Spatial modeling of conflict vulnerability of Sumatran elephants (*Elephas maximus sumatranus*) with humans in Besitang

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Abstract. High human activity around and in the forest is one of the causes of damage to Sumatran elephant (*Elephas maximus sumatranus*) habitat in the forest landscape of Besitang. Deforestation and degradation have caused forest fragmentation so that Sumatran elephant habitat becomes narrow. As a result, Sumatran elephants look for a new space outside their natural habitat such as agricultural land and plantations owned by communities around the forest. The conflict between Sumatran elephants and humans cannot be avoided. The objective of this study was to get information about the vulnerability distribution of Sumatran elephant conflict with humans based on the influenced factors in Besitang. The Principal Component Analysis (PCA) method was used to select and weight the factors that are thought to influence the distribution of Sumatran elephant conflict with humans. Overlay analysis of the factors that influence the conflicts distribution between Sumatran elephants and humans was done using Geographic Information System (GIS). The results of the study showed that the vulnerability of human-elephant conflict could be divided into three classes, namely the highly vulnerable areas of conflict which are 43,981.11 ha (26.99%), medium vulnerable areas which are 41,632.74 ha (25.56%) and not vulnerable areas which are 77,291.73 ha (47.45%). The results of the model validation test showed a value of 87.5%.

1. Introduction
One of the conservation priorities in the world is the effort to mitigate wildlife conflicts with humans [1], including in Indonesia. Conflicts between Sumatran elephants-human occur in many parts of Indonesia, especially in Besitang, Langkat Regency. Deforestation and forest degradation cause the Sumatran elephant's habitat to become increasingly narrow. It can be seen from the high rate of deforestation in Langkat Regency at 1,292.01 ha per year in the period 1990-2015 [2].

Forest destruction as a Sumatran elephant habitat is often caused by human activities that convert forests to agricultural and oil palm plantation for economic purposes. It causes the forest to become fragmented [3] so that the elephant occupies the remaining forest. The remaining habitat is usually in the form of relatively small forests with unfavorable feed conditions. It causes the Sumatran elephant to
search for new space to move to agriculture and human settlements, resulting in a conflict between the people and the Sumatran elephant [4].

Information predicting the level of human-elephant conflict is important to know as an effort to mitigate elephant-human conflict. The utilization of GIS technology and remote sensing can be used to model the level of human-elephant conflict [5]. The objective of this study was to get information about the vulnerability distribution of Sumatran elephant conflict with humans based on influenced factors in Besitang.

2. Materials and method

2.1. Research location

This research was carried out in the Besitang Forest and the surrounding villages (village of Bukit Selamat, Bukit Mas, PIR ADB, Harapan Maju, Mekar Makmur, Sawit Hulu, Sei Serdang, Namo Sialang and Sei Musam). Besitang Forest is part of the Gunung Leuser National Park located in Langkat Regency, North Sumatra Province (figure 1).

![Figure 1. Map of the study area in Besitang, North Sumatra.](image)

2.2. Spatial analysis

The sample data in the form of the coordinates of human-elephant conflict were obtained from direct observation in the field using GPS and from secondary data from Gunung Leuser National Park. The total number of samples was 56 sample points, of which 38 samples (70%) were used to build the model, and 16 samples (30%) were used for the model validation test. The selection of model data and validation data was done randomly. Furthermore, these conflict points were overlaid with conflict trigger factors using ArcGIS 10.5.

Factors that are suspected as triggers of conflict consist of biophysical and social factors referring to previous studies [5–8]. Elevation and slope data were derived from Shuttle Radar Topography Mission (SRTM). Data of distance from the road, distance from the river, distance from the forest, distance from the mixed garden and distance from the settlement were obtained using the Euclidian distance [9]. Population density data was obtained from BPS data in 2018. Whereas Normalized Difference Vegetation Index (NDVI) was obtained from Landsat 8 imagery path/row: 129/57 and path/row: 129/58, with the date of acquisition February 13, 2018.
The use of PCA in this study refers to [10], where PCA is used to reduce factors that do not influence and give weight to the factors that influence the distribution of human-elephant conflict. In the PCA analysis, the variable feasibility assessment is tested by measuring the Bartlett test of sphericity and Measure Sampling Adequacy (MSA) with a significance value below 0.05 [11].

The mathematical equation model of the level of conflict between Sumatran-human elephants based on PCA weighting can be written as follows:

$$Y = a FK1 + b FK2 + c FK3 + d FK4 + e FK5 + f FK6 + g FK7 + h FK8 + i FK9 + j FK10$$  \hspace{1cm} (1)$$

where:

- $Y$ = total value of Sumatran elephants-humans conflict areas
- $a$-$j$ = the weight value of each variable
- FK1 = NDVI
- FK2 = elevation
- FK3 = slope
- FK4 = distance from road
- FK5 = distance from the river
- FK6 = distance from forest
- FK7 = distance from oil palm plantations
- FK8 = distance from the mixed garden
- FK9 = distance from the settlement
- FK10 = population density

2.3 Model validation

The measurement of validity level was done by overlaying 16 human-elephant conflict validation data with human-elephant conflict maps that have been produced. The validation test for a spatial model of human-elephant conflict areas is as follows:

$$V = \frac{n}{N} \times 100\%$$  \hspace{1cm} (2)$$

where:

- $n$ = number of human-elephant conflict points in vulnerable class
- $N$ = total number of human-elephant conflict points
- $V$ = level of validity

3. Results and discussion

3.1. Spatial model

The test results of Kaiser-Meyer-Olkin index (KMO) obtained a value of 0.448 and the Bartlett test of sphericity value of 95.634 with a significance of 0.000, this indicates that the variables and samples have not been analyzed further. To increase the KMO value, it is necessary to issue a variable with a Measure Sampling Adequacy (MSA) value of <0.5. Variables issued are variables with the smallest MSA value, namely the distance variable from the oil palm plantation, the distance from the mixed garden and NDVI. The final results of PCA analysis of seven variables (figure 2) are feasible to be analyzed further. After issuing the variable with the smallest MSA value, the results of testing the KMO value of 0.613 and the Bartlett test of sphericity value of 59.333 with a significance of 0.000, and it is known that the MSA value> 0.5 for each variable. The requirements of the PCA have been fulfilled and the analysis can continue.

The results of extraction using PCA show that of the seven variables used to build human-elephant conflict model, three new components can explain the total data diversity with a total percentage of 70.335% with the total eigenvalues value exceeding 1 (table 1). The proportion of diversity is considered sufficient to represent the total diversity of data if the cumulative diversity reaches 70% - 80% [12].

Based on table 2, four variables are highly correlated with the first component, namely elevation, slope, distance from the river and population density. In other words, these four variables have the most influence on the incidence of human-elephant conflict in the study area. This component as a whole illustrates the activities of elephants in meeting their needs and avoiding disturbances and obstacles,
with a diversity of 38.477%. The second component consists of the distance from the road and the distance from the settlement which illustrates the closeness to the activity and human existence with a diversity value of 16.662%. Whereas for the third component only has one variable, the distance from the forest that represents the place of arrival of elephants with a value of 15.196%.

Table 1. Initial eigenvalues of driving factors of Sumatran elephants-humans conflict in Besitang.

| Component | Total | % of Variance | Cumulative (%) |
|-----------|-------|---------------|----------------|
| 1         | 2.693 | 38.477        | 38.477         |
| 2         | 1.166 | 16.662        | 55.139         |
| 3         | 1.064 | 15.196        | 70.335         |
| 4         | 0.829 | 11.843        | 82.178         |
| 5         | 0.571 | 8.163         | 90.341         |
| 6         | 0.408 | 5.832         | 96.173         |
| 7         | 0.268 | 3.827         | 100.000        |

Figure 2. Driving factors of Sumatran elephants-humans conflict in Besitang.

Table 2. Rotated component matrix.

| Variable                  | Component | 1    | 2    | 3    |
|---------------------------|-----------|------|------|------|
| Elevation                 | 0.788     | -0.019 | 0.345 |
| Slope                     | 0.601     | -0.172 | -0.014 |
| Distance from road        | -0.151    | 0.881 | -0.100 |
| Distance from river       | 0.812     | -0.125 | 0.110 |
| Distance from forest      | 0.104     | -0.129 | 0.918 |
| Distance from settlement  | -0.176    | 0.869 | -0.031 |
| Populations density       | 0.656     | -0.280 | -0.358 |

The results of this study reveal many similarities with the results of [6], where human-elephant conflicts occur in areas close to forests, areas close to roads, and areas with low population density and areas close to elephant shelters during the day. Results of research by [5] also reported more or less the same thing where the distance from the settlement, the distance from the forest, slope, and elevation were contributors to human-elephant conflict.
The results of the weighting of each critical variable (table 2) based on the PCA diversity score (table 1) are shown in table 3.

| No | Variable               | Total of eigenvalues |
|----|------------------------|----------------------|
| 1  | Elevation              | 2.693                |
| 2  | Slope                  | 2.693                |
| 3  | Distance from road     | 1.166                |
| 4  | Distance from river    | 2.693                |
| 5  | Distance from forest   | 1.064                |
| 6  | Distance from settlement | 1.166            |
| 7  | Populations density    | 2.693                |

Based on table 3, the human-elephant conflict spatial model formed is written with the following equation:

\[ Y = (2.693 \times \text{Elevation}) + (2.693 \times \text{Slope}) + (1.166 \times \text{Distance from road}) + (2.693 \times \text{Distance from river}) + (1.064 \times \text{Distance from forest}) + (1.166 \times \text{Distance from settlement}) + (2.693 \times \text{Populations density}) \] (3)

The results of the spatial analysis with weighting method using PCA produced the lowest pixel value of 22.25, the highest pixel value of 70.84 with an interval value of 16.20. The results of the observation are presented in table 3 and visualized in figure 3. The results of the elaboration of elephant conflict vulnerability areas were obtained from the vulnerable class ranging from 54.64 - 70.84 with an area of 43,981.11 ha or around 26.99% of the field of the study.

| No | Vulnerability class     | Range   | Total (Ha) | Percentage (%) |
|----|-------------------------|---------|------------|----------------|
| 1  | Not vulnerable          | 22.25 – 38.45 | 77,291.73  | 47.45          |
| 2  | Medium vulnerable       | 38.45 – 54.64 | 41,632.74  | 25.56          |
| 3  | Vulnerable              | 54.64 – 70.84 | 43,981.11  | 26.99          |

![Figure 3. Map of Sumatran elephants-humans conflict in Besitang.](image)
3.2. Validation model
The results of the validation test of the human-elephant conflict spatial model showed that there were 14 points in the human-elephant conflict vulnerable class, while 2 points were in the vulnerable medium class. The value of the level of validity produced reached 87.5%; this number is quite good.

4. Conclusion
The utilization of GIS with weighting using PCA can be used to model the mapping of Sumatran elephant-human conflict vulnerability in Besitang with a validation level of 87.5%. Based on the spatial modeling that has been carried out, the vulnerability area of Sumatran-human elephants is 43,981.11 ha (26.99%) from the study area.

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