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Carrying capacity estimation and habitat suitability of Sumatran elephant in Datuk Gedang Wildlife Corridor, Bukit Tigapuluh Landscape, Jambi, Indonesia

NAUFAL FIKRI[1], DEDE AULIA RAHMAN[2,♥], NYOTO SANTOSO[2]
[1]Program Study of Tropical Biodiversity Conservation, Department of Forest Conservation Resources and Ecotourism, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Raya Dramaga, Bogor 16680, West Java, Indonesia
[2]Department of Forest Conservation Resources and Ecotourism, Faculty of Forestry and Environment, Institut Pertanian Bogor. Jl. Ulin-Lingkar Akademik, Dramaga, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8621947, ♥email: dede.auliarahman@gmail.com

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Abstract. *Fikri N, Rahman DA, Santoso N. 2023. Carrying capacity estimation and habitat suitability of Sumatran elephant in Datuk Gedang Wildlife Corridor, Bukit Tigapuluh Landscape, Jambi, Indonesia. Biodiversitas 24: 5548-5557.* Rapid land use changes, including deforestation and land conversion into human areas, lead to the fragmentation of Sumatran elephant (*Elephas maximus sumatranus*) habitat. This study aimed to assess food capacity and determine habitat suitability for Sumatra elephants in Datuk Gedang Wildlife Corridor Bukit Tigapuluh Landscape. The research was conducted from January to May 2023. Data on potential, productivity, and carrying food capacity were collected with a direct method in the field with vegetation analysis. Carrying capacity estimation is based on data on productivity, land cover area, proper use, and Sumatran elephant food needs in a day. The habitat suitability model used the present coordinate point data from the GPS collar period of January-December 2022 with eight environment variables. The data were then analyzed for the build Sumatera Elephant habitat suitability model using the Maximum Entropy (MaxEnt) algorithm. We recorded 95 species of the potential Sumatran elephant food. The total feed productivity is 1,032,740.722 kg/ha /day and the carrying capacity is 258 elephants. There were three models of habitat suitability categories: high 4,238.66 ha (7%), medium 8,522.34 ha (14%), and low 11,130.36 ha (18%). The studied landscape can adequately accommodate the current population of Sumatran elephants depending on landscape governance (policy and spatial planning) outside conservation areas.

Keywords: Conservation, essential ecosystem area, habitat suitability, MaxEnt, modelling

INTRODUCTION

The Sumatran elephant (*Elephas maximus sumatranus*) is one of the endemic animals of Sumatra Island, which is categorized as endangered (Gopala et al. 2011). Rapid land use change, including deforestation and conversion of land to human use, has led to a significant loss of natural habitat for Sumatran elephants and fragmentation in many areas (Rahman et al. 2020; Yoza et al. 2020; Abdullah et al. 2022). The International Union for Conservation of Nature and Natural Resources IUCN Red List has elevated the species conservation status from endangered to critically endangered, owing to a population decline of at least 80% during the last 75 years. The population decline of Sumatran elephants drastically occurred in 1999, with as many as 700-800 individuals (Direktorat Jenderal KSDAE 2020). The conservation of Sumatran elephants is increasingly threatened when they are outside the conservation area. Several studies mentioned that the highest level of conflict between elephants and humans is found in spaces that were shared by humans and elephants (Sitompul et al. 2013b; de Mel et al. 2022; Rahman et al. 2022; Budd et al. 2023). Currently, 85% of the Sumatran elephants' habitat is outside the conservation area (Gopala et al. 2011).

Bukit Tigapuluh Landscape (hereafter referred to as BABT) is one of the most critical non-conservation areas on the island of Sumatra that has a strategic function to support the conservation of Sumatran elephant wildlife. The estimated population size of Sumatran elephants in the Bukit Tigapuluh ecosystem is 143 individuals (Moßbrucker et al. 2015). Although Sumatran elephants were designated as protected species, the threat to their survival in BABT is high (Moßbrucker et al. 2016a). According to a report by the Jambi Natural Resources Conservation Center, from 2016 to 2018, there were 543 cases of elephant disturbance in BABT (BKSDA 2019). Economic interests have led to the opening up of space needs for humans, such as plantations, settlements, and the establishment of areas within BABT in the form of mining and natural forest concessions that have been going on for a long time and were still ongoing today, making the habitat of Sumatran elephants continue to be eroded and fragmented. Currently, Sumatran elephants survive in pockets of habitat that are actually different from their natural habitat, so they must be able to adapt to environmental conditions to survive by utilizing the limited resources available in BABT (Moßbrucker et al. 2016b).

Urgent action is a planned effort that needs to be done immediately related to habitat management (Goswami et al. 2014; Rahman et al. 2019; Shaffer et al. 2019; Novriyanti et al. 2021). One of the efforts made by Jambi BKSDA in managing Sumatran elephant habitat in BABT is by establishing an Essential Ecosystem Area (KEE) by building the Datuk Gedang Wildlife Corridor, which is authorized in Jambi Governor Regulation No. 8 of 2022, covering 61,829.11 ha. The establishment of the Datuk Gedang Wildlife Corridor of Bukit Tigapuluh Landscape (now referred to as KHLDG BABT) is an effort to encourage BABT to become the remaining pocket of sustainable Sumatran elephant habitat in central Sumatra Island, as well as a bridge that reconnects pockets of habitat fragmented by development and forest conversion activities.

The study of the vegetation of wild elephants is essential to improve the results of analysis and certainty of the quantity and quality of resources in it, especially identifying vegetation eaten by elephants based on differences in resources in each land cover class (Jathanna et al. 2015). The distribution of wildlife is primarily determined by the quantity and quality of its habitat (Monteith et al. 2015; Zhang et al. 2015; Merkle et al. 2016; Aikens et al. 2017; Rahman 2020; Rahman et al. 2020; Sagar et al. 2023), so the basics of the carrying capacity concept can be used to analyze and evaluate habitat. Carrying capacity is the optimum ability that can be accommodated in a habitat at a specific time and condition. The concept of carrying capacity in this study is calculated from the parameters of feed availability (feed productivity) in each type of land cover. This study aimed to analyze the potential food plants, their productivity and the carrying capacity of natural food plants for Sumatran elephants in KHLDG BABT. Additionally, it examined the distribution, habitat suitability, and environmental variables that influence the presence of Sumatran elephants in KHLDG BABT.

MATERIALS AND METHODS

Study area

This research was conducted in January-May 2023 in Datuk Gedang Wildlife Corridor in Bukit Tiga Puluh Landscape, Tebo District, Jambi, Indonesia. The located at 102° 11' 1.387" East-102° 45' 20.697" East and 0° 55' 17.962" LS - 1° 20' 28.585" LS, with an area of 61.829,12 ha and its surrounding landscape (Figure 1).

Data collection

The data obtained in this study were primary data and secondary data. Primary data were obtained directly through direct observation about potential feed and elephant habitat productivity with analysis of vegetation. Secondary data in the form of data on elephant food types and Sumatran elephant coordinate points (GPS Collar) for the period January-December 2022 in eight Sumatran elephant groups received 8085 coordinate point data from BKSDA Jambi and five captive Sumatran elephants at the Sumatran Elephant Conservation Information Center (PIKG), were observed and their dietary habits were recorded to verify potential food sources in the wild.

Data collection on elephant potential feed production was carried out by analyzing vegetation in secondary forests, shrubs, industrial plantation forests, cultivated and oil palm estates. Vegetation analysis was conducted using the method with a plot size of 20 m x 20 m with a systematic laying of sample plots on each land classification with a distance between each 20 m (Mandal and Joshi 2014; Tohir et al. 2018; Rahman 2021).

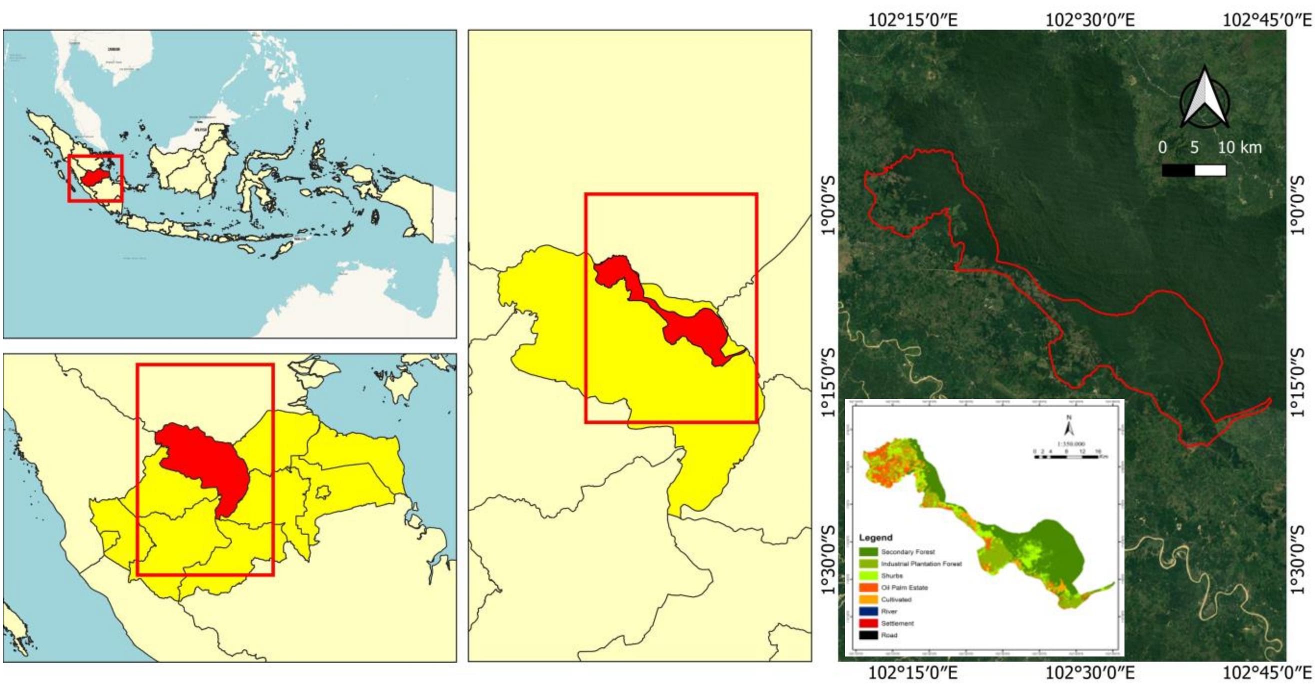

Figure 1. Map the study area showcase the location of the entire Datuk Gedang Wildlife corridor in the Bukit Tigapuluh landscape (KHLDG BABT), Tebo District, Jambi, Indonesia

Table 1. Variables used in building the model

Variable	Variable types	Default file format	Source
NDVI	Continuous	Raster	Google Earth Engine
LST	Continuous	Raster	Google Earth Engine
Slope	Continuous	Raster	DEM SRTM 1 Arc-Second
Elevation	Continuous	Raster	DEM SRTM 1 Arc-Second
Feed productivity	Categorical	Raster	Landsat 8 OLI/TIRS and observation
Distance secondary forest	Continuous	Vector polygon	Landsat 8 OLI/TIRS
Distance secondary settlement	Continuous	Vector polygon	Landsat 8 OLI/TIRS
Distance secondary river	Continuous	Vector polygon	Generated from RBI map

Placement plots were purposive sampling based on the observation location of feed sources by considering the area of the Sumatran elephant's home range and the findings of food traces in the field, with a total number of sample plots of 60 plots. The data collected includes information regarding plant type, diameter and height of the potential feed of Sumatran elephant. Potential elephant feed production is quantified by cutting feed plants (destructive measurement) with two repetitions. The observation sample plots for grass types measure 1 m x 1 m, while those for seedlings and shrubs/herbs measure 2 m x 2 m, with arranging sample plots based on the analysis plot of the vegetation. The modeling of the suitability map uses an algorithm-based Maxent application to calculate the degree of habitat preference utilizing information on factors and the presence of species. The environmental variables used were eight variables: NDVI, LST, slope, elevation, the productivity of feed, euclidean distance of forest secondary, euclidean distance of settlement, and euclidean distance of river (Table 1).

Data analysis

Cover class classification using the supervised classification method within the software Arcgis 10.3. The classification results were tested by looking at the cappa accuracy index value referring to KLHK 2020 land cover data, using Google Earth Pro and ground check results in the field. Elephant food potential is the result of field studies (vegetation analysis; exploration), interviews, and literature studies that were synthesized into a list of food types. The results of food observations were analyzed descriptively and tabulated the types of food. Analysis to determine the productivity of elephant forage for understorey and seedling growth types was calculated using the equation: Productivity = Forage production (kg/ha/day) x area of each land cover (ha) (Susetyo 1980).

The calculation of food carrying capacity is based on the productivity of forage per day (P), the surface area of land covered by forage (A), proper use (percent of land utilization), and the need for food (percent of land utilization), and forage needs per individual per day as animal feed per individual per day. Proper use slope (50%) (Susetyo 1980), habitat potential (30%) (Alikodra 2010) and part of the forage eaten (50%) (Riba'i et al. 2013; Pradhan et al. 2015) (Pu). The feed requirement of elephants is 10% / 300 (kg/individual/day) of their body weight (C) (Abdullah et al. 2022). Carrying capacity = P x Pu x A / C.

Prediction of habitat suitability is approached by calculating the probability of Sumatran elephant presence in a landscape, modeling species distribution based on machine learning algorithms. Spatial analysis was conducted using maximum entropy. Sumatran elephant distribution coordinates data for the period January to December 2022 is compiled in Comma Separated Value (CSV) format. Maxent menu settings by checking auto features, creating response curves, making pictures of predictions, and jackknifing to measure variable importance. Meanwhile, the output format is in logistic form, and the output file type is asc. In the settings menu, the random test percentage is filled at 25%, with 10 replications with a Bootsrap run type. Other settings were default. The model was assessed in this study utilizing Area Under the Curve (AUC). MaxEnt's output contains important information such as the number of predictions or regions Under the Curve (AUC), each variable's performance, and the influencer's input into the prediction model (Rahman et al. 2020; Rahman et al. 2022). The AUC intervals with respect to model performance as <0.7 (poor model performance), 0.7-0.9 (fair/useful), and >0.9 (excellent) (Manel et al. 2001). The habitat suitability map is divided into three classes: low suitability, medium suitability and high suitability.

RESULTS AND DISCUSSION

Potential forage vegetation

We successfully identified as many as 115 species; 95 of 37 families have the potential as natural food for Sumatran elephants. Sumatran elephant food is scattered in each land cover class presented in Figure 2. Almost all vegetation types found in the land cover classes of industrial plantation forests, shrubs, oil palm plantations, and cultivated have the potential to become natural food for Sumatran elephants. Open canopy cover conditions cause sunlight to penetrate the forest floor (Rahman and Setiawan 2020), thus encouraging the growth and development of light-intolerant understory plants.

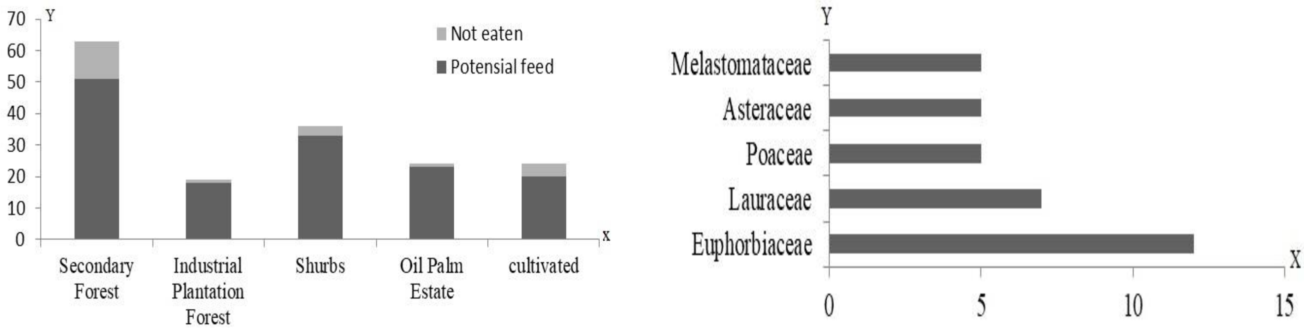

Figure 2. Natural food potential of Sumatran elephants in each land cover class in KHLDG BABT, Tebo District, Jambi, Indonesia

The most common types found were ferns and grasses. The food is evenly distributed in each land cover class. The understory species found were mostly invasive understory species, such as *Climedia hirta*, *Chormonela odorata*, *Mikania micantha*, etc (Tjitrosoedirjo et al. 2016). Family Euphorbiaceae is a family that has the highest number of species, namely 12 species are balik angin (*Mallotus paniculatus*), danglo (*Macaranga denticulata* Mull.), karet (*Hevea brasiliensis*), ludai (*Balakata baccata*), mahang (*Macaranga hosei*), medang labu (*Endospermum diadenum*), melabai (*Alchornea tiliifolia*), Nilau (*Macaranga thrictocarpa*), putat (*Mallotus peltatus*), sebentung (*Macaranga tanarius*), Sekubung (*Macaranga gigantea*) and Tarak (*Macaranga conifera*). The part that is eaten is the top of the leaves and leaves. Followed by the family Lauraceae, with as many as seven species. Five types of families were dominantly compared to other families (Figure 2).

The result of important vegetation index (now referred to as IVI), the composition structure of forage vegetation in KHLDG BABT for understorey is dominated by pakis putih (*Nephrolepis biserrata*) with IVI 24.32, seedlings were dominated by melabai (*Alchornea tiliifolia*) with IVI 15.74, sapling level was dominated by nilau (*Macaranga thritocarpa*) with IVI 26.80), at pole level is karet (*Hevea brasiliensis*) with IVI 24.12, and at tree level, meranti (*Shorea leprosula)* had a dominance with IVI 14.58. The difference in the dominant species at each growth level indicated that several species lost in competition or death during the natural regeneration process (Kuswanda and Sunandar 2019). Species from the Dipterocarpaceae and Euphorbiaceae were found to be in almost every level of growth and are generally lowland forests suitable for these families (Reddy et al. 2013).

Most types of food for Sumatran elephants were lower plant species because this type has a lot of carbohydrate content (Gill et al. 2023). In addition to lower plants, elephants also eat other food in the form of leaves, bark, twigs, and stems at the sapling level (Pradhan et al. 2015; Coverdale et al. 2016). The selection of parts of the plant is due to the level of preference and is influenced by the season (Riba'i et al. 2013; Branco et al. 2019). In the rainy season, elephants tend to be grazers, which consume grasses. On the contrary, in the dry season, they tend to be browsers, which tend to consume shrubs and young shoots (Mohapatra et al. 2013). In addition, the selection of food plant species is influenced by the availability in the habitat; if the availability of these food plant species is abundant, elephants will consume these types of food more often and vice versa (Abdullah et al. 2022).

Various studies related to elephant behavior in consuming food show that there are variations in plant species in the diet from one region to another. The results of research by Sitompul et al. (2013a), managed to identify 273 species of elephant natural food plants divided into 69 families in the Sebelat Conservation Center (SECC) area; five types of families are dominantly eaten by elephants, namely Moraceae, Arecaceae, Leguminocea, Poaceae and Euphorbiaceae. In Teso Nilo National Park, 110 species from 47 families were found as potential natural food for elephants, with the dominant Sumatran elephant natural food families being the Poaceae and Leguminoceae families (Tohir et al. 2018). The difference in the number of species and types of dominant families from previous studies is thought to be due to differences in community structure (land cover conditions). In addition, the types of food identified cannot be extrapolated to the types of food found in other areas (Abdullah et al. 2022).

Feed productivity and carrying capacity

The study findings indicate variations in the productivity of natural food greenery for Sumatran elephants in KHLDG BABT. Differences in the type and condition of the physical environment of each sample plot distribution and land cover class cause this. The light intensity factor is the most influential factor on productivity. Sample plots with more open canopy cover have higher productivity values. Greater light intensity penetrating the forest floor positively affects understory growth, particularly grasses that serve as food for Sumatran elephants (Tohir et al. 2018). The productivity values of understory plants and seedlings in the five land cover classes are presented in Table 2.

Cultivated land cover has the highest productivity compared to other locations at 49.38 kg/ha/day. This area is primarily used for cultivating plants such as coffee, oranges, limes, and rubber, with sapling-size plants and an uncleaned forest floor (as shown in Figure 3A). It can be seen that grasses and ferns dominate in various locations of cultivated land cover, which are natural food for Sumatran elephants. The abundance of food availability in the cultivated cover class causes elephants to tend to visit the location and ultimately causes conflict between elephants and humans because elephants damage the planted land due to elephant trampling (Figure 3B).

The food carrying capacity of elephants in KHLDG BABT, with an area of 61,403.77 ha, is a vegetated area of a total area of 61,829.11 ha, total forage production of fresh weight per 1,032,740.722 kg/day, feed requirements of 300 kg, and the proper use value of slope (50%), habitat potential (30%) and the average percentage of each part of food consumed (50%). So, the value of the natural food-carrying capacity of Sumatran elephants in KHLDG BABT is 258 individuals. The productivity capability of the area does not continue to be linear. The results of the calculation of the food carrying capacity obtained, assuming that the elephant's habitat conditions were not damaged quickly and elephants can move to find food in each type of cover class in KHLDG BABT. This estimated value is prone to overestimation because the variable factors of food competition and shared space with other mammals need to be considered in this study, particularly in the case of mammals that feed on the same food.

Distribution of Sumatran elephants

The results of overlaying with land cover classes show that the frequency of elephant presence in secondary forest land cover (28%), plantation forest (36%), shrubs (28%), oil palm estate (1%), and cultivated (5%) and 2% were rivers and roads. The proportion of Sumatran elephant presence frequency is mainly found in the land cover classes of secondary forest, shrubs, and industrial plantation forest (Table 3).

Industrial plantation forest has the highest proportion of distribution points compared to other land cover classes. Industrial plantation forest is often used as a corridor in activities because this location has a slope class with a sloping category between 8-15°. Sumatran elephants tend to avoid high places and slopes with steep categories (Abdullah et al. 2022). In addition, almost all types of lower plants in the plantation forest land cover class have the potential to become natural food for Sumatran elephants.

Although the results of the productivity analysis indicate that the cultivated land cover class has a higher productivity value than other land cover classes, Sumatran elephants are unable to fully utilize the available food due to the prevalence of electric fences surrounding the cultivated areas. This also causes the low proportion of Sumatran elephant distribution concentration in the cultivated and oil palm estate land cover classes in KHLDG BABT. Secondary forests and shrubs were the natural habitat of Sumatran elephants in KHLDG BABT. This area provides abundant food potential and minimal disturbance from human activities, such as electric fences that hinder the movement of elephants in their activities. Sumatran elephants can effectively utilize their available resources. The animal's habitat distribution and range are impacted by both the quantity and quality of their environment (Rahman 2020; Rahman et al. 2020; Rahman and Mardiastuti 2021). The higher the value, the higher the frequency of species to come to the area. Distribution and frequency of distribution of eight groups of Sumatran elephants in January to December 2022 in KHLDG BABT (Figure 4).

The number of coordinate point frequency proportions of the eight Sumatran elephant groups were not all the same. The Cinta Elephant group has the most number of distribution points, namely 2,348 points. On the other hand, the Santiago Elephant group has the least number of distribution points, as many as 330 points. Although eight groups of Sumatran elephants live in the same landscape habitat, it can be seen that there were variations in the distribution and frequency of the eight groups of Sumatran elephants (Figure 4). The variation in distribution is one of the group strategies in utilizing space and time to avoid competition in utilizing the potential within the habitat (de Silva et al. 2023; Gill et al. 2023). Currently, Sumatran elephants survive in pockets of fragmented habitat, so Sumatran elephants must be able to adapt to environmental conditions to survive by utilizing the limited resources available in the KHLDG BABT.

Figure 3. A. Forest floor condition of cultivated land cover, and B. Condition of damaged lime plants in KHLDG BABT, Tebo District, Jambi, Indonesia

Table 2. Productivity of natural food plants and carrying capacity of Sumatran elephants in five land cover classes in KHLDG BABT, Tebo District, Jambi, Indonesia

Land cover	Productivity (kg/ha/day)	Land cover area (ha)	Total production (kg/day)	Carrying capacity (ind)
Secondary forest	5.32	30,166.83	160,487.54	40
Industrial plantation forest	25.54	8,862.17	226,339.82	57
Shurbs	24.7	10,928.61	269,936.66	67
Oil palm estate	16.6	5,772.84	95,829.14	24
Cultivated	49.38	5,673.30	280,147.55	70
Total number		61,403.77	1,032,740.722	258

Table 3. Coordinates the distribution of eight Sumatran elephant groups in January to December 2022 in KHLDG BABT, Tebo District, Jambi, Indonesia

Land cover	NDVI value	Average NDVI value	Number of distribution points	Percentage
Secondary forest	0.317-0.838	0.678	2,285	28%
Industrial plantation forest	0.207-0.831	0.638	2,909	36%
Shurbs	0.281-0.824	0.604	2,271	28%
Oil palm estate	0.237-0.344	0.282	117	1%
Cultivated	0.189-0.651	0.422	423	5%
Other	-0.044-0	-0.024	80	2%
Total number			8,085	100%

Sumatran elephant's distribution relationship on environmental variables

The variables that contribute to the distribution model can be seen in (Table 4). Of the 8 environmental variables analyzed, 5 (of them include environmental variables that have the most significant percentage contribution, namely NDVI (42.8%), distance from settlements (19%), elevation (13.4%), distance from rivers (10.3%) and feed productivity (6.5%). The jackknife analysis results for the distribution model of eight Sumatran elephant groups in KHLDG BABT indicate that the NDVI variable has a significant contribution. Omitting NDVI data from model-building will diminish the model's predictive ability (Figure 5). The AUC (Area Under Curve) value on the ROC (Receiver Operating Characteristic) graph for the Sumatran elephant distribution model in KHLDG is 0.85, with a standard deviation of 0.014. The model building can make feasible predictions with a value between 0.7 and 0.9 (Manel et al. 2001). Table 4. Influence of environmental variables on the distribution of eight Sumatran elephant groups in KHLDG BABT.

NDVI is an index that describes the greenness or photosynthetic activity of vegetation. NDVI values were closely related to the potential distribution of food (habitat quality and quantity) (Garroutte et al. 2016; Branco et al. 2019). In utilizing space, elephants tend to use area that have medium canopy and open canopy. Meanwhile, the closed canopy is often used at night (Abdullah et al. 2022). Elephants use shrubs, plantations, and other plantations as foraging area and primary/secondary forests for shelter, resting, and mating (Sitompul et al. 2013b).

Habitat suitability

The results of the habitat suitability analysis in the KHLDG BABT area show that the area of suitable habitat is 23,891.37 ha or 238.913 km² (39%) of 61,829.11 ha, which is divided into three classes, namely low class with an area of 11,130.36 ha (18%), medium with an area of 8,522.34 (14%) and high with an area of 4,238.66 (7%) (Figure 6). The results of modeling the suitability of Sumatran elephant habitat in KHLDG BABT show that the suitable habitat is lower than the unsuitable habitat. This illustrates that the threat to the existence of these animals is still relatively high. The magnitude of the threat to the existence of the Sumatran elephant population in KHLDG BABT is not only from habitat unsuitability but also the many changes in the function of the area to other uses (Moßbrucker et al. 2016a). The growth of new villages along the corridor road and the reduction of the elephant range in KHLDG BABT were followed by increasing conflict between wildlife and humans. From the results of habitat suitability modeling, suitable habitat has a carrying capacity of 130 Sumatran elephants with a total forage plant productivity of 518,340.606 kg/day.

Table 4. Influence of environmental variables on the distribution of eight Sumatran elephant groups in KHLDG BABT, Tebo District, Jambi, Indonesia

Environmental variables	Percentage contribution	Importance of permutations
NDVI	42.8	52.9
Distance from settlements	19	13.6
Elevation	13.4	4.5
Distance from rivers	10.3	14.5
Feed productivity	6.5	5.4
Distance from secondary forest	2.9	4.8
LST	2.7	3.2
Slope	2.4	1.2

Figure 5. Jacknife analysis of environmental variables on Sumatran elephant habitat suitability model in KHLDG BABT, Tebo District, Jambi, Indonesia

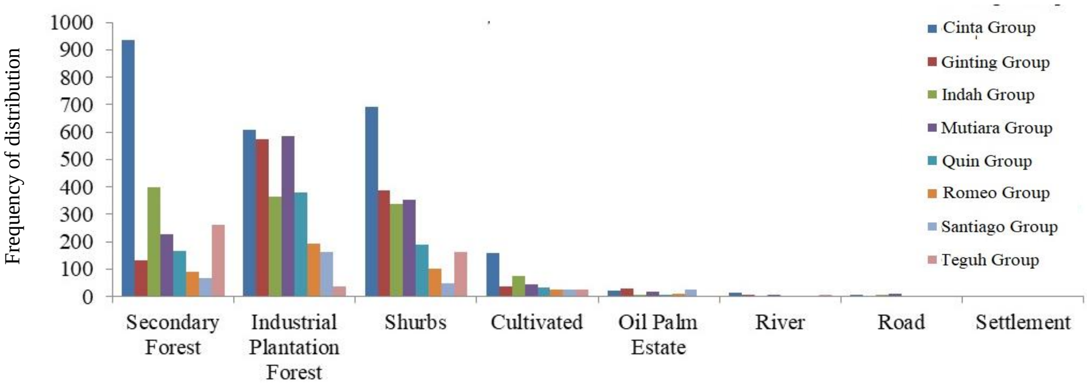

Figure 4. Distribution and frequency of distribution of eight groups of Sumatran elephants in January-December 2022 in KHLDG BABT, Tebo District, Jambi, Indonesia

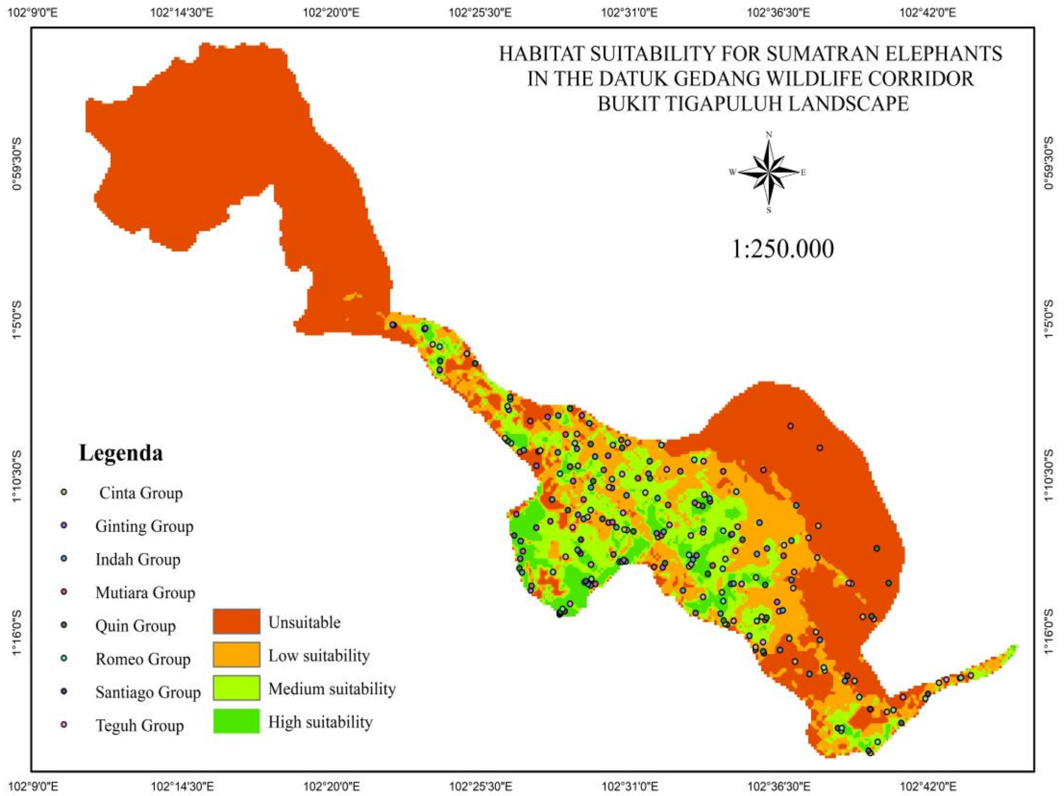

Figure 6. Thematic map of Sumatran elephant habitat suitability and condition habitat in KHLDG BABT

In 2018-2021, the distribution of coordinates of the Sumatran Elephant's home range reached Pemayungan Village or the PT ABT Block II concession area. However, in 2022, Sumatran elephants were not found in the PT ABT Block II concession area. This is caused by land utilization that is different from its function. With this incident, the Sumatran elephant was inhibited from moving to the northwest or the PT ABT Block II concession area. This is also a factor why the PT BLOK II concession is not suitable as a habitat for Sumatran elephants in KHLDG BABT. Field findings show that most of the elephant's range has been converted into oil palm, rubber, and cultivated (Figure 6). This condition is further exacerbated by the use of electric wires in elephant roaming paths with irregular installations by local communities, which hinders elephant movement.

Sumatran elephant habitat conditions in KHLDG BABT are included in Remnant Fragmentation. Remnant fragmentation is a fragmentation formed due to disturbances in the original habitat and replaced by new habitats (Morand et al. 2015; Schlaepfer et al. 2018). An example of the formation of this fragment is the development of extensive plantation forests, oil palm plantations, and mixed agriculture that replace natural forests (natural habitats). Thus, the original habitat in the form of natural forest areas is only fragmented in a very narrow area. The process of Remnant Fragment formation leads to habitat fragmentation and isolation that drives the local extinction of species (Karanth et al. 2013; Sawyer et al. 2013; Martinuzzi et al. 2015; Goossens et al. 2016; Numata et al. 2017; Kuswanda and Sunandar 2019).

In the long term, Sumatran elephants are in danger of extinction because the remaining habitat cannot sustain their survival anymore. This is due to the conservation of the natural Sumatran elephant habitat into oil palm plantations, which is continuing in KHLDG BABT. In this context, utilization activities are carried out within specific limits and according to zoning regulations (Bhan 2013; Tiller and Williams 2021). Zoning activities within suitable Sumatran elephant habitats are intended only for ecological research and scientific development (Pringle 2017). Meanwhile, the utilization zone serves various purposes, such as religious, ecotourism, historical, and cultural activities; thus, community utilization carried out in the corridor area must be adjusted according to the respective zone. Formulating and preparing spatial planning policies for the Tebo Regency area is the appropriate course of action to attain the goals of the KHLDG area function in BABT.

In conclusion, this research can also be used to make decisions for Sumatran elephant habitat management strategy at BABT, especially in KHLDG BABT, assuming that the elephant's habitat conditions were not damaged quickly and elephants can move to find food in each type of cover class in KHLDG BABT. The results showed that the BABT corridor area can accommodate 258 individual Sumatran elephants, with a productivity level of 1,032,740.722 kg/day. To get sufficiently accurate data, Periodic and comprehensive studies are needed to estimate productivity and food-carrying capacity. The potential research that can be continued to develop this research is to estimate productivity and food capacity with pole and tree level rates by considering the season and the variable factors of food competition and space use with other mammals. Especially mammal species that utilize the same food.

Meanwhile, the potential to become a suitable habitat is only 39% of the total area of KHLDG BABT and can only accommodate 130 individuals. Therefore, efforts are needed to maintain this area. Utilization activities are carried out in a limited or specific manner according to the zone. Activity zoning is limited to suitable elephant habitats, intended only for research and development of science in ecology. Meanwhile, the utilization zone can be through religious, ecotourism, historical and cultural activities, so the utilization carried out by the community around the corridor area must be adjusted to its site. In this case, formulating and preparing spatial planning policies for the Tebo Regency area is the right direction of action to achieve the objectives of the KHLDG area function in BABT. This needs to be supported bt good cooperation between BKSDA Jambi and its partners in increasing research on Sumatran elephant habitat so that the Sumatran elephant habitat at KHLDG BABT can be managed properly.

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