HUMAN-ELEPHANT CONFLICT TRIGGERING FACTORS IDENTIFICATION USING FUZZY LOGIC MODELLING

Nurafiqkah MUHID[1] and Noordyana HASSAN[1,2]*

[1]Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM), 81310 UTM Skudai, Johor, Malaysia.

[2]Geoscience and Digital Earth Centre (INSTeG), Research Institute of Sustainable Environment (RISE), Universiti Teknologi Malaysia (UTM), 81310 UTM Skudai, Johor, Malaysia.
**noordyana@utm.my*

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Abstract Human-elephant conflict (HEC) occurrences is becoming more frequent every year in elephant range countries. Changes in landscape from forested to non-forested areas have fragmented elephant habitat, forcing elephants to approach human-populated areas in search of food and water. This resulted in HEC, in which elephant occurrences always terrify people because they destroy property, cause injury, and death. Therefore, identification of HEC triggering factor is crucial to overcome this issue. Thus, this study hypothesized that factors such as landscape change, greenness, slope, and water resource availability are triggering HEC occurrence. Geospatial approach has capability to provide multi-temporal data and data product at large spatial extent to identify the triggering factors. A fuzzy logic spatial modelling was applied to geospatial data in identification of HEC triggering factors. Results suggested that fuzzy logic model was strongly influenced by proximity to the water source (less than 1.5 km), greenness status (high vegetation), slope (less than 10°) and landscape change. The HEC triggering factors demonstrated that water resource availability ($R^2 = 0.981$, p-value < 0.001) and slope ($R^2 = 0.927$, p-value < 0.005) has significant relationship with the HEC occurrences. As a conclusion, the results obtained from this study would be useful for the Department of Wildlife and National Park (DWNP) and the local communities to alleviate the HEC occurrences.

1.0 INTRODUCTION

The conflict between humans and elephants has become urgent attention in many parts of the world. The conflict occurs when both human and elephants need to share the limited resources at the same time and place (Wahab et al., 2016; Roskaft, 2010). Human settlements and agricultural fields expansion have resulted in loss of elephant habitat, escalation of forest degradation and fragmentation. In Peninsular Malaysia, Wong et al. (2018) have reported that human elephant conflict occurrence since before the mass forest conversion took place. Recent studies by Malaysian Elephant Management and Ecology (MEME) indicate that elephants in Peninsular Malaysia have lost 70 percent of their range in human-dominated ecosystems over the past 35 years (The Star, 2018). Thus, Asian Elephants are listed as endangered on the International Union for the Conservation of Nature (IUCN) Red List. Besides, they are primarily at risk of habitat loss and fragmentation, contributing to an escalation of human-elephant conflicts (The Star, 2018)

Human-elephant conflict often refers to any human-elephant interaction which has a negative impact on human social, economic or cultural life, the conservation of elephants or the environment (Parker et al., 2007). The effect of the HEC is causing the villagers the greatest fear because it can damage vast areas of crops, destroy property, cause injury and death. (Parker et al., 2007). The livelihoods of a rural farmer are affected especially when elephants destroy their cash crops to gain food (Parker et al., 2007). However, research from Sukumar (1990) on feeding ecology of Asian elephants, believes that elephants are attracted to cash crops because they are more palatable, more nutritious, and have lower secondary defenses than wild browse plants (Nelson et al., 2003). In Kemaman, Terengganu, about fifty palm farmers reported a loss of nearly sixty thousand Malaysia Ringgit after their crops had been attacked by wild elephants (Utusan Malaysia, 2020). Consequently, the costs of such conflict can be high and intolerable to the local farmer.

Therefore, the Department of Wildlife and National Parks (DWNP) implemented an alternative method known as translocation, which involves capturing elephants from conflict areas and then releasing them to protected areas such as National Park (Saaban et al., 2020). Although this method is good, translocation costs are very expensive, involve specialized expertise and have uncertain outcomes. (Nelson et al., 2003). Geospatial approach is capable to provide multi-temporal data at large spatial extend to monitor the human-elephant conflicts occurrences.

This study uses fuzzy overlay analysis to evaluate the relationship between the memberships of multiple sets. Fuzzy overlay analysis would be great in identifying the HEC triggering factors to gain a better understanding of the elephant habitat. This study hypothesized that factors such as slope, water availability, NDVI and landscape change are triggering the HEC to happen. Therefore, this study aims to explore human-elephant conflict for Asian elephants in GIS environment. The objectives include identifying triggering factors of HEC in Kota Tinggi using spatial analysis and exploring the relationship of triggering factors and HEC in Kota Tinggi.

2.0 MATERIALS AND METHODOLOGY

2.1 Study area

Kota Tinggi is the largest district in Johor, Malaysia, which covers 18.34% of the state area and located at 1.733333° N, 103.9° E, refer figure 1. It has an area of approximately 3,482 km2. There are 10 mukims in this district, with more than 200,000 residents, including 26 traditional main villages, 117 network villages, 29 FELDA settlement areas and 5 recent KEJORA urban areas. The main economy of this study area is agriculture, where 60% of its land is used for agricultural purposes, primarily dominated by oil palms and rubber crops. Most of the crops are cultivated by the FELDA settlers. It also has three main forests: Gunung Panti, Gunung Muntahak and Hutan Lipur Panti. This shows that Kota Tinggi is surrounded by forests, has well developed and is a pioneer in agriculture. Human elephant conflict occurrences have been reported the most frequent in Kota Tinggi, Johor, Malaysia. Besides, a total of 15 to 20 complaints about wild elephant disturbances are received by the Johor DWNP monthly.

2.2 Materials

There are two types of data were used in this study which is (i) primary data and (ii) secondary data. Where primary data used in this study is satellite-based data for example ASTER GDEM satellite data and satellite-based land use changed data. Meanwhile, secondary data is the supporting data, (i) normalized different vegetation index, (ii) water resource availability and (iii) ground data.

2.2.1 Satellite-based Land Use Change

The Landsat images (Landsat 5 TM and Landsat 8 OLI) dated 26 July 2006 and 27 June 2013 respectively were acquired from USGS Earth Explorer. The Landsat images were used to evaluate landscape changes for 8 years from 2006 to 2013 The Landsat images have 30 m spatial resolution which able to provide broad area information needed for elephant habitat. The raw Landsat images then were performed cloud masking using Fmask approach in Matlab and ENVI software. This process is necessary to remove cloud and cloud-shadow from satellite images since pixels with cloud are always considered contaminated pixels that can reduce data usability. The Landsat images were classified using Maximum Likelihood classifier to generate land use land cover map (Figure 1). Change detection analysis was then implemented to identify the percentage of changes in land use of Kota Tinggi by observing it at different times. This analysis mainly focuses on the initial state classification changes (year 2006); i.e., for each initial state class, the analysis determines the classes in which the pixels changed in the final state image (year 2013) (Table 1).

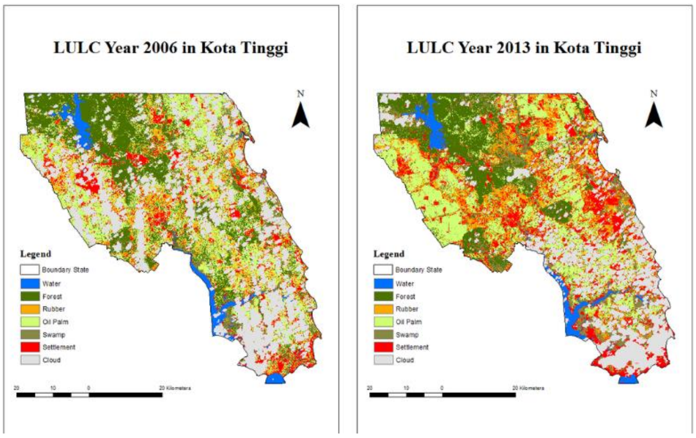

Figure 1: Land use change of Kota Tinggi area between year 2006 to 2013. Results shows that 5.36% of forested area has converted into oil palm, rubber, and settlement.

Table 1: The percentage of land use change in Kota Tinggi between year 2006 and 2013.

	Initial state (2006) %						
Final state (2013)		Water	Forest	Rubber	Oil Palm	Swamp	Settlement
%	Water	2.54	0.00	0.00	0.00	0.00	0.05
	Forest	0.00	9.15	0.29	1.69	0.94	0.37
	Rubber	0.00	1.49	1.70	3.56	0.54	1.48
	Oil Palm	0.00	2.13	1.62	8.96	0.42	1.62
	Swamp	0.01	2.70	0.68	2.17	1.56	0.85
	Settlement	0.23	1.74	1.20	2.88	0.82	3.41

2.2.2 ASTER GDEM satellite data

This study uses data from ASTER GDEM as it capable to provide a global digital elevation model for land areas on Earth. The geographical coverage ranges from 83° north to 83° south, which includes 99% of the Earth's landmass. The current version of ASTER GDEM has improved its coverage and reduced the occurrence of artifacts with a refined production algorithm. It also has maintained the GeoTIFF format and the same gridding and tile structure, as in previous versions, with 30-meter spatial resolution. The slope analysis then was applied to ASTER GDEM data to produce slope map in degrees. Slope analysis was applied to identify the steepness of study area. The classes of slope in degree and their description are shown in Table 2.

Table 2: Classification of slope (Sikdar et al., 2004)

Class	Description
0 to 5°	Very gentle
5° to 10°	Gentle
10° to 15°	Moderate
15° to 25°	Moderately steep
25° to 35°	Steep
> 35°	Very steep

2.2.3 Normalized Difference Vegetation Index (NDVI)

NDVI was calculated on ArcGIS 10.4 using raster tool for the year 2013 of Landsat 8 OLI image. Band 5 and band 4 were applied to identify greenness status of the study area. NDVI was determined by using the following expression:

$$NDVI = \frac{(\text{NIR} - \text{R})}{(\text{NIR} + \text{R})} \qquad \text{Eq.1}$$

where, NIR is near infrared band and R is red band.

The NDVI calculation results range between -1 and 1. Table 3 indicates the NDVI value corresponds to vegetation classes. The higher value of NDVI shows the presence of food availability.

Table 3 NDVI value and vegetation classes (Hashim et al., 2019)

Vegetation classes	NDVI value	Description
Non-Vegetation	-1 to 0.199	Barren areas, build area, road network
Low-Vegetation	0.2 to 0.5	Shrub and grassland
High-Vegetation	0.501 to 1.0	Temperate and tropical urban forest

2.2.4 Water resource availability

Kota Tinggi having 5 main catchment areas with 158 rivers. Because of that water resources availability become one of the factors included in this study. Water resources availability is the other factor triggering HEC cases. The catchment data was obtained from Department of Irrigation and Drainage (JPS) Johor. The Euclidean distance analysis was performed on water resource availability data with 5 km maximum distance and then was reclassify to 10 classes. This process used when data representing distance from a particular object was needed.

2.2.5 Ground data

The human elephant conflict data was obtained from Wildlife Department and National Park (DWNP) Johor. Data obtained based on report made by the residents. The HEC data provided by DWNP consisting of date of attack, location, and address of the reporter.

2.3 Methodology

2.3.1 Identification of the area with high risk HEC occurrences

The area with high risk of HEC occurrences was selected based on HEC report obtained from DWNP. The area with highest frequency of HEC occurrences was selected from the report obtained. According to the report, there is five area with high risk of HEC occurrences (refer Figure 2).

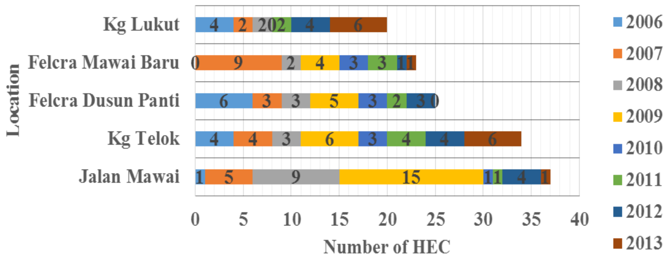

Figure 2 Selected high risk of HEC occurrence based on the highest frequency of HEC between year 2006 to 2013.

2.3.2 Fuzzy membership

Fuzzy membership tool was assigned to all the datasets that have been processed. This process aims to determine the degree of the members of dataset whether a particular location is either suitable or unsuitable (Aini et al., 2017). The value range of fuzzy membership is 0 to 1, with 1 representing full membership and 0 representing non-membership. There are several types of fuzzy membership functions, include sigmoidal functions such as fuzzy linear, fuzzy small, and fuzzy large. Those functions are chosen based on which best represents the data transformation based on the phenomenon being modelled. Table 4 summarizes the fuzzy membership functions that were applied to all the factors in this study. Furthermore, the midpoint used for all these factors is based on suggestion from previous findings.

Table 4 Summary of fuzzy membership functions

Factors	FMF	Justification	References
NDVI	Large	Large membership for large input values	(Aini, Sood and Saaban, 2015)
Slope (degree)	Small	High membership for smaller input values	(Sharma et al., 2020)
Water availability (m)	Small	High membership for value closer to water	(Aini, Sood and Saaban, 2015)
Landscape change (%)	Linear	Based on specific classification of area change	

Then, the fuzzy overlay was employed on the outputs of the fuzzy membership functions to produce an outcome map of most suitable human elephant conflict occurrences in Kota Tinggi. There are various types of fuzzy overlay operators available, such as fuzzy AND, fuzzy OR, fuzzy PRODUCT, fuzzy SUM, and fuzzy GAMMA, each of which provides a different aspect of each cell's membership to the multiple input criteria. In this study, the fuzzy AND was applied to the slope factor, the fuzzy OR was applied to the water resource, NDVI, and change detection factors. Finally, the fuzzy PRODUCT was used to the intermediate output maps to generate the potential HEC occurrences map of the study area.

3.0 RESULT AND ANALYSIS

3.1 Fuzzy Logic Modelling on Human Elephant Conflicts Occurrences

Results shows the fuzzy logic model was performed to identify HEC occurrences at selected village. The results shows that Kg. Telok, Jln Mawai and Kg. Lukut are highly at risk to face HEC occurrences. Meanwhile, Felcra Dusun Panti and Felcra Mawai Baru are moderately and unsuitable at risk to face HEC occurrences, respectively (See Figure 3). According to table 5, the results shows that Kg. Telok, Jln Mawai and Kg. Lukut is highly at risk due to the proximity to water resource (less than 1.5 km). Besides, these three villages were located at a flat physical landscape (< 10°).

3.2 Human Elephant Conflicts Triggering Factor Identification

Regression analysis was employed to identify the most significant factor that caused HEC occurrences. Figure 8 shows that the significant relationship between the number of HEC cases in 2013 with the water resource availability (R^2= 0.981, p-value < 0.001). The slope also showing a significant relationship with the HEC cases (R^2= 0.927, p-value <0.005).

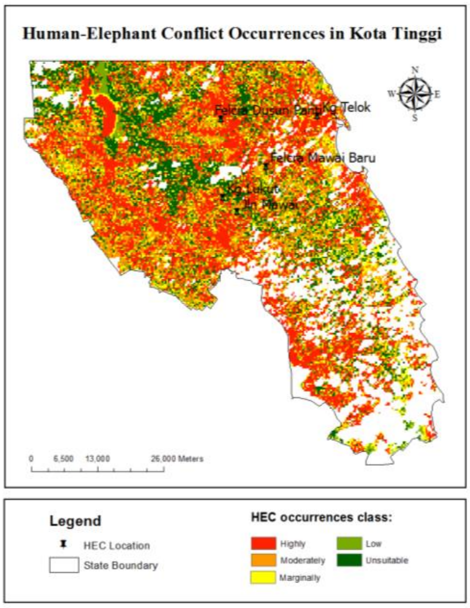

Figure 3 Predicted HEC frequency at selected area using weighted overlay analysis

Table 5: HEC occurrences value on HEC locations

HEC Location	HEC Occurrences Value	HEC Occurrences Class	Proximity to water (m)	Slope (deg)	NDVI	Landscape Change (%)
Kg Lukut	0.9937	Highly	500	3	0.43	3.41
Kg Telok	0.9293	Highly	500	4	0.57	2.88
Jln Mawai	0.8748	Highly	1000	10	0.34	4.62
Felcra Dusun Panti	0.6821	Moderately	1000	15	0.35	3.41
Felcra Mawai Baru	0.0852	Unsuitable	1000	14	0.69	1.62

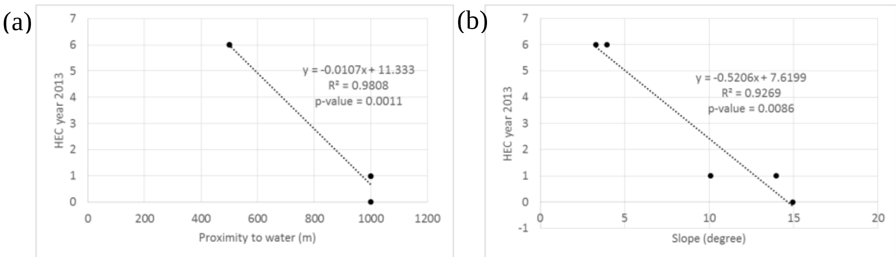

Figure 4 (a) Water resource and (b) slope showing significant relationship with the HEC occurrence in Kota Tinggi

3.2 Discussion

Results suggested that fuzzy logic modelling capable to identify the triggering factors of HEC where the HEC may occur at the area near water resource (less than 1.5 km) and flat physical landscape (0° to 10°). Therefore, the elephant has easy access to the source of food and water. This is aligned with the results obtained by Aini et al., (2017) and Sharma et al. (2020). Instead of that, about 5.36% of forest area has converted to oil palm, rubber and settlement within year 2006 to 2013 (Table 1). The landscape change for three villages was quite high from forested area into agricultural areas. The agricultural area is dominated by oil palm which is one of the sources of food. This demonstrates a rapid decrease in the forest which may be attributed to anthropogenic activity and resulted in the depletion of food sources for the Asian Elephants. As a consequence, this phenomenon has forced elephant habitat to migrate to agricultural areas, resulting in interactions between humans and elephants (Areendran et al., 2014).

4.0 CONCLUSION

As a conclusion, this study employed fuzzy overlay with factors such as water availability, slope, NDVI, and landscape change, which could be the cause of HEC. Elephants preferred to be in areas with near water sources and gentle slope. Exploring the ability fuzzy overlay with presence data is more suitable for determining the triggering factors since the relative weight of the input data can be controlled and the significance of each habitat factor can be evaluated. The model output produces in visual can easily be used by authorities to observe possible HEC occurrences for elephant conservation and propose better planning in mitigating HEC in future. Recommendation for this study is to add another factor to explore other factors that may be triggering HEC. Distance to settlement is an example of a factor that can be added because it is frequently used in elephant habitat studies. Besides, to handle the problem of limited ground data, it is suggested that a website or application be established where the public may simply report the presence of elephants in their villages over the internet. By overcoming this limitation, a data-driven study of elephant habitat can be conducted.

5.0 ACKNOWLEDGEMENT

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