Mapping of human-elephant conflict risk zones: a case study of Sooriyawewa divisional secretariat division, Sri Lanka

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Abstract - *With developments and human civilization, people are facing hazards. But without identifying such hazard areas, no action can be taken to prevent such incidents. The Human Elephant Conflict (HEC) is a main hazard that impacts rural society in Sri Lanka. HEC is the conflict between elephants and humans and implies the death of elephants and humans. Increased populations of elephants and humans, habitat modification, rainfall, water bodies, and land use changes are vital for HEC. This study focuses on mapping the spatial distribution of HEC risk zones in Sooriyawewa DSD. Furthermore, this study develops a method to validate the accuracy of risk zones. Furthermore, the directions of the HEC hazard propagation are demonstrated over the risk zones. Embedding geographic information system (GIS) with spatial interpolation is prominent to identify risk zones. Moreover, integrating GIS can greatly facilitate the classification of HEC risk zones into low risk, moderate risk, and high risk. Additionally, this study used Inverse distance weighted (IDW) spatial interpolation to create its hazard risk validation approach. A comparison of spots with some interstitial buffers was made to determine the propagation of the HEC from the center of Sooriyawewa. Therefore, it is crucial to determine the direction of risk and take action to reduce the risk of HEC hazards. This will help in generating an HEC scenario map for the future and formulating an action plan of mitigation measures to avoid damage, loss of life, and socio-economic impacts in the study area.*

Keywords - HEC, hazard, spatial distribution, geographic information system (GIS)

I. INTRODUCTION

During hazards, it depends on exposure, vulnerability, and capacity (Aitsi-Selmi *et al.*, 2016). A hazard is a situation that threatens property or the health of people. When these threats cause widespread destruction of human life and property, they are called disasters. A hazard becomes a disaster when it becomes active and threatening. Furthermore, hazards can be divided into two main categories: natural hazards and man-made hazards (Sugathapala, 2005). Disasters can be classified into major types such as biological, technological, environmental, etc. The inability to withstand a risk or react to a disaster is called vulnerability. Disaster risk reduction (DRR) has been identified as a significant element in disaster management (DM). Because DM is a relatively new issue in Sri Lanka, the majority of DRR activities are not directly considered DM (Sugathapala, 2005). Since the beginning of human civilization, people have been facing various hazards (Gunaryadi, Sugiyo, and Hedges, 2017).

The human-elephant conflict (HEC) in Sri Lanka is a long-standing issue (San Tiapillai et al., 2010). When considering the HEC in Sri Lanka, most of the time, the deforestation by local farmers and the loss of habitat for elephants are the main influences (Hodam *et al.*, 2017). Elephants typically have a greater impact on paddy cultivation. Paddy is cultivated by many farmers who are living in the Sooriyawewa Divisional Secretariat Division (DSD) (Prakash, Wijeratne, and Fernando, 2020).

The HEC can be identified as a current disaster in the Sooriyawewa DSD. Elephants mainly attack during harvest time and where paddy is stored. The attacks can be analyzed using some spatial data because elephant habits depend on physical and natural features (WHO/EHA/ETHTP, 1999). Sooriyawewa DSD doesn't have a proper HEC risk assessment plan. Therefore, most people face different hazards during the year. Furthermore, by using proper pre-identification method of hazards, human lives, and property can be saved. Therefore, this study demonstrates spatial analysis and distribution to identify a method for preparing a proper HEC zonation map for the Sooriyawewa. Development can be achieved in a sustainable manner after identifying the hazards in this area. The relevant data on HEC has been shown in previous studies. Wildlife conservation in Sri Lanka has been documented for information (Rathnayake, Nagai and Honda, 2011).

According to Fernando (2015), elephants are the largest land animals. Elephants in Sri Lanka have home ranges that range from 50 to 400 km^2 Sri Lanka, which has a land size of 65,610 km2 and a large human population of more than 20 million, is home to at least 4,400 elephants, according to estimates. It represents roughly 10% of global Asian elephants in the wild (Kemf and Santiapillai, 2000). Paddy is the favorite crop eaten by elephants. Even when the harvest is harvested and stored in the houses, paddy is eaten by them (Santiapillai *et al.*, 2010). Sri Lanka plays a unique and crucial role in preserving Asian elephants (Fernando, 2015).

Disaster risk and research can be linked to solving serious environmental problems by integrating a Geographic Information System (GIS). Furthermore, GIS combines spatial data analyzing software and techniques. Moreover, Remote Sensing (RS) can be adopted for that. GIS is useful for hazard zone mapping embedded in the data collection of RS, and people use these maps to mitigate their risk in the event of an emergency. In mitigation methods and preparedness plans, GIS and RS are extremely useful. Real-time geographic data can help in resource distribution during a disaster (Chang et al., 2013; Wickramathilaka *et al.*, 2021; Rupathunga, Wickramathilaka and Hansamal, 2022).

Distance from protected areas, altitude, mean annual rainfall, the area used for agriculture, and the sand bed were the main spatial predictors of HEC on a finer scale, while the area used for tea plantations was included on a coarser scale (Naha et al., 2019). According to past studies, elephant corridor location (to identify elephant movement) has been used as its primary data, and that study has created a corridor map with 2 km buffers for each corridor location with the ArcGIS platform. Two factors, namely habitation, and connectivity, were used to create the conflict map (Nad, Roy and Roy, 2022). HEC has turned into a crisis throughout the dry zone and the tank villages. Also, the risk of being attacked by elephants increases near the tank. One of the most important causes of this conflict is the destruction of elephant habitat types in the dry zone because of agricultural activities brought about by the growth of small-scale farming. Manly identifies chena cultivation land transformation as a major cause of HEC (Anuradha et al., 2019).

This study has collected data on elephant-caused attacks by the Department of Wildlife Conservation, Sri Lanka. This data includes the date, the place where incidents have happened, and the local administrative division. But the problem was that these location-specific data were not georeferenced; therefore, the data were converted to decimal degrees to create a map. Due to this problem, my study will follow the digitalization technique through Google Earth Pro. This study provides important information on the daily lives of elephants. For example, they need 135-300 Kg of food and spend around 16 hours getting food. Finally, they travel 20-25 km for their primary needs. Therefore, 20 km from the area where elephants live can be called an elephant attack risk zone. This study said that every day or month, elephant-caused attacks are not the same.

II. STUDY AREA

Sooriyawewa Divisional Secretariat Division (DSD) is a town located in the Hambantota District in the Southern Province. It has 185 km^2 of land area, and the location coordinates are 6.3194˚ N, 81.0024˚ E. There are 21 Grama Niladhari divisions in this region, and the population of the region is 43102 according to the 2012 census and statistics data in Sri Lanka. Figure 1 shows the study area. According to data from the Southern Province Wildlife Conservation Office, Sooriyawewa DSD has recorded the highest number of HECs in recent years. Therefore, it is vital to identify the area with the highest risk of HEC.

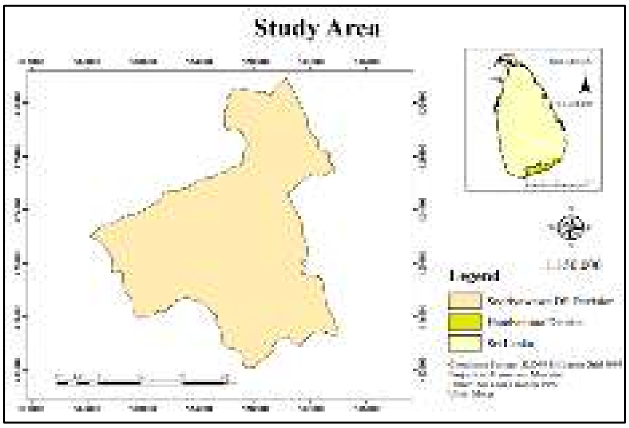

Figure 1. Research study area
Source: Survey Department

III. METHODOLOGY

The present study is used to determine the nature and extent of the risk by conducting hazard analysis and evaluating the existing risk conditions, which may harm people, property, livelihoods, and the environment on which they depend. The procedure for the preparation of various thematic maps and criteria was used for the identification of HEC risk areas in the study area using GIS.

Figure 2 illustrates the research workflow of the study. The main objective of this is to identify the HEC hazard risk zones. Furthermore, the direction of propagation of HEC is demonstrated over the risk zones. Data were collected by conducting the questionnaires. Moreover, previous studies were embedded to create the risk map. And this study is quantitative.

Due to the cultivation, HEC is experiencing rapid growth in this study area. Because they are doing farming along with the deforestation and because of that elephants are losing this habitat. Embedded with questionnaires and past studies, the criteria were found for the HEC. These criteria were the distance from forests, the distance from tanks, the distance from elephant corridors, and the type of cultivation. Again, a questionnaire was conducted to identify the level of influence based on the selected spatial criteria from the center of the spatial feature to the outer edge of the Sooriyawewa DSD.

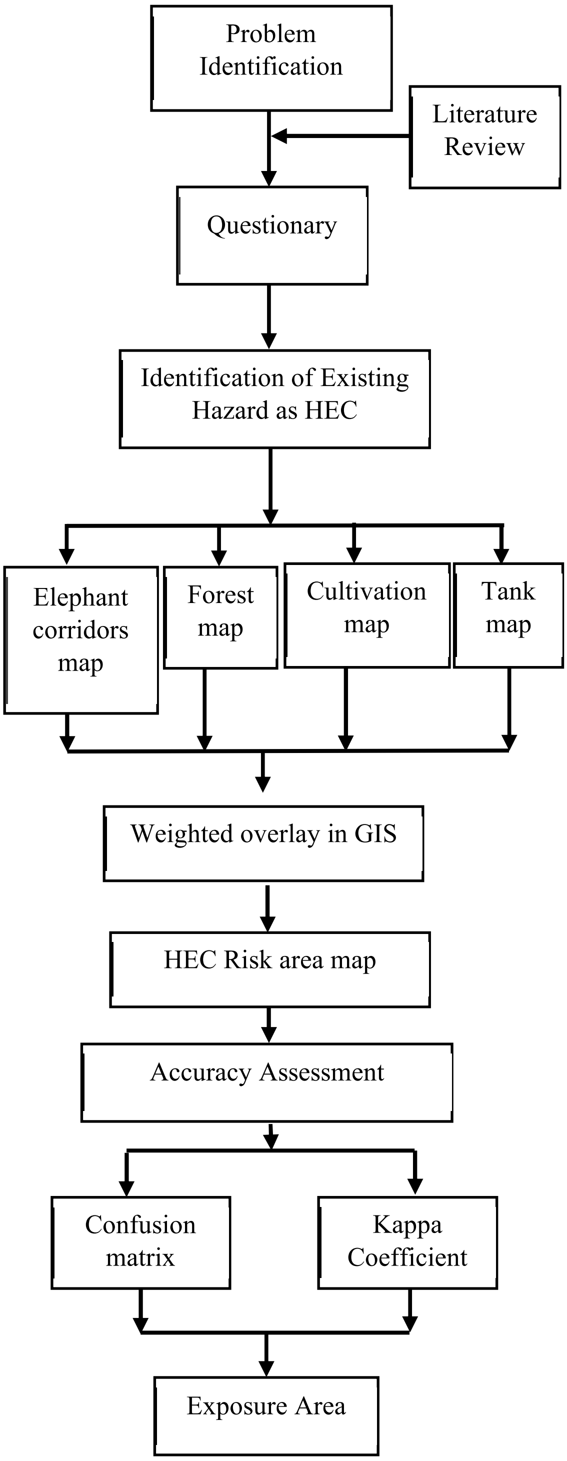

Figure 2. Research study workflow

These levels of criteria were obtained through a questionnaire survey. A separate thematic map was created for the elephant living forest layer, elephant corridor, tank layer, and land use layer. Accordingly, the forest buffer map was created at distances of 0 m, 50 m, 500 m, 1000 m, and >1000 m. The most damaged crops in this area are paddy and chena. Then 0 m, 50 m, 1000 m, 2000 m, and >2000 m distances were considered, and buffer zones were created for tanks (Prasad *et al.*, 2011).

A map was then prepared for the locations of elephant corridors in Sooriyawewa DSD. All the places are close to the forest. Therefore, buffer zones were created for elephant corridors considering distances of 0 m, 50 m, 500 m, 1000 m, and >1000 m. All the buffer zone range values were identified by past studies, and their scale values were found by questionnaire. After that, the four criteria buffer maps were combined.

Also, using the results of the questionnaire, the weight of each criterion was found for these four maps. The following Table 1 shows levels of scales, and Table 2 shows the different criteria with weights. Using the results of the questionnaire, the weight of each criterion was found according to past research. The weighted overlay map was created using the weighted overlay tool in ArcGIS. Then, using past literature, the classification risk map was created. Furthermore, the final map was created using ArcGIS based on the questionnaire survey results and past literature (Prasad *et al.*, 2011; Dias, Kalpitha and Wickramathilaka, 2022).

IDW spatial interpolation was used for visualizing the property damage locations and human death locations. The locations were obtained using a handheld GPS (Prakash, Wijeratne and Fernando, 2020). As shown in Table 3, high weight (60%) was given to human death locations, and low weight (40%) was given to damage to the physical properties. Since the value of human life damage is higher than property damage, 60% was given for human life damage and 40% for property damage. Also, these two weights were assigned by the past literatus, and divided into three categories: low risk, moderate risk, and high risk.

The accuracy of the results was checked using the confusion matrix and kappa coefficient. 160 random points were used for the validation of accuracy. The referenced data source and classified map were used to extract the errors of commission and omission, which were used to generate the confusion matrix. The confusion matrix is created using the random accuracy assessment points. Each class includes a measurement of user and producer accuracy as well as a kappa coefficient. This index ranges from 0 to 1, with 1 representing complete correctness (Hasara, Singhawansha, and Wickramathilaka, 2020).

For qualitative items, the inter-rater reliability is assessed using the static kappa coefficient. Because it accounts for the possibility of agreement occurring by chance, it is generally considered a more reliable measure than a simple percent agreement calculation. According to those values, > 0.75 = excellent, 0.40 - 0.75 = fair, and < 0.40 = poor (González Alonso and Pazmiño Santacruz, 2015; Hasara, Singhawansha and Wickramathilaka, 2020).

IV. RESULTS AND DISCUSSION

This chapter presents an overview of the results. In parallel, the results of the objectives of the study are discussed here.

Table 1. Scales assigned to the parameters

Criteria	Scale
1. Forest	
1. 0 - 50m	1
2. 50 - 500m	5
3. 500 - 1000m	3
4. >1000m	5
2. Cultivation	
1. Paddy Cultivation	5
2. Chena Cultivation	4
3. Other Cultivation	1
3. Tanks	
1. 0 - 50m	3
2. 50 - 1000m	5
3. 1000 - 2000m	4
4. >2000m	1
4. Corridor	
1. 0 - 50m	1
2. 50 - 500m	5
3. 500 - 1000m	4
4. >1000m	3

Table 2. Ranks assigned to the parameters

Criteria	Scale	Weight (%)
Forest	2	14
Cultivation	4	29
Tank	3	21
Corridor	5	36

Table 3. Given weights for human deaths and properties damages

Criteria	Weight (%)
Human death location	60
Property damage location	40

Table 4. The extended and area percentages of different regions.

Zone	Extend (Km^2)	Percentage
Low Risk	81.4059	43%
Moderate Risk	104.6520	55%
High Risk	4.8339	3%

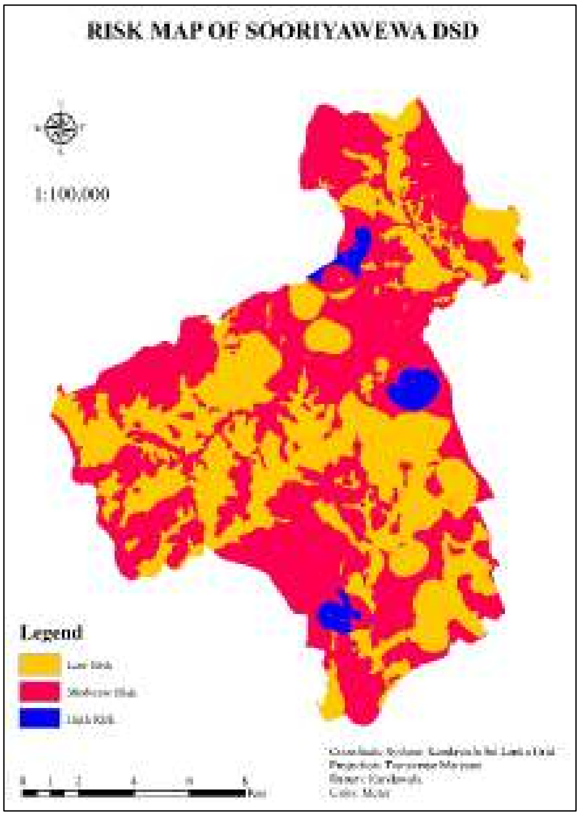

Figure 3. Final risk map of Sooriyawewa DSD

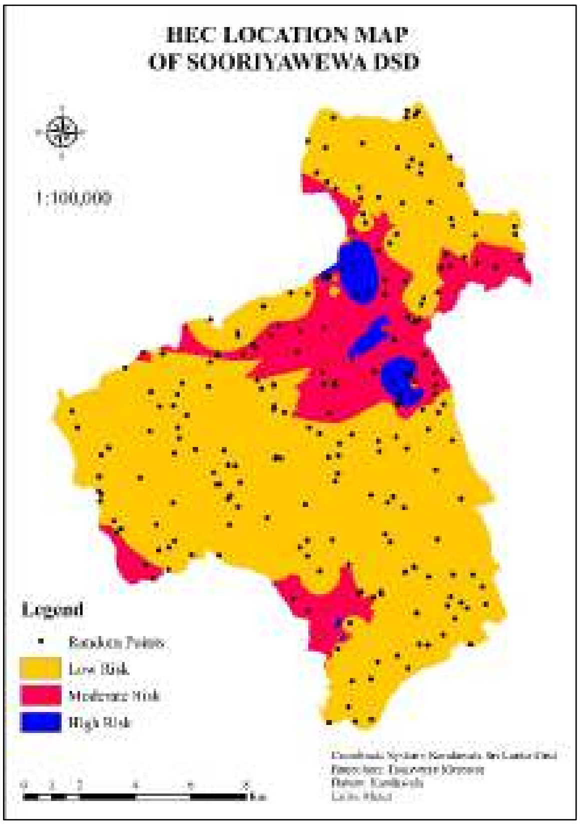

Figure 4. Elephant attack location-based map

The HEC was identified as a major hazard in Sooriyawewa DSD. These risk zones existed because of four factors: the locations of corridors, the distance to the elephant living forest, the locations of water tanks, and the type of cultivation. The final risk map was created by combining the ranges of the spatial data that affect the above-mentioned facts. Figure 3 shows the distribution of risk areas for HEC. The high-risk area is shown in blue color, and the low-risk area is in yellow. The moderate risk area is shown in red color. Table 4 shows the risky areas and percentages. Where 81 km^2 belongs to low-risk areas. It is 43% and 3% high-risk zone and is approximately 5 km^2. The high-risk area is smaller as a result of the study. But there is a very high likelihood that something will happen. Additionally, a larger region can indicate a safety area.

The accuracy assessment was performed using the confusion matrix method. As shown in Figure 4, the IDW interpolation map was divided into three parts, such as low-risk, modern-risk, and high-risk, by considering collected ground truth values like the locations of HEC (Woodcock and Gopal, 2000). The previous positions of the HEC are shown in Figure 4 as a base map with random points for accuracy evaluation. The values for user accuracy and producer accuracy are shown in Table 5, and the overall accuracy obtained is 81%. The Kappa coefficient measures the frequency agreement between two sets of data collected on two different occasions (Sim and Wright, 2005). In this study, the Kappa coefficient was 0.64. Thus, the range of the kappa coefficient had a fair level of agreement strength.

Table 5. Accuracy assessment

Zones	User Accuracy	Producer Accuracy
Low	84%	92%
Medium	77%	71%
High	75%	75%

As shown in Figure 5, buffer zones of 1 km were created. There, more risk directions have been propagated to the northeast, east, and south directions of Sooriyawewa city center. But no risk zone has extended westward from the city canter. The high-risk zone is indicated by the Andarawewa area, which is about 5 km from the city center. Also, Meghahajandara and Weliwawa areas show higher risk zones at a distance of 6 km. It also shows a small high-risk zone at a distance of 9 km in Habarattawala area. But moderate risk areas spread in all directions from the city canter. Some of those areas are Madunagala, Vadivewa, Weeriyagama, Hathporuwa, and Bediganthota.

V. CONCLUSION

This study mainly focuses on the identification of HEC risk areas in Sooriyawewa DSD. When determining the risk zones and creating raster maps for human and property damage, weighted overlay and IDW interpolation techniques were used. These results underline the need to employ spatial analysis and GIS technology to estimate the risk of HEC and pinpoint potential hotspots for

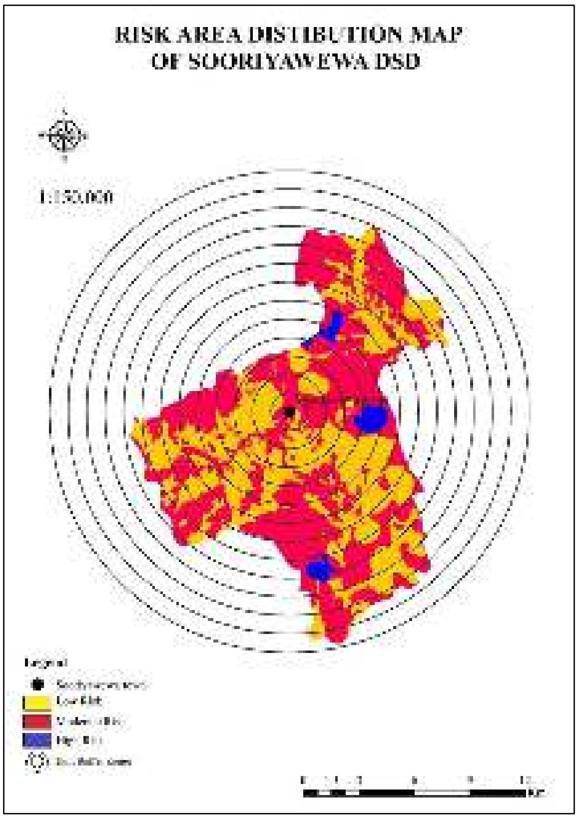

Figure 5. Risk area distribution from Sooriyawewa town

interventions to reduce human-elephant conflict. Meghahajandura, Weliwala, and Habaratta are grama niladari divisions that are located in areas at high risk for HEC. Those areas are close to the existing forests of Sooriyawewa DSD and have a high chance of accidents. Furthermore, this study has serious limitations and has significant implications for HEC. For example, the number of annual HECs depended on how many people received compensation. But some people who experienced an elephant attack that resulted in injury or property damage and didn't ask for compensation were left out of the current study. On the other hand, HEC is dependent on the climatic season of the year, but this study was unable to consider this. Furthermore, this study does not consider vulnerabilities like physical, social, or economic ones. The vulnerability presents the ability of people to be exposed to hazards. This study can be developed with the crop calendar designed for the study area. On the other hand, elephant habits change with climate change. Therefore, this study can be developed according to the weather. Accordingly, during the rainy season, elephants can find food in the forests. But during the dry season, elephants go to the villages due to a lack of food. Along with the development of Hambantota district, the city tends towards urbanization. If it is planned and uncontrolled, it will affect the entire society. Hence, the HEC increases significantly. Because development is destroying the habitats of wild elephants. This is very important for government authorities and planners in any region to quantify, map, and monitor the risk area to control the unintended consequences caused by HCE. Early identification of elephant-prone areas can reduce the consequences of indiscriminate and unplanned elephant and human casualties.

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