

Variation of weekly home range characteristics of Sumatran elephants (*Elephas maximus sumatranus*) in Bentang Seblat, Bengkulu Province, Indonesia

IRMA KUSUMA NINGRUM^{1,*}, YANTO SANTOSA², YUDI SETIAWAN²

¹Program of Tropical Biodiversity Conservation, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Ulin Kampus IPB, Dramaga, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8621677, *email: irmakusuma2@gmail.com

²Department of Forest Resources Conservation and Ecotourism, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Ulin Kampus IPB, Dramaga, Bogor 16680, West Java, Indonesia

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Abstract. Ningrum IK, Santosa Y, Setiawan Y. 2023. Variation of weekly home range characteristics of Sumatran elephants (*Elephas maximus sumatranus*) in Bentang Seblat, Bengkulu Province, Indonesia. *Biodiversitas* 24: 5854-5862. Bentang Seblat is one of the areas of conflict between Sumatran elephants and humans arising from space use problems because Sumatran elephants have specific preferences for habitat characteristics. This study aims to identify the characteristics of the weekly home range and analyze the relationship of weekly home range with habitat characteristics of Sumatran elephants in Bentang Seblat. GPS collar data from November 2020 until August 2022 were obtained from the Natural Resources Conservation Agency of Bengkulu-Lampung Province and habitat characteristics were obtained from Landsat 8 imagery. The data obtained were analyzed using chi-square test and Multiple Regression Analysis (MRA) with five variables: land cover, slope, distance from water sources, roads, and settlements. The results showed that the weekly home range was between 2.67 ha-239.98 ha, averaging 46.1 ha. The highest percentage of each habitat characteristic includes secondary forest (55.38%), flat slopes (59.01%), distances of 0-450 m from water sources (35.11%), distances of 0-400 m from roads (70.81%), and distances of 6-8 km from settlements (50.37%). The weekly home range is closely related to all habitat characteristics, with the highest level of relationship significance being the distance from water sources and the distance from the settlement.

Keywords: Bentang Seblat, habitat characteristics, Sumatran elephant, variation, weekly home range

INTRODUCTION

Sumatran elephant conflict with humans is one of the main factors in the decline of Sumatran elephant population (Rustiati et al. 2020; Ardiantiono et al. 2021; Purba et al. 2023). According to the Director General of KSDAE (2020), the Sumatran elephant population in 2017 was only 1.694-2.038 individuals. The conflict between elephants and humans was initiated by the decline and fragmentation of the natural habitat of Sumatran elephants (Sukmantoro et al. 2019; Ramadhanti et al. 2022; Yoza et al. 2023). Santoro et al. (2023) state that the forest area on Sumatra Island, which is the habitat of Sumatran elephants, has decreased by 356,100 ha/year. Conflicts occurred in all Sumatran elephant distribution areas, namely Aceh, North Sumatra, Riau, Jambi, Bengkulu, South Sumatra and Lampung (Wettasin et al. 2023; Yoza et al. 2023). One of the areas with the highest conflict in Bengkulu is the Bentang Seblat (Imtiyaz et al. 2021). The Bentang Seblat area consists of Seblat Nature Park (TWA) to Kerinci Seblat National Park (TNKS). According to Budianto (2010), the frequency of conflicts in the Seblat area in 2007-2009 reached 78 conflicts, with estimated losses worth Rp2,791,650 per family head per year.

Based on public perception, Sumatran elephants are considered pests of community plantations (Berliani et al. 2018; Qomariah et al. 2019). The community has yet to realize that the conflict with the Sumatran elephant resulted

from activities carried out by the community. Sumatran elephants are considered the cause of community crop failure and cause high economic losses (Kuswanda et al. 2022; Yoza et al. 2023). Community plantations are temporary foraging grounds for Sumatran elephants. Sumatran elephants often visit community plantations for food Yoza (2023), so many community plantation crops are damaged due to ingestion and trampling (Saputra et al. 2023). This is because Asian elephants, including Sumatran elephants have a high preference for the types of crops grown by the community, such as coconut, areca nut, and cocoa (Ramkumar et al. 2014; Berliani et al. 2016; Govind and Jayson 2018).

Sumatran elephants (*Elephas maximus sumatranus*) are included in Indonesia's list of priority animals that must be protected. Various conservation and mitigation efforts have been carried out to minimize the intensity of conflict between elephants and humans. All parties synergistically carry out conflict mitigation efforts through patrols, activation, planting plant species that Sumatran elephants do not like, building trenches, using noises, and installing electric fences (Perera 2009). However, this method is considered less effective because it requires a lot of resources. In addition, the use of sounds and electric fences has the potential to endanger Sumatran elephants because it can cause injuries and stress (Enukwa 2017; de Mel et al. 2023). Based on this, it is necessary to conduct a study related to how the characteristics of the Sumatran

elephant's weekly roaming area are used to carry out activities in the spatial dimension.

Research related to the home range area of Sumatran elephants has been conducted by Nugraha et al. (2014) but is only limited to the location of Tesso Nilo National Park. Another study related to the movement of Sumatran elephants in Seblat was conducted by Sitompul (2013) but did not specifically study the weekly roaming area. Therefore, it is necessary to conduct studies on how the characteristics of the Sumatran elephant's weekly home range are used to carry out activities in the spatial dimension of the Bentang Seblat. In general, research on Sumatran elephant home ranges and their relationship to habitat characteristics is only carried out on a monthly to annual basis. Meanwhile, studies regarding home ranges within a weekly period have never been carried out. Based on this, it is necessary to study the variations in the weekly home range of Sumatran elephants and their relationship with habitat characteristics in Bentang Seblat. The objectives of this study are 1) to identify the characteristics of the weekly home range of Sumatran elephants in the Bentang Seblat and 2) to analyze the relationship of the weekly home range with the habitat characteristics of Sumatran elephants in the Bentang Seblat.

MATERIALS AND METHODS

Study area

The research was conducted from May to June 2023 in the Bentang Seblat, Bengkulu Province, Indonesia. Bentang Seblat consists of Kerinci Seblat National Park, Limited Production Forest (Lebong Kandis), and Production Forest (Air Rami, Air Ipuh, Air Teramang). More specifically, the research location was concentrated

in the Air Rami Production Forest according to the GPS collar recordings obtained (Figure 1). Based on geographical location, HP Air Rami is directly adjacent to the Lebong Kandis Limited Production Forest, Gajah Mungkur Village, and PT Alno Agro Utama (PT AAU).

Data collection

The research data included area maps, land cover maps, DEM (Digital Elevation Model) topographical maps, water sources maps, road maps, settlement maps, and data on Sumatran elephant movements in the Bentang Seblat recorded via the GPS Collar. GPS Collar is installed on one adult female individual who is the leader of the elephant group. It is assumed that the movement of the group leader can represent the movement of the elephant group at that location. The GPS Collar data used is recorded for November 2020-August 2022. The data was obtained from the Bengkulu-Lampung Province Natural Resources Conservation Agency (BKSDA) and downloaded via the Earth Explorer USGS (United States Geological Survey) sites, HydroSHEDS, GADM, and Ina-Geoportal. The types of data and methods used in this study can be seen in Table 1.

Data analysis

GPS collar recorded data is converted into polygons using the Minimum Convex Polygon (MCP) method with the Minimum Bounding Geometry tools in ArcGIS 10.8. MCP is a method that connects the outermost points into polygons and can be used to estimate the range area of wildlife (Pairah et al. 2015; Bahar et al. 2018), including Sumatran elephant (Nugraha et al. 2014; Moßbrucker et al. 2016). Characteristic variables such as land cover were analyzed using supervised classification, slope using slope and reclassify, and distance from water sources, roads, and settlements using Euclidean distance.

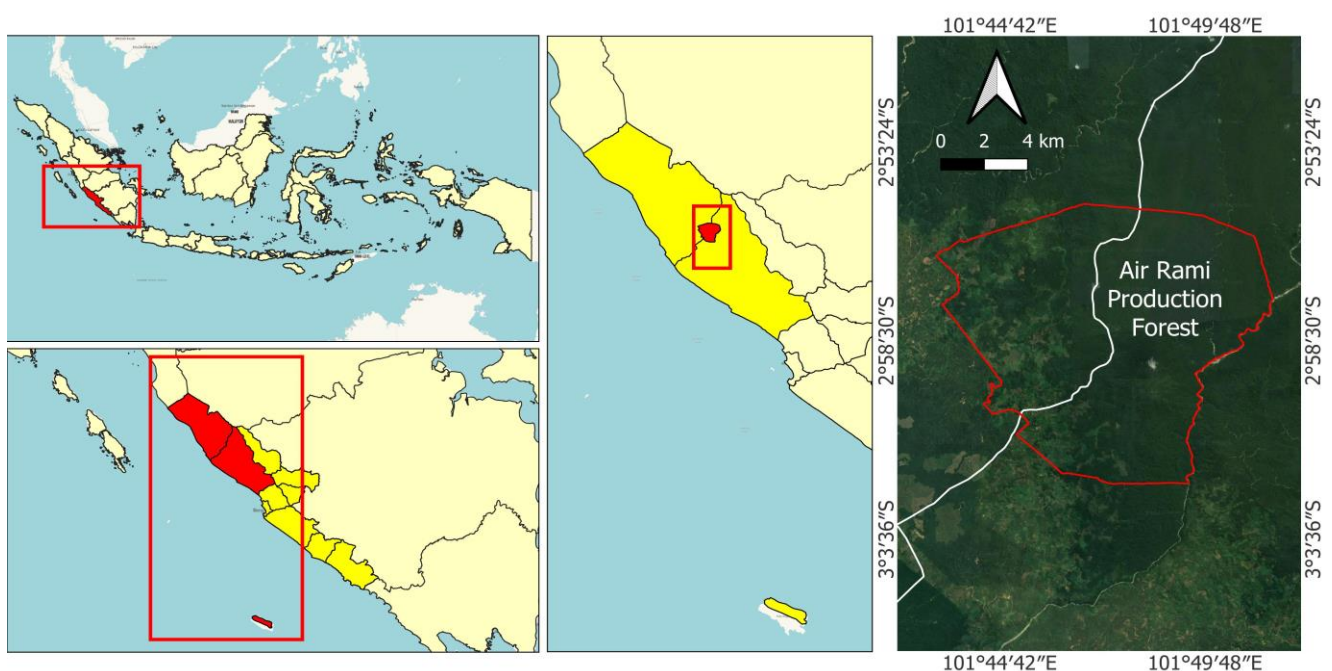


Figure 1. The research locations are in Bentang Seblat, Bengkulu Province, Indonesia, namely Air Rami Production Forest

Table 1. Types of data and research methods

Objective	Variable type	Method of collecting data	Method of data analysis
Identify the characteristics of the weekly home range of Sumatran elephants in the Bentang Seblat	<ul style="list-style-type: none"> The weekly home range of the Sumatran elephant Sumatran elephant habitat characteristics (land cover, slope, distance from water sources, distance from roads, and distance from settlements) 	<ul style="list-style-type: none"> Direct observation Data collection on the results of <i>GPS collar monitoring</i> of Sumatran elephants from the Bengkulu-Lampung Province Natural Resource Conservation Agency (BKSDA) Data download: <ol style="list-style-type: none"> Bengkulu Province administrative boundary map (https://gadm.org/) Landsat image 8 of Bengkulu Province in 2020, 2021 and 2022 (https://earthexplorer.usgs.gov/) Watersource .shp data (https://hydrosheds.org/) DEM data, RBI road and settlement map .shp data (https://tanahair.indonesia.go.id/) 	<ul style="list-style-type: none"> GIS analysis Descriptive statistical analysis Chi-square $x^2 = \sum \frac{(f_0 - f_e)^2}{f_e}$
Analyze the relationship of the weekly home range with the habitat characteristics of Sumatran elephants in the Bentang Seblat			<ul style="list-style-type: none"> Multiple Regression Analysis (MRA) $Y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5$

Furthermore, the calculation results were analyzed with descriptive statistics and chi-square. The chi-square test was only tested on the dominant category in each habitat characteristic for validation before being tested with multiple regression analysis. The software used to carry out the chi-square test is SPSS Statistics. Calculation of the value of x^2 count on the chi-square test can be done with the following formula:

$$X^2 = \sum \frac{(f_0 - f_e)^2}{f_e}$$

Where:

X^2 : Chi-square value

f_0 : Frequency of encounters obtained

f_e : Expected frequency value

Based on the chi-square test, the basis that can be used in decision-making is as follows:

- If the x^2 count value $> x^2$ table or Asymp. Sig (2-sided) < 0.05 , then reject H_0 or accept H_1 . It means there is a relationship between weekly home range area and habitat characteristics.
- If the x^2 count value $< x^2$ table or Asymp. Sig (2-sided) > 0.05 , accept H_0 or reject H_1 . It means there is no relationship between weekly home range area and habitat characteristics.

The multiple regression analysis (MRA) method is a method that can be used to identify and measure the relationship between variables. Variable in the MRA method consisting of one dependent variable (Y) and several independent variables (X_1, X_2, \dots, X_n) (Mizumoto 2023). The equation that can be used for multiple regression analysis is:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

Where:

Y : Weekly roaming area

a : Regression constant

b_1, b_2, \dots, b_5 : Regression coefficient

X_1 : Land cover area

X_2 : Slope area

X_3 : Distance from water source

X_4 : Distance from the road

X_5 : Distance from settlements

RESULTS AND DISCUSSION

Composition of weekly home range area

The home range is an area of movement or use of habitat that Sumatran elephants often traverse in carrying out their daily activities and fulfilling their needs. The weekly home range area of the Sumatran elephant in Seblat is categorized into three classes, namely small (0-80 ha), medium (80-160 ha), and large (160-240 ha). The weekly home range area varies from 2.67 ha to 239.98 ha, with an average area of 46.10 ha. This value is smaller than the home range area in other locations. According to Nugraha et al. (2014), the home range of the Sumatran elephant in Tesso Nilo National Park in 1 year is 22,362.27 ha. Research by Sitompul et al. (2013) in Bengkulu Province also stated different results, namely that the average monthly Sumatran elephant home range is 3,460 ha. The weekly home range area composition can be seen in Figure 2.

Figure 2 shows that the weekly home range area of the Sumatran elephant in the Bentang Seblat is dominated by the small category (0-80 ha), namely 81.61%. The weekly home range in the large category (160-240 ha) is the class with the lowest amount of data, namely only 5.75%. Besides that, movement in the form of the weekly home range area of the Sumatran elephant varies relatively based on seasonal differences (Figure 3). The average value of the Sumatran elephant's weekly home range area in the dry season is higher (52.81 ha) compared to the rainy season (39.23 ha). Differences in home ranges in groups of elephants can be caused by various factors, such as habitat conditions and levels of disturbance. This is in accordance

with Moßbrucker et al. (2016), who stated that home range sizes varied between locations, individuals, seasons, and habitat conditions (availability of food, water, and human activity). The availability of optimal resources in a habitat will make the Sumatran elephant not have to move too far to find and water sources (Bakri et al. 2022). These conditions will form a narrower and smaller home range area. Sumatran elephants tend to explore larger areas when there is a decrease in feed productivity in a habitat.

Composition of the land cover

Cover is an important aspect in supporting the life of Sumatran elephants. Analysis of the weekly home range of the Sumatran elephant was carried out on three types of land cover, namely primary forest, secondary forest, and shrubs. Primary forest is a forest that grows naturally for a long time without significant disturbance or human intervention. Secondary forest is defined as a regenerating forest that grows back due to disturbance or human activity, such as logging and forest fires. Shrubs are areas of former dry forest that grow again and are inhabited by undergrowth. The composition and distribution map of weekly home ranges for Sumatran elephants based on land cover can be seen in Figure 4.

Most weekly home ranges were found in secondary forests, with a percentage value of 55.38%. Chi-square test between weekly home ranges and secondary forest land cover show that the two are significantly related. The value of χ^2 count is 97.804 > χ^2 tables at $\alpha = 5\%$ which is 9.49. This is in line with de Silva et al. (2023), who stated that secondary forest is the most suitable habitat for Sumatran elephants because it is generally able to fulfill the components of food and cover (Khairani et al. 2022). Secondary forests have a lot of food availability that suits the preferences of Sumatran elephants, ranging from the growth rate of undergrowth plants to trees. The research location is a production forest area still active today, so the secondary forest cover is higher than other land covers. Sumatran elephants prefer secondary forests and transitional areas because they consider the density of vegetation and the amount of young vegetation that can be a food source (de la Torre et al. 2022).

Composition of the slope

Slopes are one of the physical characteristics of the habitat that need to be considered in this study because Sumatran elephants have special preferences related to slopes. The slope is classified into five classes, namely flat (0-8%), gentle (8-15%), wavy (16-25%), steep (25-40%), and very steep (>40%). The calculation results show that Sumatran elephants in the Bentang Seblat are only found in 4 slope classes (Figure 5).

Figure 5 shows that the presence of Sumatran elephants based on their slopes is mainly found on flat slopes (59.01%). In addition to flat slopes, the sloping slope class also shows a reasonably high percentage value of 34.56%. The value of χ^2 calculated on the chi-square test of flat slope (69.933) and gentle slope (118.426) is greater than the χ^2 table at the significant level ($\alpha = 0.05$) = 9.49. This value resulted in a decision to accept H1, which means that

the Sumatran elephant's weekly home range is related to flat and gentle slopes (Table 2). Sumatran elephants will avoid difficult terrain, such as very steep slopes, to save energy usage (Jiang et al. 2023). In accordance with Wilson et al. (2021) and Wettasin et al. (2023), Sumatran elephants prefer flat to gentle slopes with consideration of ease of accessibility in fulfilling daily needs and movement of Sumatran elephants, especially when meeting predators.

Composition of the distance from the water source

Water is one component of the resources needed by Sumatran elephants to fulfill their needs. The water source at the research location comes from the Sepunggur River, which is further categorized into 5 classes, namely 0-450 m, 450-900 m, 900-1,350 m, 1,350-1,800 m, and 1,800-2,250 m (Figure 6).

The results show that the Sumatran elephant's weekly home range is close to water sources. Based on Figure 4, as much as 35.11% of the Sumatran elephant's weekly home range is found at a distance of 0-450 m and 23.36% at a distance of 450-900 m. These results are in accordance with Kumar et al. (2023), which state that the presence of Sumatran elephants based on distance from water sources is found in intervals 0-500 m. It is suspected that the presence of Sumatran elephants in specific habitats does not occur randomly but rather occurs due to preferences or level of preference. The chi-square test results on the distance from the water source showed that the calculated χ^2 count was 35.237 and 48.285 greater than the χ^2 tables at the significant level ($\alpha = 0.05$) = 9.49. This value produces a decision to accept H1 (Table 3). Sumatran elephants have a high preference for water availability because they are classified as water-dependent species (Cook et al. 2023). Elephants cannot stand the heat during the day, so they need water to wallow and drink (Wen et al. 2018; Rendana et al. 2023).

Table 2. Chi-square test results for flat and sloping slopes

	X ² count	X ² tab	Decision
Weekly home range area with flat slope (0-8%)	69.933	9.49	Accept H1
Weekly home range area with gentle slope (8-15%)	118.426	9.49	Accept H1

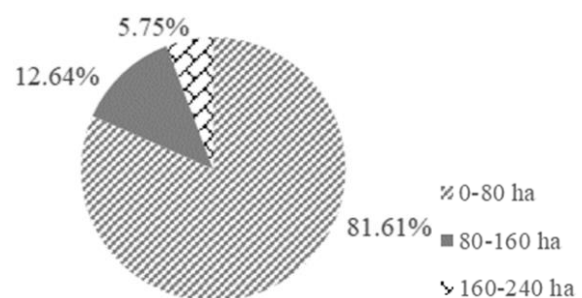


Figure 2. Composition of the weekly home range area of the Sumatran elephant

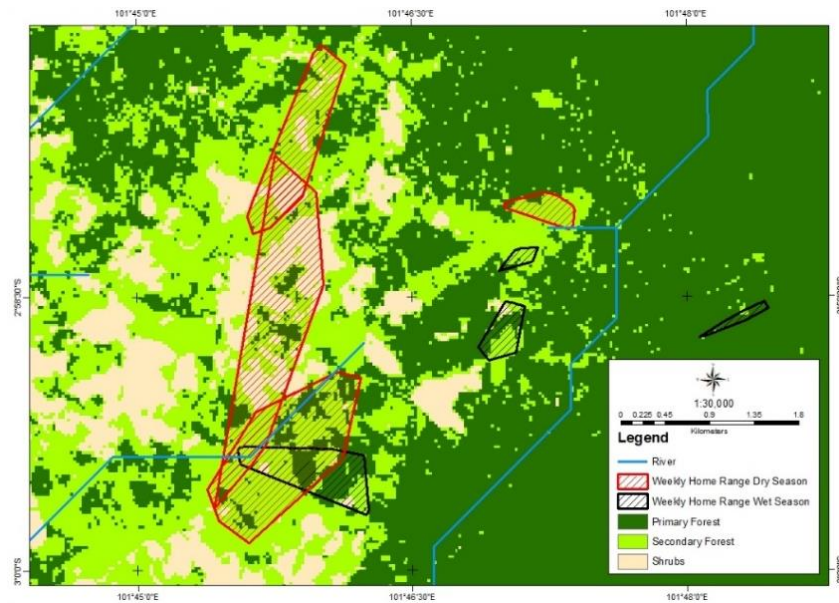


Figure 3. Weekly home range composition of Sumatran elephants based on season

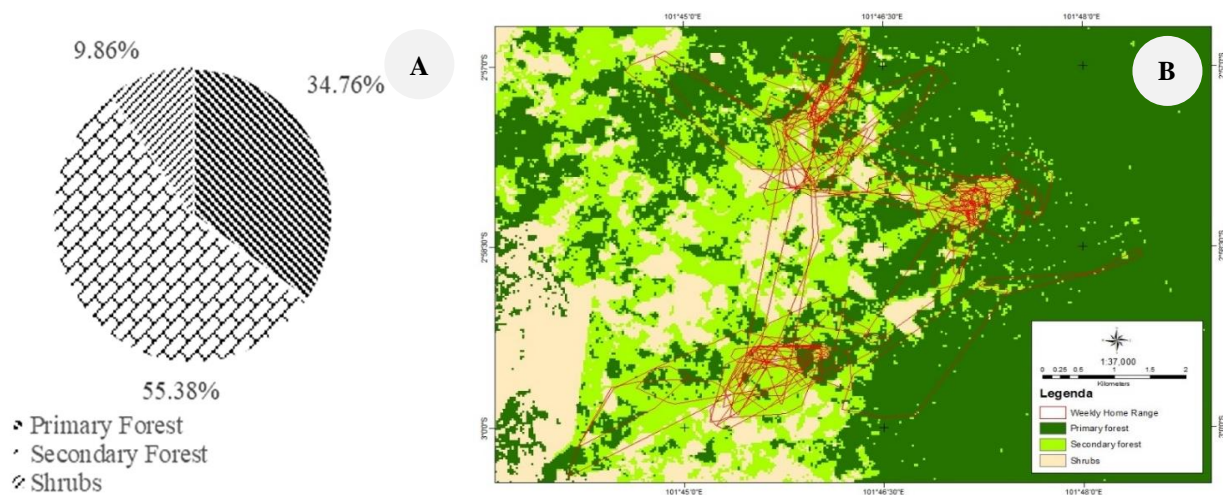


Figure 4. Weekly home range composition of Sumatran elephants based on land cover: A. Composition, B. Distribution map

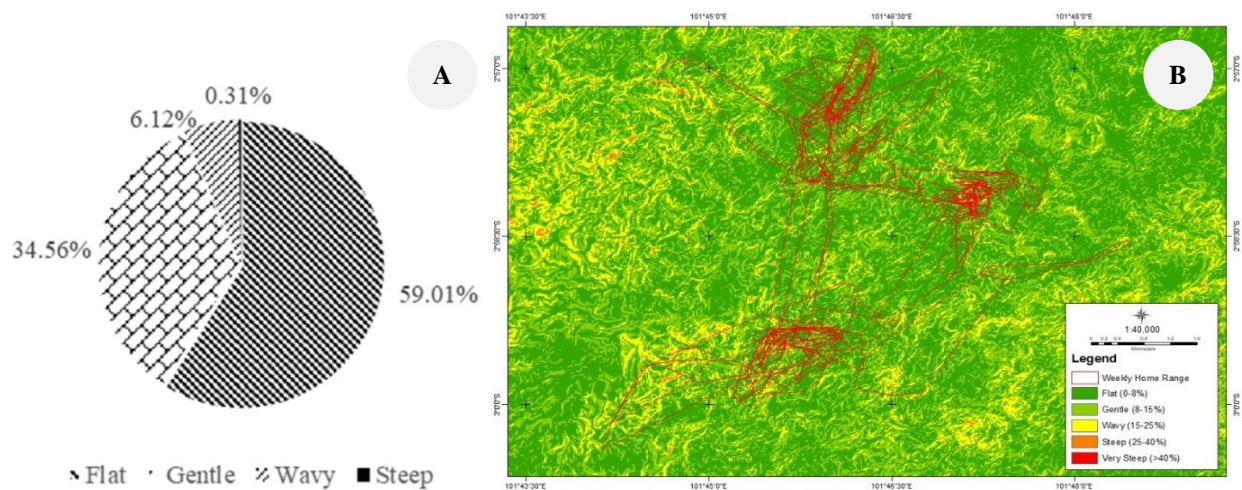


Figure 5. Weekly home range composition of Sumatran elephants based on slope: A. Composition, B. Distribution map

Composition of the distance from the road

The Sumatran elephant's weekly home range cannot be separated from the existence of roads that can affect the movement of elephants. The road in question includes major roads (main roads), as well as small roads (patrol routes, encroachment routes, skid trails, etc.). Variations in weekly home range characteristics related to distance from the road can be seen in Figure 7.

The comparative results in Figure 5 shows that the highest proportion or percentage is in the short distance range, namely 0-400 m (70.81%). The next high percentage is 19.62% at 400-800 m. This happens because there is a relationship between the home range area and the distance from the road 0-400 m and 400-800 m, according to the chi-square test results presented in Table 4. The weekly home range area with the smallest coverage is at a distance >1,600 m, only 0.77%.

The factor causing the Sumatran elephant's home range at the study site to be close to the road is the function of the forest area. The research location is part of a production forest area, so the level of human activity and road opening is high. This situation makes the elephant habitat closer and intersects with the roads traversed by humans. The Sumatran elephant chooses an area close to the road because the trail of the road opened by encroachers or patrol officers can reveal shoots of leaves that have the potential to be a source of food for Sumatran elephants and is compatible with one of the Sumatran elephant feed guilds, namely folivore. Based on the feed guild, elephants are classified not only as browsers and grazers but also as folivores (Koirala et al. 2016). Young leaves have a soft texture, good taste, and high nutritional content. Sumatran elephants consume more of the leaves or shoots of trees than tree bark or roots because the protein has a higher nutritional value. The water content in the leaves also has a high percentage level of 50-95%, so by consuming leaves Sumatran elephants not only meet feed needs but also simultaneously fulfill their water needs.

Composition of the distance from the settlements

In general, the presence of humans is a potential disturbance to wildlife, especially for sensitive wildlife species such as the Sumatran elephant. Settlements can be a limiting factor for the movement and size of the Sumatran home range. Based on the variation in the distance characteristics from settlements, it appears that the Sumatran elephants at the study site chose habitats far from settlements (Figure 8).

Figure 8 shows that 50.37% of the Sumatran elephant's weekly home range is located 6-8 km from human settlements. The next highest proportion, 24.77% is at a distance of 4-6 km. This is in accordance with Azmi's research (2022), which states that more traces of Sumatran elephant activity are found at a distance of >5 km from settlements. Sumatran elephants avoid settlements to gain a sense of security, especially for carrying out specific behaviors such as reproduction. In addition, the group of elephants at the study site is led by an adult female individual. According to Von Gerhardt et al. (2014), female elephants prefer to live by avoiding conflicts with humans, especially in residential areas. The chi-square test results at distances of 4-6 km and 6-8 km show a relationship with weekly home ranges, as presented in Table 5.

Table 3. Results of the chi-square test for distance from water sources

	X ² count	X ² tab	Decision
Weekly home range area with water source distance of 0-450 m	35,237	9.49	Accept H1
Weekly home range area with water source distance of 450-900 m	48,285	9.49	Accept H1

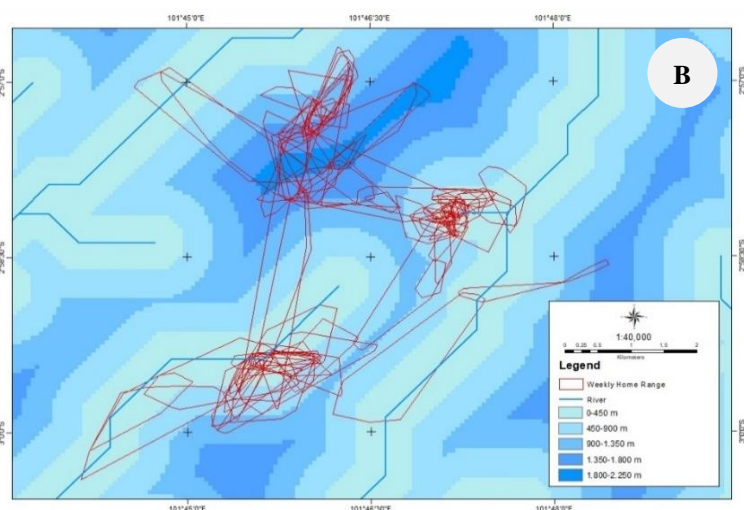
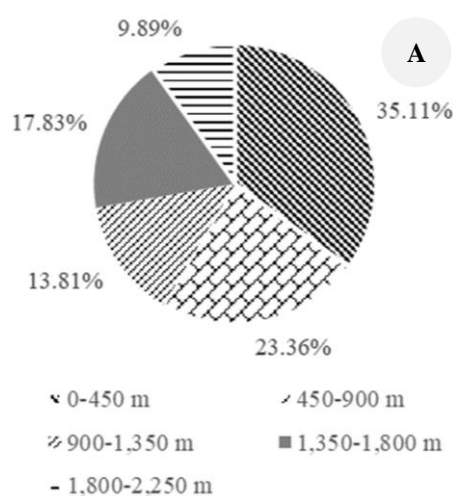


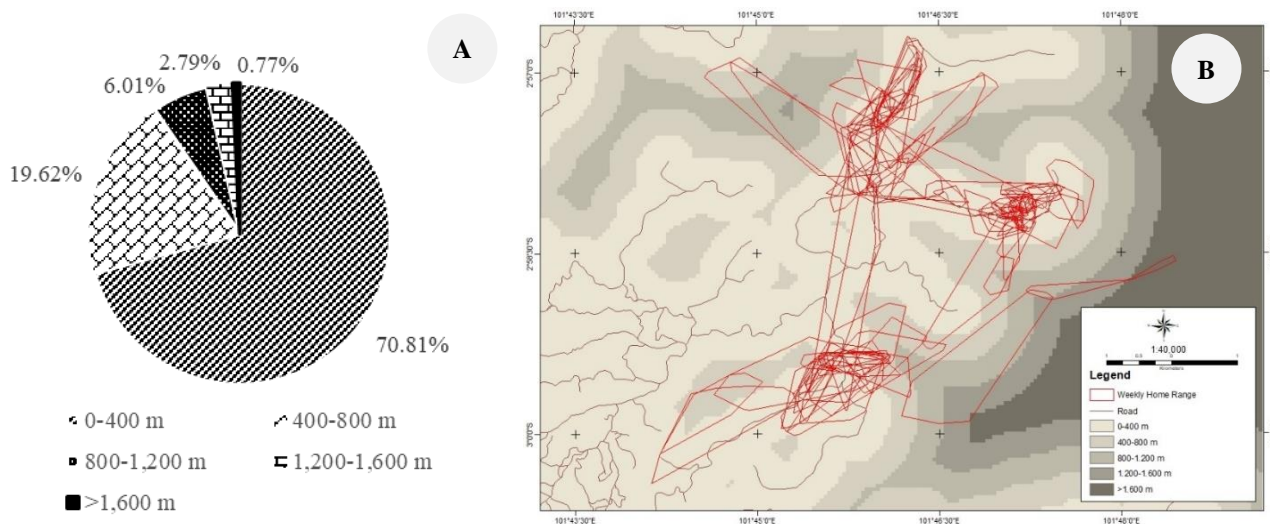
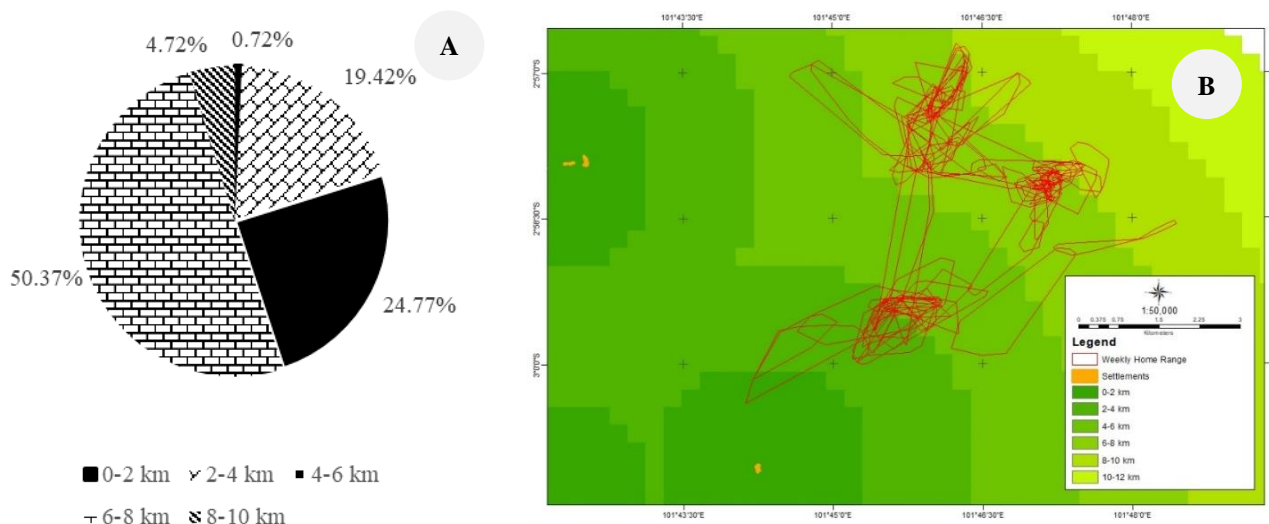
Figure 6. Weekly home range variations of Sumatran elephants based on distance from water sources: A. Composition, B. Distribution map

Table 4. The results of the chi-square test for distance from the road

	X ² count	X ² tab	Decision
Weekly home range area with road distance of 0-400 m	92,458	9.49	Accept H1
Weekly home range area with road distance of 400-800 m	40,401	9.49	Accept H1

Table 5. Results of the chi-square test for distance from settlements

	X ² count	X ² tab	Decision
Weekly home range area with settlement distance of 4-6 km	50,118	9.49	Accept H1
Weekly home range area with settlement distance of 6-8 km	39,7	9.49	Accept H1

**Figure 7.** Weekly home range composition of Sumatran elephants based on distance from road: A. Composition, B. Distribution map**Figure 8.** Weekly home range composition of Sumatran elephants based on distance from settlements: A. Composition, B. Distribution map

Relationship of weekly home range area with habitat characteristics

Multiple linear regression analysis was performed by testing the weekly home range area (Y) with various habitat characteristics (X). Habitat characteristics tested

included secondary forest cover area (X1), flat slope area (X2), distance from water sources (X3), distance from roads (X4), and distance from settlements (X5). The results of multiple linear regression analysis and their significance can be seen in Table 6.

Table 6. Results of multiple linear regression analysis of weekly home range area with habitat characteristics

Equality	Sig.	r (partial)	R Square
Y = 18.024 + 0.173 X ₁ + 1.52 X ₂ - 0.005 X ₃ + 0.011 X ₄ - 0.003 X ₅	X ₁ = 0.030	0.238	0.972
	X ₂ = 0.000	0.923	
	X ₃ = 0.010	-0.282	
	X ₄ = 0.022	0.251	
	X ₅ = 0.000	-0.424	

Based on the results of the analysis in Table 6, it can be seen that the significance value for all habitat characteristics is <0.05, which means it has a relationship with the weekly home range area. The highest significance is shown in the variables of flat slope and distance from settlements, with a significance value of 0.000. This is in line with the results of the partial correlation that shows the flat slope area is a habitat characteristic with the highest r value of 0.923. This result indicates that the correlation of the flat slope area is very strong when other variables are held constant. Sumatran elephants are intelligent animals and will try to make their movements efficient, especially avoiding predators or disturbances. This is in line with the anti-predator theory which explains that wild animals will choose a location far from predators or disturbances, including humans. Debnath et al. (2023) stated that the presence of predators can cause fear and even affect the decline in the reproduction and population of these animals. Besides that, Wilson et al. (2021) also stated that slope has a large impact on elephant movement in foraging.

In addition, multiple linear regression analysis also produces a high R squared value of 0.972. The R square value indicates that all tested habitat characteristics contribute to the weekly home range of 97.2%. The other 2.8% is explained by other independent variables outside of this study. The value of the regression coefficient (B) for habitat characteristics in the form of secondary forest cover, flat slope, and distance from the road is positive (+), while the distance from water sources and distance from settlements is negative (-). This shows that the weekly home range area will increase with the increase in the unit value of secondary forest cover area, flat slope area and distance from the road. On the contrary, this result is in accordance with Snyder et al. (2023) the negative sign (-) has the opposite meaning that the higher the area of the home range, the smaller the value of habitat characteristics in the form of distance from water sources and settlements.

Overall, this present study indicates that the weekly home range area of the Sumatran elephant in Bentang Seblat varies greatly, especially from season to season. Weekly home ranges are dominated by habitat characteristics in the form of secondary forest land cover, flat slope, distance of 0-450 m from water sources, distance of 0-400 m from roads, and distance of 6-8 km from settlements. Habitats with these criteria can be used as essential or priority areas that require special attention from all parties, especially managers, to ensure the survival of the Sumatran elephant population. Based on this research, it is hoped that the stakeholders can monitor and re-install the GPS Collar to find out the latest movements and ensure that the Sumatran elephant is in a suitable habitat.

All habitat characteristics are very significantly related to the weekly range of the Sumatran elephant. The highest level of significance is shown in the variable area of flat slope and distance from settlements. Weekly home range area is directly proportional to secondary forest cover area, flat slope area, and distance from the road but inversely proportional to distance from water sources and distance from settlements. Relocation of community activities and access to resource use to areas that do not intersect with Sumatran elephant home range areas is recommended so that elephants can avoid stress due to human presence. Stakeholders concerned in this field are encouraged to educate the public on how to avoid the Sumatran elephant habitat (socialization, appeal, prohibition). People are not allowed to approach elephant habitat (farming, settlement) and use the same resources as the water sources from the Aek Simunggur River. In addition, another study is needed to carry out multiple linear regression tests with the addition of habitat characteristics that have not been tested in this study (availability of feed, availability of scrub trees, availability of mineral resources).

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