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Analysis of biophysical factors influencing nest site use by Sumatran orangutans (*Pongo abelii*) at the Ketambe Research Station, Gunung Leuser National Park

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ABSTRACT

Nest-site use provides important insights into habitat quality and resource availability for Sumatran orangutans (*Pongo abelii*). This research investigated the biophysical characteristics of nesting habitats and evaluated the habitat variables associated with nest-site use at the Ketambe Research Station in Gunung Leuser National Park. Field data were collected using line transects and vegetation plots to document nest trees, food trees, and surrounding habitat characteristics. Vegetation composition was described, while multiple linear regression and Chi-square analyses were used to examine the relationships between habitat variables and nest occurrence. A total of 46 tree species (164 individuals) were recorded, with 64% identified as orangutan food trees. Multiple linear regression indicated that habitat biophysical factors significantly affected nest-site use ($p = 0.006$; $R^2 = 0.583$). Among these factors, only the distance to food trees was significantly associated with nest-site use ($p = 0.023$). The Chi-square test revealed a marginal association between nest occurrence and the presence of food trees ($p = 0.087$). These results indicate that proximity to food trees is the main factor influencing where orangutans build nests, underscoring the importance it maintaining food-tree resources for habitat management and conservation.

Keyword: Food Trees, Gunung Leuser National Park, Habitat Biophysical Characteristics, Nest-site Use, *Pongo abelii*

1. Introduction

The Sumatran orangutan (*Pongo abelii*) is an arboreal great ape found only on the island of Sumatra, Indonesia. Because they live almost entirely in the forest canopy, orangutans carry out nearly all their daily activities there, including feeding, moving between trees, resting, and building nests [1]. Nest building is one of the most distinctive behaviors of orangutans, with individuals usually constructing a new nest each day, primarily for sleeping [2]. However, nests also function as shelters and are used for feeding, mating, and caring for offspring [3]. Because orangutan nests remain visible for extended periods after abandonment, they provide a practical and reliable indicator of orangutan presence in the wild. Nest surveys are therefore widely used to estimate density and distribution, assess habitat use, and monitor orangutan populations [4]. Nest surveys have also been successfully applied to assess the distribution and habitat use of Tapanuli orangutans in forest landscapes outside protected areas, highlighting their value as a practical tool for habitat assessment and conservation planning [5]. Understanding the factors associated with nest-site use is therefore important for describing habitat conditions and supporting conservation management.

Nest-site use in orangutans is associated with a range of habitat characteristics. Previous studies have shown that nesting trees typically possess suitable height, diameter, crown structure, and branch architecture that provide stability and protection [2]. At the habitat level, biophysical conditions such as elevation, slope, canopy cover, vegetation structure, temperature, humidity, and food-tree availability may also be associated with nest distribution and use patterns [3,6]. These factors influence microclimatic conditions, accessibility, protection from disturbance, and proximity to feeding resources. As predominantly frugivorous primates, Sumatran orangutans rely strongly on food-tree availability, which may therefore be closely linked to patterns of nest-site use and daily ranging behavior [7].

Habitat degradation caused by deforestation, fragmentation, and other anthropogenic pressures can alter forest structure and resource availability, which, in turn, may affect orangutan space use and behavior [8,9]. Similar concerns have also been highlighted in studies on forest management and conservation, which emphasize that maintaining forest quality is essential for sustaining biodiversity and ecological functions [10]. Although previous studies have described nest characteristics and aspects of nesting behavior, fewer have examined how multiple biophysical habitat variables are associated with nest-site use, particularly in natural populations of Sumatran orangutans. This information helps us understand the habitat conditions orangutans need to survive, and supports conservation planning.

The Ketambe Research Station, located within Gunung Leuser National Park, is one of the longest-running field sites for orangutan research anywhere. Recent nest surveys estimated an orangutan density of approximately 0.73 individuals per km² at the station [11]. The forest is characterized by heterogeneous vegetation that supports a diverse assemblage of food-tree species and suitable nesting habitat for Sumatran orangutans. Previous studies at Ketambe have demonstrated that vegetation structure, topography, and food-tree availability are key factors influencing orangutan habitat use and nest-site selection [12]–[15]. However, the relative contribution of individual habitat variables to nest-site selection remains poorly quantified. To address this gap, this study assesses the biophysical characteristics of orangutan nesting habitats at the Ketambe Research Station. It examines the relative contribution of habitat variables to nest-site selection. The findings contribute to a better understanding of Orangutan nesting ecology and provide a scientific basis for habitat management and conservation planning.

2. Methods

2.1. Study area

The study was conducted at the Ketambe Research Station (3°41′ N, 97°39′ E), located within Gunung Leuser National Park, Southeast Aceh Regency, Aceh Province, Indonesia (Figure 1). The station covers approximately 450 ha of lowland tropical rainforest and has supported long-term research on Sumatran orangutans since 1971. Fieldwork was carried out between January and February 2025 along three line transects established in forest areas where orangutan nests had previously been recorded.

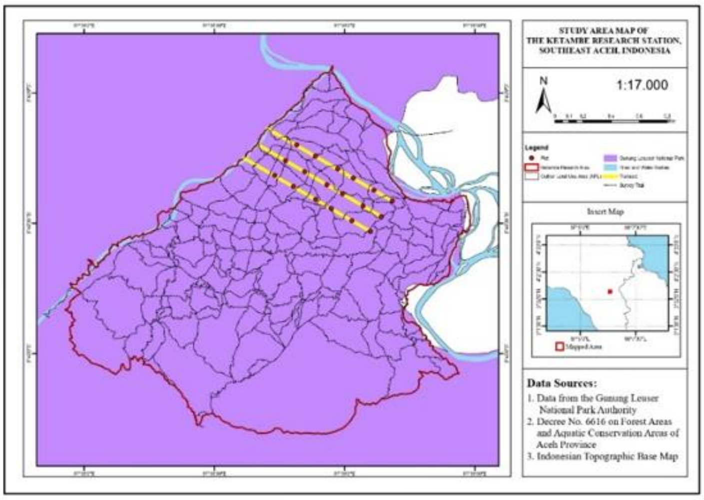

Figure 1. Study site at the Ketambe Research Station, Gunung Leuser National Park, Southeast Aceh Regency, Aceh Province

2.2. Data collection

Vegetation data were collected from sample plots established along three line transects. Each transect was 1,000 m long, with a spacing of approximately 100 m between transects. Along each transect, six vegetation plots measuring 20 × 20 m were established at approximately 150 m intervals, resulting in a total of 18 observation plots (Figure 2). This design allowed simultaneous observation of orangutan nests and habitat characteristics, and is a method commonly used in wildlife habitat and vegetation studies [16].

A total of 26 orangutan nests were found across the 18 observation plots. Because some plots contained more than one nest while others contained none, each nest was treated as an independent sampling unit. Habitat characteristics were measured separately at each nest location to evaluate the biophysical factors associated with nest-site selection. In addition, 164 individual trees were identified and measured across all observation plots to describe the vegetation structure and species composition surrounding the nest sites.

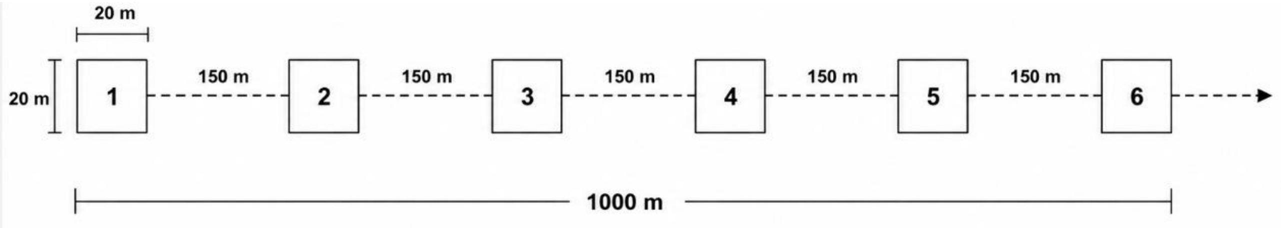

Figure 2. Illustration of the sampling design for one line transect.

A tally sheet was used to inventory every tree in the sampling plots, recording the population of each species found. Tree species were identified using leaf, stem, and bark characteristics. Species names were initially checked with the PlantNet application and subsequently confirmed by experienced staff at Ketambe Research Station. Tree species that could not be identified in the field were photographed, and the images were later compared with botanical references. Each species was then classified as either a food tree or a non-food tree according to published records of Sumatran orangutan diets.

Habitat and nest characteristics were assessed at every sampling plot. Measurements included tree height, bole height, diameter at breast height (DBH), distance to the nearest water source, distance to the nearest food tree, air temperature, and relative humidity. Information on nest-tree species, food-tree species, topography, and the presence of water sources was recorded during field observations. Tree height and bole height were measured with a clinometer, while DBH was measured at 1.3 m above ground using a diameter tape. Distances from each nest to the nearest water source and food tree were determined with a measuring tape.

Air temperature and relative humidity were measured in the morning and afternoon using a thermo-hygrometer to characterize the microclimatic conditions at each sampling plot. For the regression analysis, the explanatory variables included tree height, bole height, DBH, distance to the nearest water source, distance to the nearest food tree, and the number of food-tree species recorded around each nest site.

2.3. Data Analysis

Vegetation data were summarized descriptively and presented as tables, figures, and percentages. Vegetation characteristics were described using standard quantitative parameters, including density, frequency, and dominance, following the procedures of Mueller-Dombois and Ellenberg [16]. Food-tree diversity was evaluated using the Margalef Species Richness Index:

$$Dmg = (S - 1)/\ln(N) \tag{1}$$

where Dmg is the Margalef species richness index, S is the total number of species recorded, and N is the total number of individuals recorded.

A multiple linear regression analysis was conducted to evaluate the influence of habitat characteristics on orangutan nest site use. Prior to fitting the multiple linear regression model, data normality and multicollinearity among predictor variables were evaluated using the Shapiro–Wilk test and the Variance Inflation Factor (VIF), respectively. Six habitat variables were included as predictors: tree height (X_1), bole height (X_2), diameter at breast height (DBH; X_3), distance to the nearest water source (X_4), distance to the nearest food tree (X_5), and the number of food-tree species (X_6). The multiple linear regression model was expressed as follows:

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \varepsilon \tag{2}$$

where β_0 is the intercept, β_1–β_6 are regression coefficients, and ε is the error term.

F-tests were used to evaluate the overall significance of the regression model, whereas t-tests were used to assess the significance of individual predictors at $\alpha = 0.05$. The predictor variables with p-values between 0.05 and 0.10 were considered to show marginal evidence of association. To examine the association between orangutan nest occurrence and food-tree presence, Chi-square (χ^2) tests of independence were used. IBM SPSS Statistics is used for all statistical analyses.

3. Results and Discussion

3.1. Biophysical Characteristics of Nesting Sites of Sumatran Orangutan at the Ketambe Research Station

Across the three transects (Table 1), a total of 69 tree species comprising 164 individual trees were recorded. This vegetation community encompassed both orangutan food-tree species and non-food species, exhibiting considerable variation in tree size and species composition. This structural heterogeneity may influence orangutan habitat use by affecting the availability of food resources, the suitability of trees for nesting, and forest canopy connectivity, which facilitates arboreal movement [17].

Table 1. Tree community structure and composition across the three study transects.

Parameter	Transect			Total
	I	II	III	
Number of species	25	21	23	69
Number of individuals	58	48	58	164
Density (individuals/ha)	29	24	29	82
Frequency of occurrence (number of plots)	7	5.50	6.67	19.17
Dominance (m^2/ha)	12.27	3.53	5.25	21.05

Variations in tree community structure across transects reflect spatial heterogeneity in habitat conditions. Transect II generally exhibited lower tree species richness and fewer individual trees than Transects I and III; this pattern is likely attributable to differences in topography, elevation, and hydrological characteristics, factors known to influence vegetation structure and species composition [13]. These findings align with previous research indicating that topographic factors, particularly steeper slopes, can contribute to lower vegetation abundance and reduced species richness [18].

The vegetation survey revealed a substantial representation of food-tree species within the study area, with 29 of the 69 tree species (42.0%) identified as food trees for Sumatran Orangutans. The diversity of food-tree species provides a broad dietary resource base that may enhance orangutan dietary flexibility under seasonal variation in fruit availability and tree phenology [19]. Food-tree richness varied among transects, with the highest Margalef Index recorded in Transect I (4.75), followed by Transect III (3.94) and Transect II (3.68) (Figure 3). The higher food-tree species richness in Transect I suggests greater habitat heterogeneity and a wider diversity of food resources. Among the recorded food-tree taxa, Euphorbiaceae was the most frequently represented family, including *Macaranga trilobata, Mallotus sphaerocarpus, Blumeodendron tokbraii, Macaranga tanarius,* and *Baccaurea bracteata*. The prominence of this family underscores its likely role as a key contributor to food resource availability for Sumatran orangutans at Ketambe.

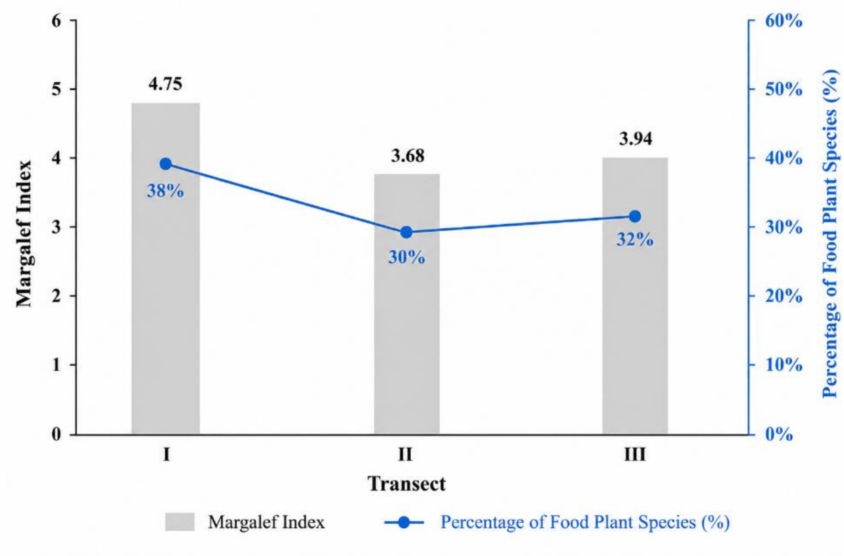

Figure 3. Margalef species richness index and percentage of orangutan food tree species across the three study transects at the Ketambe Research Station.

Regression analysis indicated that only the distance to the nearest food tree significantly influenced orangutan nest-site use. However, food-tree species diversity was not significantly associated with nest-site use. This finding may reflect the flexible foraging strategy of Sumatran orangutans. By nesting closer to food resources, they may reduce the energetic costs associated with daily foraging. Similar patterns have been reported in habitat suitability studies of Sumatran orangutans, where the spatial distribution of food resources has been identified as an important factor influencing habitat use [14].

Several tree species used as nesting sites, including *Aglaia macrocarpa, Aglaia korthalsii, Phoebe elliptica, Mastixia trichotoma, Siphonodon celastrinus, Mallotus sphaerocarpus, Blumeodendron tokbraii, Nephelium lappaceum*, and *Parashorea lucida* (Figure 4), were also recorded as food trees for Sumatran orangutans. The overlap between nesting and feeding trees is consistent with previous studies showing that orangutans frequently use food trees as nesting sites because these trees provide both structural support and immediate access to feeding resources [2,20]. In several instances, nests were built directly in food trees, resulting in a distance of 0 m between the nest and the nearest food source.

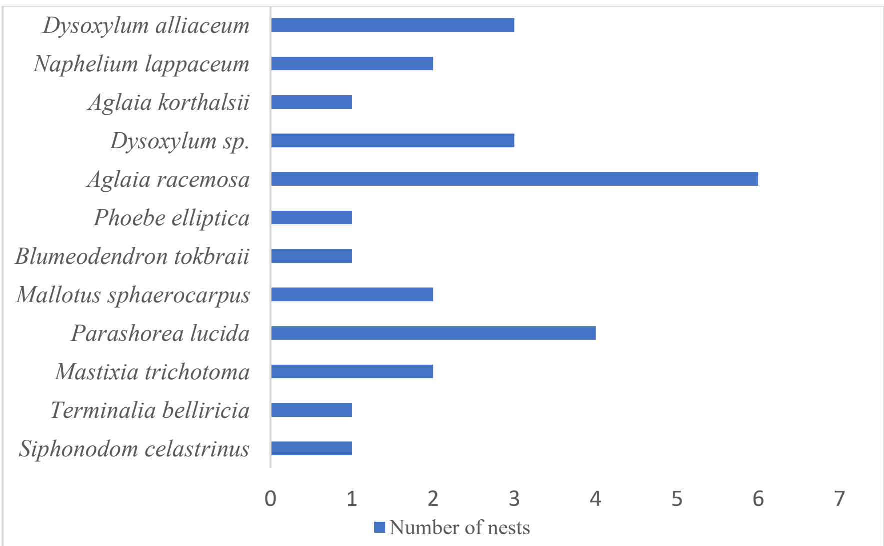

Figure 4. Frequency of nest occurrence on each tree species recorded at the Ketambe Research Station (n = 26 nests).

The trees selected for nesting showed considerable variation in size (Table 2). Tree height ranged from 10 to 30 m, whereas diameter at breast height ranged from 21 to 55 cm. Although larger trees are generally considered more suitable for nest construction because they provide stronger branches and a more stable canopy [2], tree height, bole height, and DBH were not significant predictors of nest-site use in the present study. These results indicate that tree size was not a primary determinant of orangutan nest-site selection, as nests were observed across trees with varying structural dimensions.

Table 2. Characteristics of nest trees used by Sumatran orangutans at the Ketambe Research Station.

Transect	Number of nest tree species	Number of nests	Tree nest height (m)			Diameter at Breast Height (cm)		
			Min	Max	mean	Min	Max	Mean
I	2	5	10	20	14	26	55	30
II	7	10	10	30	20.5	25	43	26.2
III	7	12	10	25	18.18	21	40	26

Beyond vegetation structure, several environmental conditions provide additional context for interpreting orangutan nesting preferences. The study area was characterized by humid lowland tropical rainforest conditions, with air temperature ranging from 22°C to 30°C and relative humidity ranging from 78% to 99%. Although these climatic variables were not included as predictors in the regression model, they remain important environmental drivers of forest dynamics. Variation in temperature and humidity may affect vegetation growth and fruit production, thereby indirectly influencing habitat suitability for orangutans [21].

Water availability represents another important biophysical component of orangutan habitat. Water sources were widely and evenly distributed throughout the study area, reflecting the riparian nature of the Ketambe landscape, where river systems contribute to the forest environment used by orangutans for feeding and nesting [22]. However, distance to the nearest water source was not a significant predictor of nest-site use, suggesting that water availability was not a limiting factor for nest-site selection. This pattern may result from the extensive distribution of rivers and streams across the Ketambe Research Station, leading to limited variation in water accessibility among potential nesting sites. Consequently, nest placement may have been more strongly associated with the distribution and accessibility of food resources than with proximity to water sources [14].

The regression model explained 58.3% of the variation in nest-site use ($R^2 = 0.583$; adjusted $R^2 = 0.451$), indicating that the measured habitat variables captured a substantial proportion of the factors associated with nest-site patterns. However, the unexplained variation indicates that nest-site use likely reflects additional ecological processes beyond those captured by the model, including temporal changes in food availability, broader-scale forest structure, canopy connectivity, and individual variation in orangutan behavior. Align with the previous finding that orangutan habitat use and nesting patterns are driven by multiple interacting factors, particularly resource availability and habitat characteristics [14].

Overall, the habitat at the Ketambe Research Station provides favorable conditions for Sumatran orangutans. Diverse vegetation, abundant food trees, suitable nesting trees, and favorable microclimatic conditions contribute to habitat quality. Among the habitat variables analyzed, only distance to food trees was significantly associated with nest-site use, underscoring the importance of maintaining food-tree resources for orangutan conservation and habitat management in Gunung Leuser National Park.

3.2. Influence of Habitat Biophysical Factors on Nest-Site Use

Prior to the multiple linear regression analysis, the normality of the residuals and multicollinearity among the predictor variables were examined. The Shapiro–Wilk test indicated that the residuals were normally distributed ($W = 0.963$, $p = 0.442$). Tolerance values ranged from 0.355 to 0.706, and variance inflation factor (VIF) values ranged from 1.416 to 2.813, indicating no evidence of multicollinearity. All six habitat variables were therefore retained in the regression analysis.

Multiple linear regression showed that habitat biophysical variables significantly affected orangutan nest-site use ($F = 4.426$, $p = 0.006$; Table 3). The model included tree height, bole height, diameter at breast height (DBH), distance to water sources, distance to food trees, and the number of food tree species.

Table 3. Analysis of variance (ANOVA) results for the multiple linear regression model explaining nest-site use by Sumatran orangutans

Source of variation	Sum of Squares (SS)	df	Mean Square (MS)	F-value	F-tabel	Sig.	Interpretation
Regression	8.519	6	1.42	4.426	2.628	0.006	Significant
Residual	6.096	19	0.321	–	–	–	–
Total	14.615	25	–	–	–	–	–

Notes: df = degrees of freedom; SS = Sum of Squares; MS = Mean Square

The coefficient of determination (R^2) was 0.583, indicating that 58.3% of the variation in nest-site selection could be explained by the combined effects of the habitat biophysical variables included in the model. In contrast, the remaining 41.7% was attributable to factors not examined in this study (Table 4). This result suggests that the model captured a substantial proportion of the habitat characteristics associated with nest-site selection by Sumatran orangutans. However, given the relatively small sample size (n = 26), this value should be interpreted with caution. The adjusted R^2 was therefore also considered to provide a more conservative estimate of the model's explanatory power.\

Table 4. Coefficient of determination (R^2) of the multiple linear regression model for nest-site use by Sumatran orangutans

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.763	0.583	0.451	0.56643

Notes: R = Multiple correlation coefficient; R2= coefficient of determination

Habitat use is generally influenced by interactions among vegetation structure, resource distribution, and environmental conditions [23]. In the present study, the habitat variables included in the regression model explained more than half of the observed variation in nest-site use. The remaining unexplained variation suggests that other ecological factors, such as seasonal fruit availability, topography, weather conditions, and human disturbance, may also influence where orangutans establish nests. Previous studies have shown that fluctuations in fruit availability affect orangutan ranging behavior and nest distribution [8], whereas human activities may reduce the use of otherwise suitable habitat [24].

Partial regression analysis showed that tree height (p = 0.625), bole height (p = 0.377), and diameter at breast height (DBH) (p = 0.492) were not significantly associated with nest-site use. Similar results were reported by [25], who found that orangutans were more responsive to the characteristics of the surrounding habitat than to the dimensions of individual nesting trees. In the present study, only distance to food trees showed a significant relationship with nest-site use, suggesting that access to food resources was more closely associated with nest use than the size of nesting trees.

3.3. Proximity to Food Trees as the Primary Determinant of Nest-Site Use

Partial regression analysis showed that distance to food trees was the only habitat variable significantly associated with orangutan nest-site use (p = 0.023; Table 5). None of the other variables had a significant effect. This result indicates that the location of food resources had a greater influence on nest-site use than the structural characteristics of nesting trees or proximity to water sources. Similar results have been reported by [1], who found that orangutan ranging patterns are closely related to food availability. Orangutans also reduce travel costs by concentrating their activities in areas with abundant food resources [26].

Table 5. Significance values of habitat variables affecting nest-site use by Sumatran orangutans

Variabel	p-value	Interpretation
Tree height (X1)	0.625	Not significant
Bole height (X2)	0.377	Not significant
Diameter at breast height (X3)	0.492	Not significant
Distance to water sources (X4)	0.081	Not significant
Distance to food trees (X5)	0.023	Significant
Number of food tree species (X6)	0.101	Not significant

The field observations support the regression results. Ten of the twelve nesting tree species recorded during the study were also used as food trees by orangutans. Several nests were constructed directly in food trees, resulting in a distance of 0 m between the nest and the nearest food source. A similar relationship between nest distribution and habitat conditions has also been reported for Tapanuli orangutans, where nest surveys were used to describe orangutan occurrence and habitat use across forest landscapes [5]. Previous studies at the Ketambe Research Station reported that feeding occupies approximately 38–40% of the daily activity budget of Sumatran orangutans [25,26]. Building nests close to feeding areas is therefore likely to reduce daily travel and energy expenditure while providing immediate access to food. Similar observations were reported by [2], who found that orangutans frequently established nests near feeding sites in response to the patchy distribution of food resources in tropical forests.

The association analysis between nest occurrence and the presence of food trees showed a marginal relationship ($p = 0.087$). Although the relationship was not statistically significant at the 5% level, the result suggests a tendency for nests to occur in areas with food trees. The present findings are in line with the habitat suitability model developed by [14], which identified the distribution of food plants as a key determinant of orangutan habitat use in Gunung Leuser National Park. In the present study, proximity to food trees was significantly associated with nest-site use, whereas the association between nest occurrence and food-tree presence was comparatively weak. These results suggest that access to food resources may be more important than the mere presence of food trees. Further studies with larger sample sizes and additional environmental variables are needed to better understand the role of food resources in orangutan nest-site selection. Regardless of the statistical strength of individual habitat variables, maintaining food-tree resources remains fundamental to habitat management and the long-term conservation of Sumatran orangutans [27].

4. Conclusion

Habitat biophysical characteristics explained a significant proportion of the variation in orangutan nest-site use at the Ketambe Research Station. Distance to food trees was the only variable significantly associated with nest-site use, indicating that food accessibility plays a central role in nest-site selection. Given the importance of food resources in nest-site use, conserving food-tree species and maintaining forest integrity should be a priority in habitat management for Sumatran orangutans.

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