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Distribution and ranging area of elephant in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

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Abstract. *Hassan NHN, Abdullah NM, Norazlimi NA, Saaban S, Yazi MFA. 2023. Distribution and ranging area of elephant in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia. Biodiversitas 24: 5731-5738.* Home range estimation is one of the most used animal ecology studies using a Geographic Information System (GIS). One adult female Asian elephant (*Elephas maximus* Linnaeus, 1758) was fitted with a telemetry satellite collar African Wildlife Tracking (AWT) to determine its home range size distribution through its ranging behaviour and to identify the relationship between the GPS collar location record and the area covered. The home range estimation was determined using GPS collar location data from a satellite telemetry system and analyzed by using the Minimum Convex Polygon methods. GPS collar location data were obtained from the Department of Wildlife and National Parks (DWNP). The movement of elephant data was overlayed with the land use data of the Simpan Panti Forest (*Hutan Simpan Panti*), Kota Tinggi District, Johor, Malaysia before being exported to ArcGIS Pro software. The ArcGIS Pro software can estimate this Asian elephant home range sizes by using the MCP method for twelve months, from 1 June 2019 until 31 May 2020. The total home range size is 447.17 km². Home range size is estimated to be 31.77 to 303.86 km² in one year. The size of this home range has presumably been impacted by extensive human activities such as highways and settlement areas. So, good and strong management is needed to control this conflict for humans to live in harmony in one area and protect the remaining forest reserve area from expanding to agricultural activity and human development areas.

Keywords: ArcGIS, Asian elephants, home range modelling, minimum convex polygon, ranging behavior

INTRODUCTION

Geographical Information Systems (GIS) have been used in comprehensive technology for gathering, organizing, evaluating, evaluating, simulating, and displaying geographic data across various applications for the past two decades (Longley et al. 2017). According to Aini et al. (2015), understanding interactions between species and their habitats can also be achieved by using these GIS tools to identify home ranges. This approach involves analysing habitat utilisation patterns using environmental and topographical parameters near this Asian elephant (*Elephas maximus* Linnaeus, 1758) species habitat.

According to Rahmi (2023), a home range is where an animal or a group of animals lives while doing their daily activities. Home range size can also impacted by several factors like feeding ecology, body size, group size and habitat quality in certain habitat of animals. It is more common for animals with large body which more require a bigger area, compared to small animals (Gregory 2017). The home range is also one of the main factors in recognizing the ranging behaviour of this Asian elephant (Rahmi 2023). Asian elephant's home range can change widely based on a various factors such as food availability, water sources, human disturbance and habitat destruction. Asian elephant family herds often have home ranges that are between 100-1,000 km² and they usually have 5-20 individuals each herds (Shaffer et al. 2018). For the Asian elephant, there is a lot of proof that their home ranges are affected by the availability of suitable habitat (Sukumar 1989). Goswami (2017), also said that the smaller an Asian elephant's home range needs to be, the more diverse its environment needs to be. This is because elephants can meet their different needs in a relatively small area. Several factors affect how elephants' home ranges in their habitat. There are two types of factors usually involved in this ranging behaviour: environmental and biological factors. The environmental factors include rainfall, productivity and seasonality for the biological factors such as sex, reproductive status and physiological status (Sitompul et al. 2013).

Home range estimation is one of the most used animal ecology studies using a Geographic Information System (GIS). Home range area estimates also help inform conservation researchers and wildlife officers about protected area sizes to change the conservation policy (Bartoń et al. 2019). Thus, providing accurate and scientific data that can be used across individuals, species and areas is important.

Minimum Convex Polygon (MCP) method is one of the methods to measure the home range area (Mohr 1947;

Hayne 1949). This MCP method is another simple method to make a convex shape that includes all the location points collected for the animals (Gregory 2017). This method has widely been used in big mammal research like elephants. For example, the research of Ngene et al. 2013, estimated the home range size of African elephants (*Loxodonta africana* Blumenbach, 1797) in Southern Kenya using the 100% MCP method and with the help of ArcGIS extension.

Elephant is the biggest terrestrial mammals that the knowledge of their home range patterns are crucial for their management and conservation (Tan et al. 2021). Over the years, increasing population growth in humans influenced the conversion of logged forests to agricultural activity, creating this elephant habitat reduction. This habitat reduction happens because it will force them to migrate to other areas and change their feeding behavior due to a depleted food supply (Sukumar 1989). Asian elephants are very social animal, and usually can be found in groups of six to seven related females lead by the oldest female called the matriarch (Vidya 2014).

The study area of this study is Simpan Panti Forest, located in Kota Tinggi, Johor. This forest reverse is also known as the island forest due to its surrounded by development areas such as human settlements and plantation areas. This area was gazetted on 15 September 1985 under the National Forestry Enactment 1985, with 13,152.13 hectares (Johor State Forestry Department 2021).

This paper aims to present data on estimating the home range size using satellite GPS telemetry (satellite GPS collars) and to determine the relationship between the roaming number and the area covered by elephants in Simpan Panti Forest, Kota Tinggi, Johor. This study can be used to guide authorities to conserve our keystone species (Asian elephant) for further use in the future and act as a tools to mitigate human-elephant conflict (HEC) in this area.

MATERIALS AND METHODS

Study area

This study was conducted in Simpan Panti Forest (*Hutan Simpan Panti*) which located 20 km from the town of Kota Tinggi in state of Johor, Peninsular Malaysia **(**Figure 1**)**. This study is surrounded by development area which predominantly covers forest plantation such as oil palm plantation and human-settlements (Johor State Forestry Department 2021). This forest area is known to have high biodiversity such as Spotted leopard (*Panthera pardus* Linnaeus, 1758), Asian elephant (*E. maximus*), Flat-headed cat (*Prionailurus planiceps* Vigors & Horsfield 1827) and Malaysian rail-babbler (*Eupetes macrocerus* Temminck, 1831) (Mariana et al. 2011).

Minimum Convex Polygon (MCP)

The minimum convex polygon (MCP) method is the oldest and most widely used way to figure out a home range in the mammalian range (Mohr 1947; Seaman et al. 1999). According to Michener (1979), percent minimum convex polygons (%MCP) can be constructed for a specific set of fixes by employing various percentage selection methods found in Home Range Tools (HRT). This method constructs home ranges by connecting points to make either convex or concave polygons (Sitompul et al. 2013). This method also one of the common home range analysis models used for the home range estimation method (Harris et al. 1990; White and Garrott 1990).

All collections of elephant movement data points were connected using ArcGIS Pro software. The elephant movement data points are 1139 points; usually, the MCP method requires more than 200 points (Kernohan et al. 2001). According to Southwood (1966), the smallest convex polygon that covers all of the measured positions and the estimated home range size is the area of this polygon. This method is also the best way to get an approximate home range size quickly (Nilsen et al. 2008).

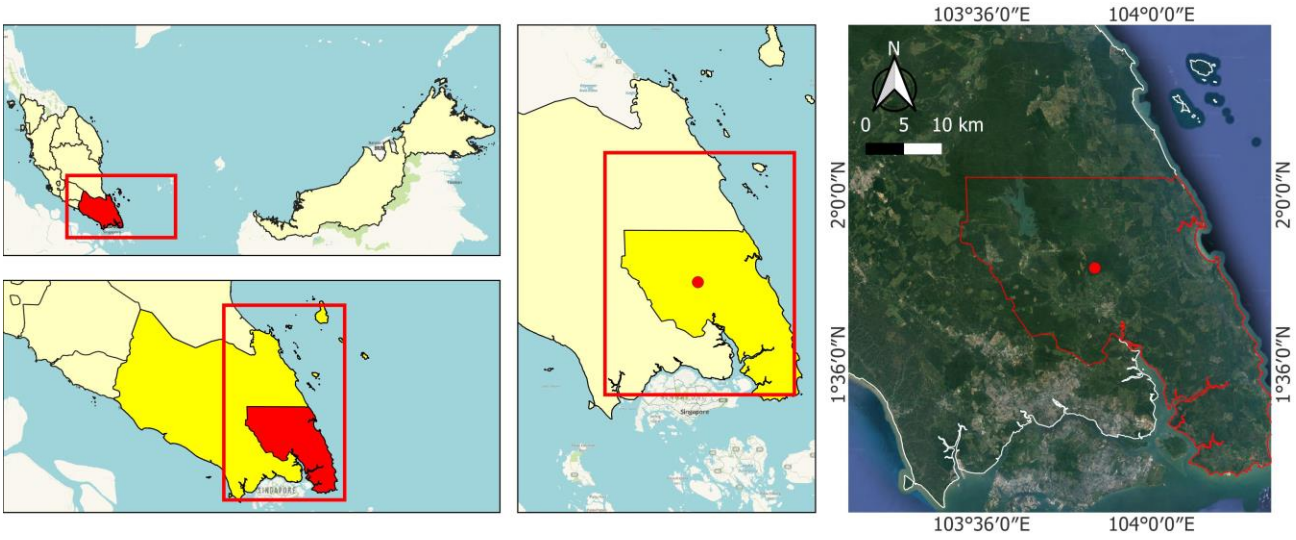

Figure 1. Location of study area Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

Data collection

GPS telemetry collar (Figure 2) is useful in studying the elephant behaviour and collecting data for elephant management (Pastorini et al. 2013). The GPS telemetry collar used in this study is manufactured by African Wildlife Tracking (AWT) in South Africa. The price of this GPS is RM 22,500.00 with the data acquisition for 24 months. It also uses the Iridium Satellite as the satellite receiver to obtain data transmission. According to Pastorini et al. (2013), these AWT collars are suitable for short-term studies and with a low budget.

The data on this Asian elephant movement were obtained by extracting data from the Department of Wildlife and National Parks (DWNP) in Shapefile format. This file shows where the Asian elephant in Simpan Panti Forest, Kota Tinggi, can be found using the Global Positioning System (GPS). The GPS location can be tracked through a satellite telemetry device mounted on a female elephant, as part of Elephant Satellite Tracking Project. This female elephant, named Mek Seluyut, was caught on March 22, 2019, and was released to Hutan Simpan Lenggor in the Mersing district of Johor. This female elephant also was part of a herd of 30 to 40 individuals of different ages and sexes. The age and sex of other members of the elephants were not recorded. The selection of this female elephant was due to the complaints received by the DWNP at the agricultural area that was mainly near to this elephant's habitat.

This female elephant was sedated on March 28, 2019, by a Department of Wildlife and National Park (DWNP) staff by using 10mL of Xylazil-100. The sedative was put inside a dart before it was fired from a dart gun. A veterinary officer administered the appropriate dosage of sedative based on the elephant's size. Once the elephant was sedated, a telemetry collar was put on it, and the researcher recorded its shoulder height, back length, tusk basal circumference, hind foot length and circumference and age estimated by body size and head shape. Before re-joining the herd, this female elephant was given a 10mL Xylazine reversal medication to awaken her. The Asian elephant herd's GPS locations were tracked every three hours for one year, from April 11, 2019, to April 11, 2020. Throughout this study, this elephant herd was shown to stay together closely and not separate into other groups.

Data analysis

After the extraction of data from the Department of Wildlife and National Park (DWNP), the movement of this elephant were overlayed using the ArcGIS Pro on the land use data of Kota Tinggi which shown in Figure 3.

Figure 2. GPS telemetry collar

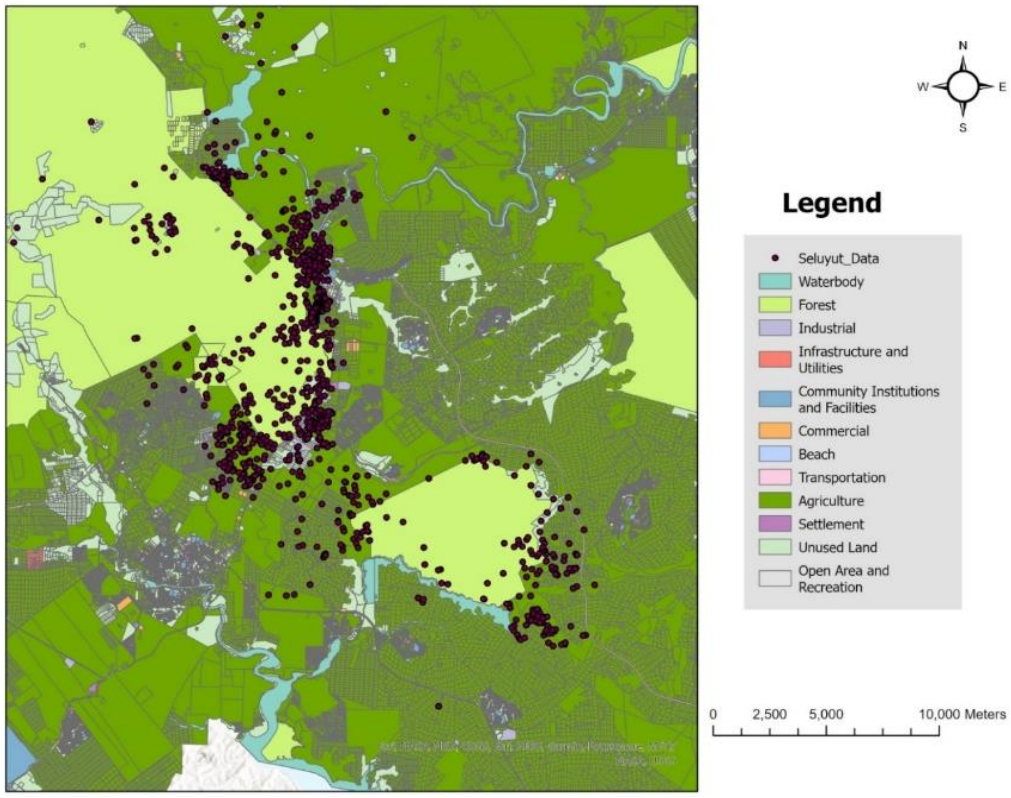

Figure 3. Distribution map of Mek Seluyut in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia in a year

This land use data were obtained by Department of Survey and Mapping Malaysia (JUPEM) which the categorized according to type of land covers such as agriculture, forest, waterbody, industrial area, infrastructure and utilities, community institutions and facilities, commercial, beach, transportation, and settlement. After that, this data were used to determine home range sizes by using the MCP method (Gregory 2017). This method was accurate in estimating the outer contours and centres of activity of home ranges (Kernohan et al. 2001). This home range sizes were calculated using Minimum Bounding Geometry in Data Management Tools extension in ArcGIS Pro. Microsoft Excel 2013 was used to analyse the relationship between the GPS collar location record and area covered of this elephant in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia.

RESULTS AND DISCUSSION

Ranging area of elephants in Simpan Panti Forest, Kota Tinggi, Johor

This forest reserve is located in the centre of agricultural and settlement areas. Oil palm plantations surround this forest reserve and cause the conflict between human and elephant. Due to this, the elephant herds often wander around through this fragmented area, such as the cultivation of oil palm plantations. In oil palm plantation areas, there are zones which allow this elephant to wander freely through this fragmented area. This happened because of the availability of food sources, forest corridors or stress response to these elephants as a shrink of habitats (Evans et al. 2020). Elephants have been recognised like to consume young shrubs, herbs and tree species with fine fibres and fresh young bark (Suhada et al. 2016).

According to Table 1, land use data were obtained by Department of Survey and Mapping Malaysia (JUPEM) which the categorized according to type of land cover such as agriculture, forest, waterbody, industrial area, infrastructure and utilities, community institutions and facilities, commercial, beach, transportation, and settlement. GPS collar location record indicates the repetition location of elephant move in one place for one month. There are 1139 locations were recorded while monitoring the movements of this Asian elephant from 1 June 2019 until 30 May 2020 using satellite telemetry data. This data also shows the repeated measure location of this elephant according to land use data. The highest GPS collar location recorded during these 12 months is in August in 151 locations. In August, these elephants were widely found in oil palm plantation areas (64) compared to other sites. This happened because this forest reserve is located in the centre of an agricultural area (oil palm plantation and rubber plantation).

The areas covered by elephants in Simpan Panti Forest, Kota Tinggi, Johor is determine by using the MCP method. By using this method, the total home range was estimated to be 447.17 km². MCP has been used in most elephant studies (Mohr 1947) because it provides simple graphical implementation (White and Garrot 1990; Kie et al. 1996).This calculation of this area covered 100% using MCP in fragmented and non-fragmented areas. In Table 2 below, August 2019 have the highest area covered by Mek Seluyut with 303.89 km², compared to May 2020 which only 31.77 km². According to Datye and Bhagwat (1995) studies, the largest home range recorded in India which between 3000 and 4000 km² due to human activity.

Table 1. Monthly repeated measure of location according to land use data

Land use data	GPS collar location record (Point)												
	Jun	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mac**	**Apr**	**May**	**Total**
Grassy/brush/shrub/wasteland	4		13		9	8	7	3	2			5	51
Bird				5	6		1	1			1	1	15
Rubber plantation	22	1	3					1		2		3	32
Forestz	19	56	25	26	51	24	25	19	5	3	8	6	267
City street			1										1
Other road	4	5	5	6	2	2	4	2	9		1	2	42
Traditional village	1												1
Use of government/other statutory bodies	28	14	5		5		12	3			1		68
Oil palm	18	26	64	34	32	88	45	3	34	7	7	5	363
Swamp									1				1
Government office/government agency					1				2				3
Manufacture of wood, wood and cork products	3	6	10	2	2	4		2	3		1	1	34
Islamic cemetery		1			3	1	1	2					8
Mining			2										2
Rehabilitation center									2				2
Dam structure									4				4
River			6	2	3					1	1		13
Land is cleared for replanting							2						2
Land is not cultivated	38	1	14	73	3		2	6	23		9	2	171
Other crops	3	10	3	2	17	5	11	5		2		1	59
Total	140	120	151	150	134	132	110	47	85	15	29	26	1139

Note: *Collared elephant Mek Seluyut

Figure 4 shows this elephant's monthly range digitization map in Simpan Panti Forest, Johor, using the ArcGIS Pro software with a MCP method. Through this study, the monthly range of this elephant was between 32 to 304 km². According to this map, these elephants had returned to certain areas due to the food availability and water source.

Figure 5 shows the highest percentage of ranging area in August 2019 with 28%. During this month, these elephants actively move around, and the highest location is in the oil palm plantation and the forest area. According to the data above, the river or other water bodies like swamp area were also an attractive location for this herd. According to Rendana et al. (2023), if the elephant had a higher movement rate, this is probably due to their herd's need for food and water sources, which can only be found in lowland forest areas.

Even though this forest reserve was fragmented and degraded, the availability of food source like various type of grass species in forest and land that is not cultivated area that create a large scale of feeding opportunities for elephants (Yamamoto-Ebina et al. 2016). Besides various type of grass species, oil palm plantation also create the ranging area of this elephants in this forest reserve. Oil palms like oil palm kernels and newly planted oil palm shoots are one of food resources for elephant (Suba et al. 2018).

Table 2. Area covered by Mek Seluyut in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

Month	Area covered (km²)
June, 2019	42.02
July, 2019	188.07
August, 2019	303.89
September, 2019	42.05
October, 2019	122.76
November, 2019	118.18
December, 2019	36.62
January, 2020	55.64
February, 2020	38.14
March, 2020	67.28
April, 2020	32.65
May, 2020	31.77

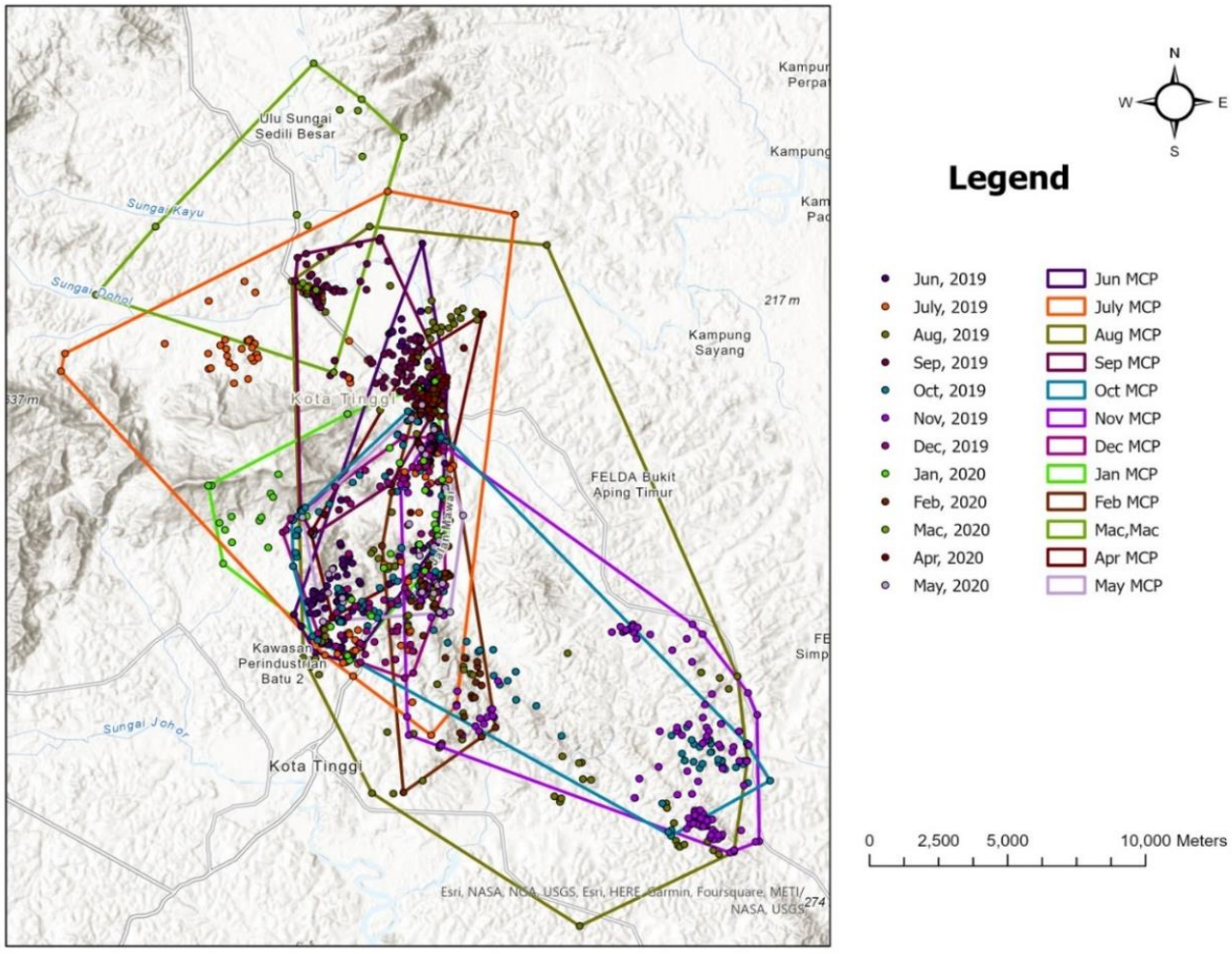

Figure 4. Monthly range using MCP method of elephants in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

According to the current results, collared elephants in this forest reserve completed their annual home ranges (maximum home range) in less than 12 months. According to Olivier (1978) research, he suggested that tracking elephants for a minimum of six months would provide a minimum home range for a herd of elephants. This method would be more precise than tracking the elephant for the whole season, even though the home range size would increase with the longer tracking period.

Distribution elephants in Simpan Panti Forest, Kota Tinggi, Johor according to Digital Elevation Model (DEM)

The output of these elephants' distribution was displayed using the ArcGIS Pro software and the home range was calculated using the MCP method. This software helps display the elephants' current location for the past 12 months. The distributed area was denser in forest and agricultural areas, especially oil palm plantations, due to the availability of food sources. Forest areas have abundant grass species that can offer this elephant large-scale feeding opportunities (Yamamoto-Ebina et al. 2016). Oil palms like oil palm kernels and newly planted oil palm shoots are one of food resources for elephant (Suba et al. 2018).

Figure 6 illustrates the elevation of Simpan Panti Forest, Johor, which indicates the distribution of this elephant's herds. As shown below, these elephants are widely distributed in lowland areas, mainly in agricultural and forest areas. According to this study, these elephants prefer lowland areas over mountainous areas because this species is shown to have a higher affinity for areas with lower elevation and gentler slopes. The study by Sharma et al. 2020 said elephants' movement would be more limited to the steeper slope and will need more energy to move along these mountainous areas due to their size.

Relationship between GPS collar location record and area covered by elephant in Simpan Panti Forest, Kota Tinggi, Johor

For the past 12 months, the number of GPS collar location records of this elephant in the Simpan Panti Forest, Kota Tinggi, Johor and the area covered was increasing, based on Figure 7 which x-axis indicates the GPS collar location records meanwhile y-axis area covered (km²).GPS collar location record is determined by the coordinates of this elephant while the area covered is determined by months.

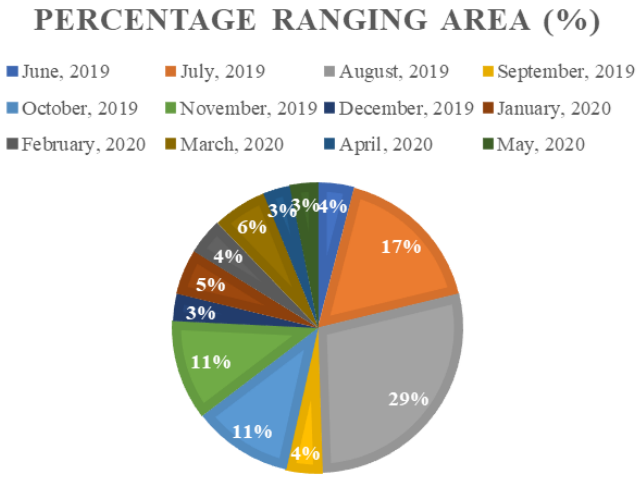

Figure 5. Percentage ranging area in twelve months

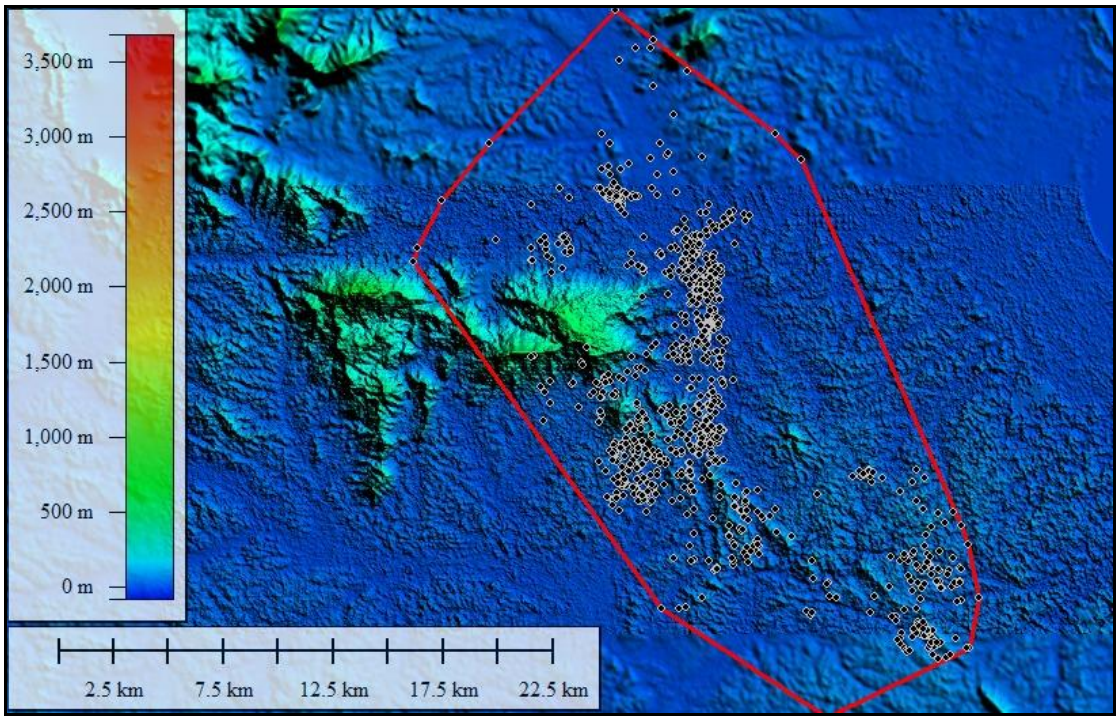

Figure 6. Digital Elevation Model (DEM) Map of elephants in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

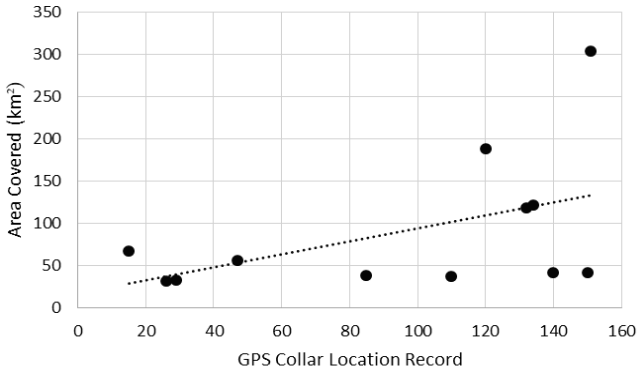

Figure 7. Relationship between GPS collar location record and area covered by Mek Seluyut in Simpan Panti Forest, Kota Tinggi, Johor, Malaysia

According to this graph, there is a connection between the GPS collar location record and the area these elephants cover. The relationship of this graph can also be called a liner relationship, which will increase proportionally. The higher the number of GPS collar location records, the higher the area covered in certain areas. According to Rendana et al. (2023), if the elephant had a higher movement rate, this is probably due to their herd's need for food and water sources, which can only be found in lowland forest areas.

From the data above, these elephants (Mek Seluyut herd) roamed over various land uses, including rivers, oil palm plantation areas, forests and land that is not cultivated. This oil palm plantation frequently visits this herd due to being nearer to water bodies areas. The elephant's movement is not only influenced by the seasonal distribution. It also includes the temporal availability of water (Sukumar 1989).

In conclusion this study shows that elephant herds in Simpan Panti Forest, Kota Tinggi, Johor needed a minimum home range area is 447.17 km² estimated. The movement rate of these elephants usually is influenced by the food availability and water source. As the shrinks of forest area, this elephant's habitat is forced to expand its size of home ranges to meet its meets for resources. Other than that, the raging area of these elephants is also influenced by the pressure of food availability, which leads to human-elephant conflicts near this area. Even though the data showed that this species is suitable to live in these areas, it would not be enough to sustain this elephant's population if land conversion, deforestation and other human activities remain in this forest reserve. Hence, this data and results can be used by authorities to conserve our keystone species for further use in the future. For the recommendations part, there are two recommendations which are strong forest management is needed to support this wild elephant to be retained in this forest reserve; disturbing this forest reserve area should be minimized to make sure our elephants can be conserved and educate the surrounding local people on the coexistence method could imply among them with this elephant species.

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