INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 13, Issue 4, October-December 2022: 1237-1248 www.ijcs.ro

HABITAT FACTORS THAT DETERMINE THE MOVEMENT OF SUMATRAN ELEPHANTS IN WAY KAMBAS NATIONAL PARK

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Abstract

Since 2009 until now, based on the IUCN Institute, the Sumatran elephant is still endangered. The factors that most influence the decline in the elephant population is caused by several things such as habitat loss, hunting, and conflicts with humans. The movement pattern is influenced by habitat factors, and as a key stone species this elephant movement pattern also affects the dynamic ecosystem. This research will be conducted in Way Kambas National Park located in East Lampung Regency, Lampung Province, South Sumatra, the data used in this study are the results of the movement of groups of Sumatran elephants during the period July-December 2021, with samples using three groups of elephants that have been paired with GPS since 2020. Information on habitat characteristics and environmental factors that are considered to influence Sumatran elephant movement in Way Kambas National Park were collected and analyzed using multiple regression analysis (MRA). Based on the results of regression analysis to three groups of Sumatran elephants in Way Kambas National Park, were identified the three biggest factors that influence the movement of Sumatran elephants and this are first the availability of food, the second is the distance to water sources and the last is the distance to settlements.

***Keywords**: Sumatran Elephant; Conservastion; Habitat Factor; MRA.*

Introduction

The Sumatran elephant (*Elephas maximus sumatranus*) is still one of the endangered animals and the only largest land mammal that remains [1]. The factors that most influence the decline in the elephant population is caused by several things such as habitat loss, hunting, and conflicts with humans [1-8]. Since 2009 until now, based on the IUCN Institute, the Sumatran elephant is still endangered [4, 5], and is included in the Appendix 1 category of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) [4, 7].

Estimates of the Sumatran elephant population were initially carried out in the 1980s with an estimated number of 2.800-4.800 individuals [9], This initial population estimate decreased by about 50% in a subsequent population survey in 2007 with an estimated population of 2.400-2.800 individuals [10], the third survey conducted a population recount in 2019 with an estimated population of 1.694-2.038 and a decline of almost 50% [11]. Mongbay (2022), obtained a copy of the updated plan, which is intended to be released in 2019, which

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gives a population estimate of 924-1.359 and based on the results of this estimate the Sumatran elephant population continues to decline [12].

The term human-wildlife conflict is widely used regarding conservation and the environment [13], the definition of conflict when there is a negative interaction between animals and humans that causes the impact of population loss, environmental damage, social order, economy, and culture life [14-18], a model to describe the definition of this conflict can be seen in figure 1 [18]. One of the most common and quite frequent human-wildlife conflicts today is the conflict between elephants and humans, human elephant conflicts have become a threat to biodiversity conservation, and controlling these conflicts is the main goal of elephant conservation in several countries [19-21]. Indonesia, especially Sumatra Island, is one of the areas contributing to human-elephant conflict, during the 2015-2021 period there were 528 conflicts, with details, in 2015 there were 49 cases, 2016 were 44 cases, 2017 were 103 cases, 2018 were 73 cases, 2019 were 107 cases, 2020 were 130 cases and in 2021 there were 76 cases. In addition to the elephant deaths, this conflict also resulted in at least 11 people being injured and eight people dead [22].

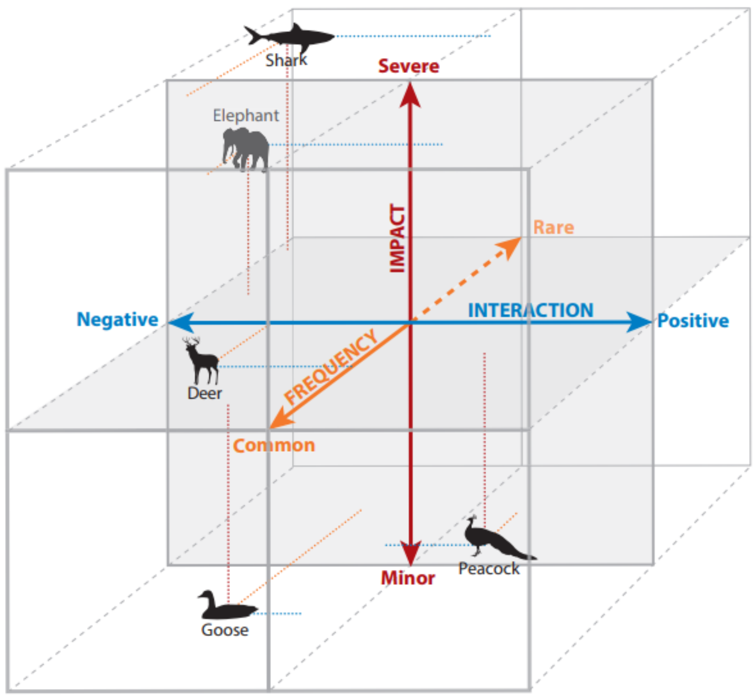

Fig. 1. A model for conceptualizing different types of humans–wildlife conflict. The *x*-axis represents a range of interactions or outcomes from negative (e.g., crop damage) to positive (e.g., income from tourism or cultural or religious benefits). The *y*-axis represents impact on a continuum from minor (e.g., nuisance interactions between people and birds in an urban park) to severe (e.g., loss of life or severe injuries). The *z*-axis represents frequency of occurrence from common to rare. Different individuals or groups of people may perceive similar interactions in different ways. Other dimensions could be added, such as whether few or many people are impacted, or whether conflict is localized or ubiquitous

The behavior of elephants having habitats is strongly influenced by habitat conditions and the position of essential habitats in an ecosystem [23, 24]. In choosing their habitat, the Sumatran elephant considers various factors such as forest type (secondary-primary), canopy cover (60-80%), food availability (>75%), distance to water sources (0-250m), slope (0 -20°), land elevation (0-400masl) [4, 23-27]. Movement identification requires researching elephant movement patterns. Elephants generally do not move randomly [28] and usually move in groups through their routes and corridors in search of food and shelter [29]. The movement pattern is influenced by habitat factors, and as a key stone species this elephant movement pattern also affects the dynamic ecosystem [30].

The use of Global Positioning System (GPS) technology has been widely used by experts in the study of elephant movement patterns since the mid-1990s [31]. The use of GPS allows researchers to track the position of animals over time and relate this position to environmental factors of these animals [32]. In particular, the aim of our study is to analyze the habitat factors that influence the movement patterns of Sumatran elephants, this will later be able to determine significant strategies to reduce the frequency of elephant-human conflicts.

Materials and Methods

Study Area

This research will be conducted in Way Kambas National Park located in East Lampung Regency, Lampung Province, South Sumatra (Fig. 2).

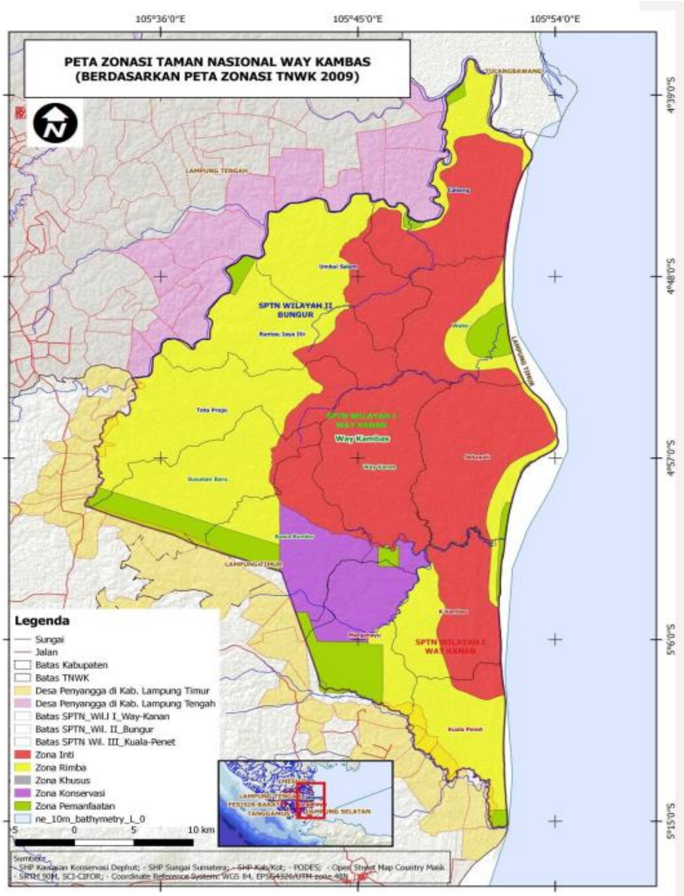

Fig. 2. Way Kambas National Park Research Location

Gaeographically, Way Kambas National Park is located between 40°37'–50°16' South Latitude and 105°33'–105°54' East Longitude. In general, the topography in the Way Kambas National Park area is relatively flat to slightly wavy in the western part of the area, with an altitude of 0-50 meters above sea level. Lampung Province was chosen because it is one of the habitats with the largest elephant population on Sumatra Island, and it is estimated that there are 550–900 individual elephants in Lampung, including those in Bukit Barisan Selatan National Park and Way Kambas National Park [2, 9], as well as those in Way Kambas National Park is an area where almost all elephant groups have GPS installed.

Data Collection

The data used in this study are the results of the movement of groups of Sumatran elephants during the period July-December 2021 with samples using 3 groups of elephants that have been paired with GPS since 2020. In addition, data collection on habitat characteristics and environmental factors that are considered to influence Sumatran elephant movement in Way Kambas National Park. Data on habitat factors and elephant groups are presented in table 1.

Table 1. Elephant group and habitat factors that influence it

Kelompok	Faktor yang mempengaruhi
Code GPS: 3866 Code GPS: 3870 Code GPS: 3871	Number of tracks Length of track Frequency of use of the track track usage time Land height Land slope Land cover Temperature Humidity Distance to settlement Distance to water source Availability of feed quantity Availability of body scrub tree

Methods

Analysis of the relationship between habitat characteristics and habitat factors, both physical and biophysical that affect elephant movement, used multiple regression analysis (MRA) or multiple regression analysis using the Minitab 20 software application. MRA is a statistical technique that analyzes the relationship between more than two variables and uses that information to estimate the value of the dependent variable. The data that becomes the predictive variable in this study is the data of habitat characteristics (number of tracks, length of the track, frequency of the track and the length of use of the track), while the coefficients are data on habitat factors. Each parameter of the path characteristics will later be associated with all the variables of the habitat factors using the equations of multiple regression analysis:

$$Y = b_1X_1 + b_2X_2 + \cdots b_nX_n + c + e,$$

where: Y = The variable wants to predict; b = Regression coefficient; c = Constant and e = Error.

The data is tested using a series of classical assumption tests to meet the assumptions that must be met. The classical assumption test carried out is as follows:

1) *Normality*
The normality test aims to assess whether or not the data is spread in a group of data or variables.

2) *Heteroscedasticity*
   The heteroscedasticity test aims to test whether there is an inequality of residual variance from one observation to another.
3) *Multicollinearity*
   The multicollinearity test aims to test whether there is a high or perfect correlation between the independent variables.

After performing multiple linear regression analysis, the next step is to test the model using the F test, T test, and the coefficient of determination.

1) F-Test

The F-test was conducted with the aim of showing whether all the independent variables included in the regression model have a joint effect on the dependent variable (Kuncoro 2009), with the hypothesis:

H0: All independent variables have no significant effect simultaneously on the dependent variable.

H1: All variables have a significant effect together on the dependent variable.

Decision used:

➔ Accept H0 if the significance value > 0,05

➔ Reject H0 if the significance value is < 0,05

2) T-Test

The T-test aims to test how far the influence of the independent variable on the dependent variable is partially (Widjarjono 2010), with the hypothesis:

H0: The independent variable partially does not have a significant effect on the dependent variable.

H1: The independent variable partially has a significant effect on the independent variable.

Keputusan yang digunakan:

➔ Accept H0 if the significance value > 0,05

➔ Reject H0 if the significance value is < 0,05

3) Coefficient of Determination

The coefficient of determination explains the variation in the effect of independent variables on the dependent variable, it can also be said as the proportion of the influence of all independent variables on the dependent variable. The coefficient of determination is carried out to determine the best level of accuracy in the regression analysis, which is expressed by a value between zero to one. A zero value in the coefficient of determination means that the independent variable has absolutely no effect on the dependent variable. Conversely, if the coefficient of determination has a value close to one, it means that the independent variable influences the dependent variable.

Results and discussion

Before you can perform the regression test, you must meet three conditions, namely passing the normality test, multicollinearity test, and heteroscedasticity test.

Normality test

Based on the results of the analysis, the first step is to determine whether the data entered in the regression analysis is normally distributed, the data is said to be normally distributed if the data points follow a diagonal line, figure 3 is the result of the normality test analysis.

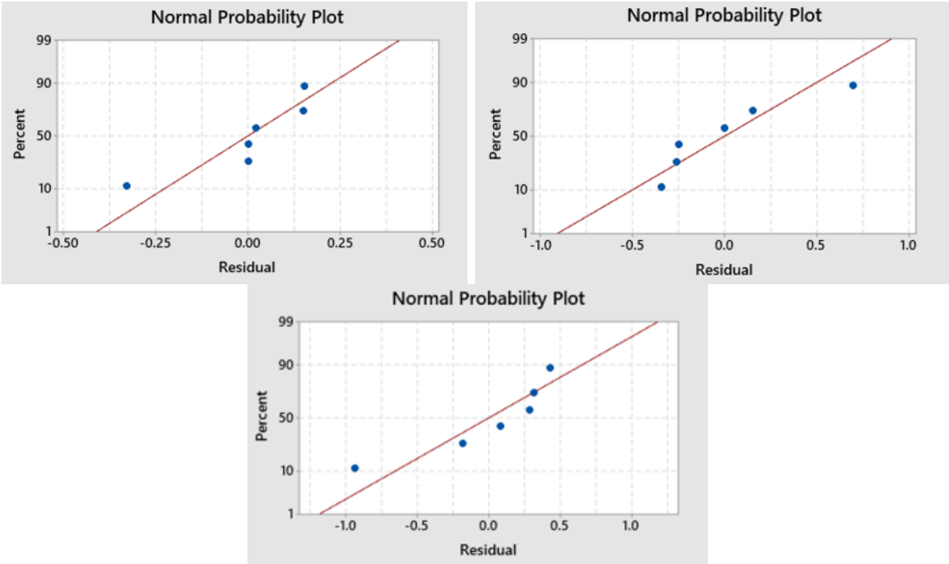

Fig. 3. Normality test analysis results

Multicollinearity Test

The second stage of the analysis is to test multicollinearity to determine the degree of correlation between variables, to be able to perform a regression test on the results of the multicollinearity test, multicollinearity cannot occur, multicollinearity is said to occur if the VIF value is > 10, and multicollinearity does not occur if the VIF value is <10. Based on the results of the analysis of the 3 data groups, there is no multicollinearity, this can be seen in the following table 2 example.

Table 2. Elephant group and habitat factors that influence it

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	32.70	2.52	12.99	0.049	
X1	-3.391	0.302	-11.23	0.157	5.18
X2	-2.355	0.345	-6.82	0.093	2.88
X3	-0.784	0.206	-3.80	0.164	2.84
X5	-0.6381	0.0903	-7.07	0.089	5.12
X6	0.1284	0.0721	1.78	0.326	2.63
X7	-0.51	3.56	-0.14	0.910	1.28
X8	-1.056	0.872	-1.21	0.439	6.17
X9	-0.149	0.226	-0.66	0.629	3.78
X10	2.390	0.262	9.12	0.070	6.46
X11	-0.4998	0.0332	-15.03	0.042	5.54
X12	-2.657	0.244	-10.90	0.058	3.32
X13	-0.7634	0.0600	-12.72	0.050	3.31

Heteroscedasticity Test

The third stage before entering the regression test is the heteroscedasticity test, the heteroscedasticity test to determine whether there is a residual inequality between variables. In the heteroscedasticity test, it can be known based on the results of the analysis, if the data points are scattered irregularly on the X and Y axes, the data is said to have no heteroscedasticity, the results of the analysis on the heteroscedasticity test are presented in figure 4.

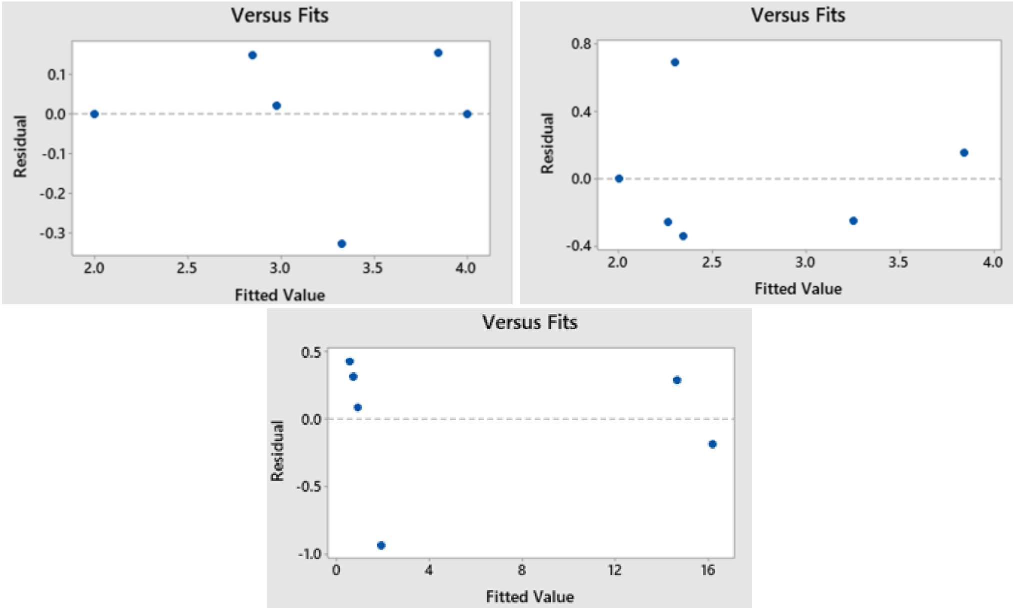

Fig. 4. Heteroscedasticity Test Results

Multiple Regression Analysis

Multiple Regression Analysis produces regression equations, F test, T test, and coefficient of determination. The results of the Multiple Regression Analysis of the relationship between elephant movement and habitat factors are presented in Table 3-5. The results of this regression are based on showing that the p-value in the F test is <, meaning that it rejects H0. This value indicates that the model is said to be suitable or significant. Meanwhile, based on the p-value on the T test, it was found that there is at least one variable that has a significant effect on Y in each X variable. The coefficient of determination shows how high the contribution of the dependent variable is to the independent variable.

Elephant Group 3866

Based on the results of the analysis carried out on the 3866 elephant group, it is known that the characteristics of the first Y1 track (number of passes) are influenced by three habitat factors, namely distance to water sources, availability of food, and availability of body scrub trees with a coefficient of determination of 73.71%. This means that there is a contribution which is high from the dependent variable to the independent variable. The second characteristic of Y2 (track length) is influenced by three habitat factors, namely settlement distance, water source distance, and food availability with a coefficient of determination of 98.36%. The characteristics of the third track Y3 (frequency of use of the track) are influenced by four habitat factors, namely the distance of settlements, the distance of water sources, the availability of food, and the availability of body scrub trees with a coefficient of determination of 86.62%. The fourth characteristic of Y4 (the length of use of the track) is influenced by 7 habitat factors, namely the number of tracks, the length of the track, the height, the slope, the distance to the water source, the availability of food, and the availability of body scrub trees with a coefficient of determination of 98.02%.

Areas that are very suitable and suitable are secondary forest vegetation types, grass and shrublands and close to water sources, altitudes < 800m above sea level and flat to gentle slopes [34]. In addition, 65% of the traces found were in the very suitable space and 35% in the suitable space; while in unsuitable and unsuitable spaces, no traces were found [34].

Table 3. The results of the regression analysis on the 3866-elephant group

No	Elephant Group	Regression Equation	F-Test (p-value)	T-Test (p- value)	Coefficient of Determination
1	3866	Y1 (number of track): -2.92 + 0.501 X2 - 0.801 X3 - 0.116 X4 + 0.158 X5 + 0.1250 X6 - 0.0150 X7 - 0.000 X8 - 0.333 X9 + 0.170 X10 + 0.005921 X11 - 0.2446 X12 + 0.3647 X13	0,000	• X11= 0.079 • X12=0.087 • X13=0.098 • Other variables indicate the value of > α	73.71%
2	3866	Y2 (length of track): 8.62 + 0.836 X1 + 0.956 X3 - 0.065 X4 - 0.218 X5 + 0.0367 X6 + 0.0076 X7+ 0.736 X8 + 0.152 X9+ 0.3676 X10 + 0.001013 X11 - 0.004571 X12 - 0.0410 X13	0,000	• X10= 0.098 • X11= 0.051 • X12= 0.099 • Other variables indicate the value of > α	98.36%
3	3866	Y3 (frequency of use of the track): -6.11 - 0.924 X1 + 0.661 X2 - 0.010 X4 + 0.2042 X5 + 0.0250 X6 + 1.91 X7 + 0.018 X8 + 0.034 X9 + 0.79417 X10 - 0.035500 X11 + 0.084085 X12 - 0.10959 X13	0,000	• X10= 0.007 • X11= 0.012 • X12= 0.004 • X13= 0.009 • Other variables indicate the value of > α	86.62%
4	3866	Y4 (track usage time): 32.70 - 3.391 X1 - 2.355 X2 - 0.784 X3 - 0.6381 X5 + 0.1284 X6 - 0.51 X7 - 1.056 X8 - 0.149 X9 + 2.390 X10 - 0.4998 X11 - 2.657 X12 - 0.7634 X13	0,000	• X2= 0.093 • X5= 0.098 • X10= 0.070 • X11= 0.042 • X12= 0.058 • X13= 0.050 • Other variables indicate the value of > α	98.02%

Table 4. Results of regression analysis on a group of 3870 elephants

No	Elephant Group	Regression Equation	F-Test (p-value)	T-Test (p- value)	Coefficient of Determination
1	3870	Y1 (number of track) = 3.70 - 0.401 X2 + 0.900 X3 - 0.2484 X4 + 0.0468 X5 + 0.107 X6 - 0.105 X7 - 0.025 X8 + 0.120 X9 + 0.2822 X10 - 0.003926 X11 + 0.04205 X12 + 0.03153 X13	0,000	• X10= 0.097 • X11= 0.018 • X12=0.035 • Other variables indicate the value of > α	97.75%
2	3870	Y2 (length of track) = 7.69 - 2.055 X1 + 2.226 X3 - 0.454 X4 + 0.0886 X5 - 0.671 X6 + 0.180 X7 + 0.359 X8 - 0.457 X9 - 4.0619 X10 - 0.006577 X11 - 0.19381 X12 - 0.2517 X13	0,000	• X3= 0.076 • X10=0.010 • X11= 0.025 • X12=0.013 • X13=0.026 • Other variables indicate the value of > α	91.16%
3	3870	Y3 (frequency of use of the track) = 14.420 - 0.918 X1 + 0.4429 X2 + 0.206 X4 - 0.0383 X5 - 0.171 X6 + 0.0857 X7 - 0.091 X8 - 0.429 X9 + 2.4136 X10 + 0.002205 X11 - 0.19406 X12 - 0.08793 X13	0,000	• X2= 0.076 • X10= 0.018 • X11= 0.027 • X12= 0.028 • X13= 0.051 • Other variables indicate the value of > α	97.72%
4	3870	Y4 (track usage time): 13.86 - 3.72 X1 - 1.33 X2 + 3.03 X3 + 0.181 X5 - 0.2606 X6 - 0.06586 X7 - 0.4204 X8 - 0.766 X9 - 2.254 X10 + 0.011257 X11 - 0.4100 X12 - 0.0589 X13	0,000	• X7= 0.081 • X10= 0.044 • X11= 0.025 • X12= 0.051 • Other variables indicate the value of> α	94.93%

Elephant Group 3870

Based on the results of the analysis conducted on the 3870 elephant group, it is known that the characteristics of the first Y1 track (number of passes) are influenced by three habitat factors, namely the distance to settlements, the distance to water sources, and the availability of food with a coefficient of determination of 97.75% which means that there is a high contribution from the variable dependent on the independent variable. The second characteristic of Y2 (track length) is influenced by the frequency of the track, the distance to settlements, the distance to water sources, the availability of food, and the availability of scrubbing trees with a coefficient of determination of 91.16%. The characteristics of the third Y3 track (frequency of track use) are influenced by four habitat factors, namely track length, settlement distance, water source distance, and food availability with a coefficient of determination of 97.72%. The fourth characteristic of Y4 (long track use) is influenced by four habitat factors, namely land cover, distance to settlements, distance to water sources, and availability of food with a coefficient of determination of 98.02%.

Areas that are very suitable and suitable are secondary forest vegetation types [34, 35], close to water sources, altitude < 800masl and flat to gentle slopes [26, 34].

Table 3. The results of the regression analysis in the elephant group 3866

No	Elephant Group	Regression Equation	F-Test (p- value)	T-Test (p- value)	Coefficient of Determination
1	3871	Y1 (number of track) = 37.8 - 0.117 X2- 0.01143 X3-0.06398 X4 - 0.0009 X5 - 19.7 X6- 0.0320 X7 1.220 X8+ 10.4 X9 + 0.01404 X10+ 0.001255 X11- 0.01411 X12 + 0.00740 X13	0,000	• X10=0.078 • X11=0.027 • X12=0.081 • Other variables indicate the value of > α	98.84%
2	3871	Y2 (length of track) = 14.53 - 2.45 X1 - 0.0523 X3 - 0.140 X4 - 0.0590 X5- 26.07 X6 - 0.02344 X7 - 0.357 X8 + 15.37 X9 + 0.003884 X10 - 0.000059 X11 - 0.0858 X12 + 0.01867 X13	0,000	• X6= 0.074 • X10=0.045 • X11=0.505 • X12=0.079 • X13= 0.076 • Other variables indicate the value of > α	84.86%
3	3871	Y3 (frequency of use of the track) = 266.9 - 63.5 X1 - 13.87 X2 - 3.87 X4 - 0.53 X5+ 388.2 X6 + 3.920 X7 + 1.12 X8 - 1519 X9 - 0.0229 X10 - 0.01953 X11 + 3.454 X12 - 0.1980 X13	0,000	• X6= 0.058 • X7= 0.090 • X10=0.284 • X11=0.078 • X12=0.079 • Other variables indicate the value of> α	80.81%
4	3871	Y4 (track usage time): 49.9 - 15.49 X1 - 1.61 X2 - 0.169 X3 + 0.003 X5 + 58.6 X6 + 3.916 X7 + 0.18 X8 - 1565 X9 - 0.00193 X10 - 0.011354 X11 + 0.1658 X12 - 0.3304 X13	0,000	• X1= 0.060 • X7= 0.095 • X9= 0.099 • X11=0.053 • X12=0.073 • X13=0.077 • Other variables indicate the value of> α	97.08%

Elephant Group 3871

Based on the results of the analysis carried out on the 3871 elephant group, it is known that the characteristics of the first Y1 track (number of tracks) are influenced by four habitat factors, namely the length of use of the track, the distance to settlements, the distance to water sources, and the availability of packs with a coefficient of determination of 98.84%. This means that there is a contribution which is high from the dependent variable to the independent variable. The second characteristic of Y2 (track length) is influenced by four habitat factors, namely slope, settlement distance, availability of food, and availability of body scrub trees with a coefficient of determination of 84.86%. The characteristics of the third track Y3 (frequency of track use) are influenced by four habitat factors, namely slope, land cover, water source distance, and food availability with a coefficient of determination of 80.81%. The fourth characteristic of Y4 (long track usage) is influenced by five habitat factors, namely the number of tracks, land cover, distance to water sources, availability of food, and availability of scrubbing trees with a coefficient of determination of 98.02%.

Areas that are very suitable and suitable are secondary forest vegetation types [34, 35], close to water sources, altitude < 800masl and flat to gentle slopes [26, 34].

Conclusions

Based on the results of regression analysis to three groups of Sumatran elephants in Way Kambas National Park, it is known that first the number of paths traversed by the three elephant groups is influenced by the distance factor from settlements and the availability of food, then secondly for the length of the path traversed by the elephants is influenced by the distance factor, water sources and the availability of food, thirdly for the frequency of use of the track is influenced by habitat factors, distance from water sources and the availability of food, and lastly the length of use of the track by elephant groups is influenced by factors of habitat distance to water sources and the availability of the amount of feed. There are other habitat factors that influence such as slope, land cover, altitude, and the availability of scrubbing trees but they do not significantly influence the movement of elephant groups.

The three biggest factors that influence the movement of Sumatran elephants are first the availability of food, the second is the distance to water sources, and the last is the distance to settlements.

Acknowledgments

The author is very grateful for the involvement and assistance that has been provided by the Way Kambas National Park, besides that the author is also grateful to the non-governmental organizations that have helped, namely WCS, AleRT and the Elephant Rescue Unit (ERU) Team.

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Received: June 02, 2022
Accepted: November 24, 2022