, available collared adult lorises etc) not possible for this study and therefore a smaller sample size was chosen. A small sample size can also be misleading and not representative for the population, but I argue that my results are strong, because I surveyed each individual several times and therefore got four replicates of each individual. Random individual variation was also added into the analysis: individual variation is important if we want to understand how these lorises are coping in the agro-forest landscape of Cipaganti. Although sample size was small, I performed replicate observations for each individual to account for some of the individual variation. If no such replicates where conducted and instead more individuals were followed I could have missed the patterns of individual variation.
Step length and turning angle distribution

My results also gave a distribution over the step length distances for the slow lorises in Cipaganti. Most step lengths have a distance of between 0 and 25 m (Fig 11) and the majority of the step lengths were below 100 m. Therefore I may argue that slow lorises step distances are skewed towards shorter distances. It could be argued that slow lorises, by moving shorter distances, reduce the cost of movement, a personal observation was that they stayed in preferred trees that had a high amount of food items. A similar pattern was found in black howler monkeys (*Alouatta pigra*), their strategy was to choose a preferred tree at each step and to decrease their costs of movement by staying at that location for a longer time compared to locations with less preferred trees. They also seemed to stay in high-quality patches and avoid going back to that or other used locations where the resource already been consumed (Plante et al. 2014).

The habitat in itself will influence the slow loris and impact the distance they move between two locations. How suitable the locations between each step are, is likely a key factor that affects whether the slow loris stay for a longer period or not. It is likely a trade-off between energy gained and energy lost when moving. It is essential to understand space use patterns of animals in relation to how the animal interacts with its environment. This is important for understanding the effects of habitat change on ecosystem functioning (Potts et al. 2014). Therefore a more disturbed area with less connectivity might force the slow loris to move a longer distance to find a new suitable location. Therefore, I argue, that the fact that slow lorises are using long step lengths (above 100 m) might be a result of disturbance within their habitat that force them to move a longer distance to find better locations. Perhaps a forest habitat would in general generate a main step length that is shorter because suitable trees or locations would be constantly present in the surrounding environment compared to how a fragmented landscape structure looks like.

When it comes to the turning angle distribution, it was skewed towards 300-350°. I can only speculate about why the otherwise evenly distributed angles had this extreme. Perhaps can the fact that the steep terrain of the study area (Fig 13) give us a clue, because it made some locations very difficult to study, and perhaps my method when these difficulties arise influenced my result. It was mainly difficulties when the random distances were longer than 100 m or in locations when the direction was in a “difficult” angle. A “difficult” angle was usually where the direction crossed steep areas that were simply not safe for the observer to cross, or would take too much time to get around. When the distance or direction of the angle was not possible to use due to difficulties, the next random distance or angle that was possible were used instead. This is probably the biggest limitation of the study, due to the fact that the result might be biased towards shorter distances or a skewed result for the angles.

The most misleading angles are probably where the canopy made it possible for slow lorises to move in a direction that the researcher could not take via the ground. Important to note, is that in the areas where it was hard for humans to cross it could be as difficult or even more for the slow lorises, if the important canopy was not connected to trees on the other side of for instance a steep river. But overall the given random distances and directions were used. The range for the random angles was between 0 and 180°. These were drawn randomly in R from the previous year data base of adult slow lorises, which make these distances and angles representative for this group of slow lorises in Cipaganti.
Slow loris fine scale habitat selection

For arboreal animals a movement analysis, focusing on step selection in relation to canopy structure, can provide insight into how animals use their habitats (Mclean et al. 2016). Such knowledge can also be comparable with other similar locations. Important to note is, that this study was conducted in a modified and human dominated area, and therefore might not be comparable with other habitat selection studies from dense forest habitats. However, my analysis reveals that there are some factors in the landscape of Cipaganti that positively and negatively influence the slow loris step selection i.e. some factors increase the probability of the slow loris to move to a certain location, and others make them more prone to choose another one. For instance the presence of important foraging trees is vital for slow lorises, and they are more likely to end up in a location if it has trees such as Red Caliandra present. Hence, a higher presence of fields seems to influence them positively, perhaps due to an increasing biodiversity that positively influences the slow lorises. In addition field and river cover had a negative effect on the slow lorises habitat selection. 

The analysis did not give a significant effect on the variables canopy cover and connectivity. My prediction that the Javan slow lorises should select locations with high tree connectivity could thereby be rejected. However my result revealed that slow lorises have an increased probability of choosing a location if it had trees present (P < 0.01), which is consistent with their arboreal lifestyle. I argue however that the basis of the canopy and connectivity are linked to the presence of trees, and therefore this provides an indirect indication of the canopies importance for these primates. Interesting to note is that slow lorises had a very strong probability to choose a location if there were a higher tree trunk cover present (P < 0.001). The estimated tree trunk cover increased in two ways, with few but large tree trunks (would indicate big trees with greater canopy) or with an increasing amount of trees present (e.g. a forest patch or tree row i.e. increasing canopy cover).

Figure 13 Views from Cipaganti with sometimes steep terrain.
Another important factor for slow lorises future survival seems to be their abilities to forage, and this is mainly connected to the presence of a narrow range of trees. For instance, Green wattle provide gum, and Red Caliandra flowers are a source of nectar, both major food items for the slow lorises (Cabana et al. 2016) therefore it is interesting that we only got a significant result for the presence of Red Caliandra (P <0.01). Not even Bamboo, which are important sleep and foraging sites for slow lorises (Rode-Margono et al. 2014), gave any significant result. Previous studies highlight the importance of tree species such as String Bamboo, Sweet Bamboo, Green Wattle and Red Caliandra (Rode-Margono et al. 2014), I agree with these trees importance for the slow lorises, even though only Red Caliandra gave a significant result, I argue that the other trees are linked to foraging or resting and thereby important for the slow lorises as well. Therefore all need to be protected and maintained in a sustainable way.

I observed insects in bushes, these was located in the edge habitat of the fields, or close to roads, or in the ground vegetation of forest patches. Insects that are more abundant in edge habitats are known to increase the foraging activity by slow lorises in more disturbed areas, thereby influencing their movement pattern (Reinhardt et al. 2016). It therefore seemed reasonable that bushes would positively influence the step selection of slow lorises (because they attract insects), but the analysis gave no indication that the presence of bushes seem to influence slow lorises in any way. In addition, the number of fields present within a location showed a positive influence on the step selection of slow lorises (P < 0.001). This ability of the insects, to affect slow lorises movement, could be the reason for why the slow lorises are positively influenced by a higher amount of fields. Perhaps the positive influence of a higher diversity of crops indirect provides an increased amount of microhabitats for insects to thrive, and thereby positively influencing the insect abundance.

In addition, my results indicate that the field cover are negatively influencing the slow lorises step selection (P <0.001, Coeff = -0.027), i.e. slow lorises chose areas with less field cover. I argue this negative effect comes from their limited ability to move in an effective way through this modified landscape, due to decreasing availability of trees and canopies that provide substrates for these arboreal primates. Not only had the field cover a negative influence on the step selection of slow lorises, but the influence by river cover also showed a significantly negative effect (P < 0.01, Coeff = -0.035) as well. Perhaps this is due to rivers interrupting the slow lorises movement, and may act as barriers in the landscape. If rivers create gaps in the canopy with trees too far apart for the lorises to cross, and when the terrain of the ground are difficult or impossible for the individual to travel, it would stop their movement towards these directions.

If primates use the fields as a stepping stones when moving or foraging they become more vulnerable to the risk of being a victim to local hunters, domestic dogs or predators (Estrada et al. 2012). Therefore I predicted that the Javan slow lorises would choose locations with less road cover (less disturbed). This prediction was not supported, I could not find any significant difference between road cover in the observed and random locations. Because wildlife trade is one of the major threats to slow lorises (Nekaris & Starr 2015), their use of human dominated areas make them more vulnerable. The system of roads (Fig 14) makes it easier for hunters to get access to slow lorises, but also increase the farmer’s ability to further reach areas that can be cultivated. Therefore, I argue that roads in a long perspective increase the human disturbance of the area, and in the future may become boarders in the landscape that interrupts slow lorises movement.
My final conclusion with regard to habitat selection is that slow lorises select areas that increases their abilities to move within their habitat and that they seem to be limited in their selection. Overall, all factors in the landscape that in some way is positive for the slow loris foraging or movement abilities, are important for their fine scale habitat selection and survival. I want to stress the importance of preventing the decline of essential feeding trees, tree rows and forest patches in the agroforest landscape of Cipaganti.

Slow lorises are showing behavioural plasticity
The fact that slow lorises adapt to the changes of their habitat, by showing behaviour plasticity such as changing their foraging and movement towards cultivated areas (Nekaris et al. 2017), is another sign of their habitats fragmentation. This ability might be positive in a long term perspective (Pozo-Montuy et al. 2011) because it makes them able to cope. Hopefully slow lorises increasing use of fields will not be a factor of future conflict between farmers and slow lorises. Therefore this relationship is important to investigate further so that these conflicts can be managed in time or even prevented.

The field type itself seems to be important for slow lorises habitat selection. For example, Chayote fields influence the slow lorises movement positively because it increases the connectivity between forest patches, and slow lorises use them when foraging for insects (Nekaris et al. 2017). If slow lorises act as a predator on pest insects in the fields it would be positive for the farmers in the area. Insect outbreaks might be seen as pest problems in the agroecosystems, negatively influencing the successful crop yields (Estrada et al. 2012). Interviews with local people in Cipaganti during 2011-2015 have shown that the farmer’s knowledge about slow lorises positive effect as insect eaters is increasing (Nekaris et al. 2017). If this interaction becomes positive from the human perspective a lot is won for the future conservation of slow lorises in the area of Cipaganti.

The fields of Chayote also have a positive effect on habitat protection due to more trees are left in these cultivated areas, when trees are used as base for climbing Chayote (Fig 15) (personal observation). This is important in Cipaganti where fields normally are left without any trees. These fields with trees left, protect the normal habitat (to some degree) for these arboreal primates, and are therefore positive for the future movement and foraging abilities for slow lorises, in a long time perspective. It is also positive for the coexistence of humans and slow lorises, due to it allow farmers to continue to grow this important crop but in a sustainable way for the ecosystem. If the natural ecosystem can be protected it is positive for slow lorises and for other species as well. Important to note is that in some areas the farmers seemed to use the tree trunks as the base frame, but cut the tree above the chayote frame. In
this case, the positive effect is gone and therefore future conservation could perhaps try to increase the farmers’ positive attitude towards leaving trees undisturbed in these fields.

Figure 15 To the left you see a field of Chayote with remaining trees and as you can see the trees are working as the base construction for the bamboo frame for the growing Chayote, but this picture is a little misleading due to it is too few trees left to maintain the connectivity among the canopies. The picture to the right show how the fields of chayote normally look like with no trees left.

Conservation of slow lorises and their ability to cope
Slow lorises are specialized climbers unable to leap, which makes them less prone to go down on the ground unless it is necessary (Nekaris 2014). This means that they also have limited ability to move over gaps since they hold on to their substrate as long as possible (they stretch their body between substrates and are thereby limited by their own body length) (Fig 16). These facts make them particularly sensitive to habitat fragmentation (Voskamp et al. 2014). I argue that the fact that slow lorises choose to go down on ground (personal observation in Cipaganti) may be a sign of poor connectivity and an indication that the slow lorises are affected by the disturbance within their habitat. Hence, slow lorises ability to forage and move within their modified habitat can provide clues about their persistence and survival in a long term perspective (Pozo-Montuy et al. 2011). Thus, how the slow loris use their habitat is important knowledge if we want to improve their future survival in Cipaganti.

Figure 16 Javan slow loris moving with a steady grip on to their substrate. Photo: Little Fireface project.
Previous studies have argued that slow lorises somehow are able to cope with living in this highly modified landscape (Rode-Margono et al. 2014, Cabana et al. 2016, Reinhardt et al. 2016 & Nekaris et al. 2017). I suggest that tree rows and forest patches left in the landscape are the key to why slow lorises manage, because these zones provides important possibilities to move and forage effectively. This knowledge is useful for future land use plans in areas that are highly disturbed by humans, and where it is important to balance conservation of species against human living (Bryson-Morrison et al. 2017). Thus, the slow lorises are probably negatively affected in their movement by the human modification of the landscape, and tree rows and forest patches are therefore essential for their future abilities to cope in a long term perspective. Consequently, it is critically important to manage these tree rows and forest patches in a sustainable way. But the fact that trees around fields can be used by the slow loris is positive for their future, but cannot be seen as a potential substitute for a suitable and natural habitat.

There are sadly already signs of slow lorises declining ability to move within their fragmented habitat. For instance the mean home range size for slow lorises in Cipaganti has decreased between 2014 and 2015 (Nekaris et al. 2017). In addition, dispersing young individuals seem to end up in the local villages (personal observation) perhaps due to the fact that the landscape offers limited amount of suitable habitats and can only hold a certain amount of home ranges. The population of slow lorises in Cipaganti reproduces regularly (Cabana et al. 2016), which is a positive sign, but also a problem for their future survival of the population if there is no ability to disperse when needed.

One speculation is that in this disturbed and modified landscape the slow lorises have no other choice than to stay in close proximity to more disturbed areas, because these areas provide pieces of valuable and suitable habitat that likely are limited elsewhere. When the road network are put in relation to the home ranges of slow lorises it is easy to see that slow lorises likely have a difficult time to avoid areas with influence of human disturbance, especially if we also take the mosaic of fields into account (Fig14). Therefore future research should continue the important work towards how slow lorises are able to survive and thrive within this disturbed and human modified landscape.

It is clear that fragmented agroforest landscapes play an important role for future conservation of primates (Estrada et al. 2012) this is especially important for the slow lorises on Java, since they mainly inhabit these kinds of fragmented landscapes. The agricultural areas within the landscape of Cipaganti are entirely in the hands of the local people’s protection (Nekaris 2016), and during my field study, I saw many signs of human exploitation and the cultivated areas were constantly changing and climbing higher and higher in altitude (Fig 17). It is worrying that these signs were present even in the protected area that borders my study site. Therefore, the situation on Java is sensitive for the slow lorises, due to the fact that not even legally protected forest remnants of the mountain regions are excluded from the intensified daily exploitation from hundreds of people. This exploitation need to be stopped if we want to preserve slow lorises and other species in the future.
Hence, it makes the conservation effort harder from an ethnological perspective and forces conservationists to focus on the primate-human relationship (McLennan et al. 2017). The local people seem to provide an interesting and important key for the survival of slow lorises in Cipaganti. Therefore, I highly recommend future research to continue to investigate the coexistence of slow lorises and local people in the area of Cipaganti. I believe a lot is won for slow loris future survival if we can find possibilities for a human – slow loris interaction, which can provide actual benefits for both humans and slow lorises. Hopefully, a combination of these recommendations can help protect this agricultural ecosystem and make it possible for slow lorises to cope even in the future.

**Conclusion**

The key to why slow lorises are able to cope in this modified and highly human dominated landscape are probably the fact that slow lorises show behavioural plasticity in movement towards cultivated areas. Another reason is probably that the presence of tree rows and forest patches in this fragmented landscape still offers vital connectivity and foraging sites. Therefore the recommendation for future conservation of slow lorises in Cipaganti is to prevent further habitat loss and fragmentation, through activities that protect or maintain the present suitable habitat. Hence, tree rows and forest patches need to be maintained in a sustainable way. In a long term perspective the connectivity can be increased through the plantation of new trees where the connectivity is poor. The focus should be to plant tree species preferred by the foraging slow loris, especially the feeding tree Calliandra calothyrsus that I found was positive for the step selection of slow lorises. Another important way to increase the abundance of lorises would be to decrease monocultures. It is therefore important to increase the positive attitudes of local people towards slow lorises, perhaps through an increasing knowledge about their positive effect on the agroforest landscape. Further research is needed to increase the knowledge of these primates’ abilities to live in this modified landscape.

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