Human-Elephant Conflict and Mitigation Methods using Participatory Rural Appraisal Techniques: A Case Study of Kuda Bellankadawala and Kelegama Grama Niladari Divisions in Thambuttegama Divisional Secretariat Division

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Abstract

The land area of Sri Lanka constitutes 65,610 sq. km with a considerable range of forest conservation zones that are prone to human-elephant conflict (HEC) that has led to various social, economic, and environmental issues. The main objective of this study is to identify the key issues in human-elephant conflict and propose viable solutions for them using Participatory Rural Appraisal (PRA). Two key HEC prone areas have been selected for this study, namely Kuda Bellankadawala and Kelegama Gramaniladari Divisions (GND) in the Thambuttegama Divisional Secretariat. Both primary and secondary data sources have been utilized in data collection and data were mainly derived from information sources, particularly published on HEC incidents reported in the key areas. Primary data were collected using PRA methods, such as resources map, seasonal map, problem tree, and risk quadrant. It was found out from the PRA survey that HEC incidents from Kuda Bellankadawala and Kelegama divisions account for 41% and 56% respectively. In terms of damage evaluation, 70% of incidents account for property damages while 25% account for damages to cultivations. According to the HEC risk value calculation, 165.85 and 100.17 risk values were found in the Kuda Bellankadawala and Kelegama villages. The most commonly used methods for HEC damage control were elephant watch towers (85%) and firecrackers (70%) and the survey has revealed that elephant corridor methods are still not used for reducing of HECs in the study areas. It is expected that the findings of this study will be instrumental in the formulation and implementation of local-level policies for minimizing damages from HECs in Sri Lanka.

Keywords: Participatory Rural Appraisal, Seasonal Maps, Problem Tree, Risk Quadrant, Thambuttegama Divisional Secretariat Division

INTRODUCTION

The elephant is the biggest and most herbivorous animal on earth and they need 135–300 kg of food per day (Vancuylenberg, 1977, Sukumar,2003). According to animal experts, elephants are divided into two types, African elephant and Asian elephant. Asian elephants are classified into three species as E.m Maximus (Sri Lankan subspecies), E.m Indicus (Asian mainland subspecies), and E.m Sumatrans (Sumatran subspecies), according to their physical characteristics. The Sri Lankan elephant, scientifically known as Elephas maximus maximus, is one of the four subspecies of the Asian elephant species. According to the Red Data Book, Asian elephants are endangered (Perera, 2009).

The Asian elephants live in the tropical rainforests and monsoon forests in Asian countries namely, Sri Lanka, Bengal, Burma, Thailand, Laos, Vietnam, Cambodia, Malaysia, and China. Kempf and Santiapillai (2000), Sukumar, (2006), and Sukumar (1998) have done a study on the distribution of elephant population in the world. Consequently, the biggest population of Asian elephants has been found in India and the number is recorded as"25000 - 27000 and Sri Lanka is in the second place. The Forest Department has estimated that about 7,500 elephants are living in Sri Lanka. About 2,500 to 3,000 elephants also live in Myanmar. African elephants live in African countries. According to their biological differences, African elephants have been categorized mainly in two types as the forest elephant (Loxodonta Africana Cylotis) and the Savannah elephant (Loxodonta Africana Africana). They live in sub-Saharan Africa.

The Human-Elephant Conflict has become a major issue in Sri Lanka and India. (Sakumar,1998). The International Union for the Conservation of Nature and Natural Resources /

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IUCN (2001) defines the HEC as any human-elephant interaction which results in negative effects on a "human social, economic and the environment". This problem adversely affects both people and elephants (Nyhus et al.,2000). The IUCN reports that Asian elephants are threatened with extinction (Choudhury, 2008). A human-elephant conflict can be simply defined as the conflict between an elephant and humans. Elephants damage human settlements the lives, crops, cultivation areas, and kill humans. Although Elephants and humans have had a close relationship since time immemorial, many conflicts between these two parties are escalating today. Currently, about 21 million people are living in Sri Lanka. According to the current population growth rate, in 2025total will be 22.62million. By 1900, Sri Lanka had 70% forest coverage, but today that number has dropped to 29%. (Department of wildlife, 2018).

Simultaneously, the natural habitat of the elephant population in Sri Lanka has also declined significantly. Desai (1998) has described decreased elephant population in Sri Lanka under three stages. The first stage has been mentioned as the early part of the third quarter of the 1800s. Between 1853 -1872, approximately 2,500 elephants were exported (Deraniyagala, 1955). At that time, the elephant was domesticated as an export commodity. A second stage has been mentioned between 1870s and 1940. At this time in Sri Lanka, the plantation industry was expanded. This reason affected the declining elephant population in Sri Lanka. According to historical records, it has been estimated that between 1882 and 1878, about 2,000 elephants died in Sri Lanka. By mid-1887, that number had risen to "3,500". As the third stage current post-independent period has been mentioned by Desani. During this period had the development of dry zone areas that are in the East region of Sri Lanka has been targeted. The main development project in the region was the accelerated Mahaweli Development Program. Its main objective was to develop 2, 60,000 hectares of new land for agriculture using irrigation water. Due to this large-scale land use, changes took place in these areas. As a result, elephant habitats in these areas have been severely destroyed, and human-elephant conflicts have been created. Jayawardene (1998) noticed that HEC is a serious problem, particularly in unprotected areas of the Northwestern and Mahaweli regions in the country. During 2010 and 2019, 807 human deaths have been recorded while 579 people have been injured. The property damage caused amounts to 10532. Two thousand six hundred thirty-one elephant deaths have also been reported due to this human-elephant conflict. Most of the elephant deaths were recorded at the elephant's transit "route" which is located at the railway lines. The average human death rate owing to HEC in Sri Lanka has gone up by 50% in previous years (Fernando et al. 2011). The HEC is very common in dry zone and arid zone in Sri Lanka. The number of human and elephant deaths is very high in the North-Western, North Central, and Eastern Province. As well, the highest number of elephant deaths during this period was recorded in North Central (39%) province, and the second-highest number (26%) was recorded in the North-Western province (Haturusinghe, et al.2012). However, very few human and elephant deaths have been reported in the Sabaragamuwa and Central Provinces. Considering the HEC at the district level, it is very high in Anuradhapura, Ampara, and Polonnaruwa districts compared to other districts of Sri Lanka. The study area is located in the Thambuttegama Divisional Secretariat Division (DSD)of Anuradhapura district.

The Thambuttegama DSD is located between 8012'46.17" and 8010'55.71" North Latitudes and 800 26'05.06'' and 80039'27.18" East Longitudes and it consists of 117.48 sq km of land. The study area consists of 26 Grama Niladari Divisions (GND). The study area has Thalawa DSD from its North, Galgamuwa DSD from its South, and Rajanganaya DSD from its West. The landscape of the Thambuttegama DSD is very flat and nearly 50 small tanks are located in the area. Ballankadawala Wawa, Aluthwawa, and Thalakolawawa are the main tanks of the study area. Water is received to the main tanks from the Mahaweli Project. The total population is recorded as 51085. Eighty percent (80%) of the total population of the area is engaged in agriculture.

The main crop is paddy and chilies, soybeans, onions, and papayas are grown during the Yala and Maha seasons. Droughts, floods, and elephant conflict are major hazards in the study area. The estimated total population of Thambuttegama DS Division is 51,000. At present, more than 60% of the population is affected by human-elephant conflict. During the dry season, human-elephant conflicts are reported in Thabuththegama DS Division. Throughout this time comes the time of harvest. Since there is a dry climate at this time, elephants come out of the forest in search of food and water. In this case, the elephant is harming crops, property, and humans. During 2015-2020, three hundred (300) property damages, 25 human deaths, and 16 elephant deaths have been reported in the study area (Sampath Pathikada, 2020). Therefore, it is important to conduct this study to minimize the HEC in the study area and to find a solution for the future.

The main objective of this study is to focus on Human-Elephant vulnerability and the risk area and find out the best solutions for the HEC problem using Participatory Rural Appraisal methods (PRA). PRA is the most important method for rural base research that assists sharing, cross-fertilization, analysis, estimation, enhancement of livelihood, knowledge, and living conditions among key stakeholders (Bharat Sontakki et al., 2019). The Participatory Rural Appraisal method is a very popular data collection and analyzing method among social scientists, geographers, scientists, researchers, and planners (Dananjaya et al., 2019). This method helps to share the views of the rural people with others, to identify problems in the area, and to find solutions to them.

LITERATURE REVIEW

Several scientists have used different methods to measure and mitigate human-elephant conflicts around the world. Antoinette van de Water et al. (2018) evaluated the human-elephant conflict in western Thailand. They have used literature and questionnaires for their studies. This study has focused on socio-economic information and the potential of human-elephant conflict and strategies to mitigate them. These questions have been addressed to the people in the plantation sector. The questionnaires have been included socio-economic information of western Thailand and the impact of the human-elephant conflict.

Data analyzed using regression used SPSS 24 for evaluating socio-economic variables and attributes about elephant conservation in western Thailand. L. Jen Schaefer (2019) researched current management strategies and future directions based on the human-elephant conflict. The research identified safe areas and environmental corridors, electric fences and ditches, agriculturally based barriers, and early detection and warning methods as strategies that can be

used to prevent human-elephant conflict. The importance of the environmental corridor for the prevention of human-elephant conflict has been emphasized by Brown et al. (1977). Tobias Ochieng Nuumba et al. (2020) have examined the impacts of human-elephant conflict on human prosperity. The Masai Mara National Park in Kenya has been selected for this study. The group discussion methodology has been used by the researcher to meet the main objective of the study. Simple Sample techniques have been used for collecting data for the study. Household information was collected through a questionnaire. The researcher has sought to gather social, economic, demographic information and information on the human-elephant conflict in the study area through this questionnaire. This study measured the impact of human-elephant conflict. Probability score matching technology was used for this study. Looking at the results of this study, the elephants had had a significant impact on the well-being of the local communities in the study area. Therefore, the study has suggested the need to encourage conservation activities that will enhance wellbeing and mitigate the negative impact of HEC. Rakash et al. (2020) conducted a study on the pattern and extent of human-elephant conflict in Sri Lanka. The study covered 25 districts and collected data on human mortality, elephant depth, and other socio-economic information. Eighteen years of data were used for this study. Accordingly, the periods from 2010 to 2018 have been selected for this. The analytical variability (Anova) methodology was used to assess the significance of the variability of HEC related factors between months, districts, and genders, and is described using tables and maps. Maps are created using GIS software. The study found that human and elephant deaths were increased between the period 2018 and 2010. Santhiyapillai C. et al. (2010) has done extensive research on the human-elephant conflict in Sri Lanka. The main objective of this research is to evaluate the impacts of HEC in the South - East, North-Western, North- Central, Uva, and Eastern provinces of Sri Lanka. Relevant data has been collected through questionnaires selecting 100 villages randomly. The geographical coordinates of the selected villages were collected via the GPS unit. Nakandala et al. (2015) researched the detection of elephants using the sensor network system. The study used a digital camera, a PLC microcontroller, and a wireless communication module to identify elephant locations. In this study, the researcher hopes to reduce the human-elephant problem in Sri Lanka. The Literature on Rajapaksha et al. (2014) studied factors affecting the distribution of elephant's habitats in the Southern, Eastern, North, Central, and Mahaweli regions. Many techniques were used to analysis the elephant habitats. Wildlife region and habitat maps were created using a weighted overlay system, and elephant density surfaces were created using Kernel density method. A Poisson model was fitted to identify the relationship between elephant counts and habitat factors. Kriging model was used to find out elephant density and also the multinomial model was used for the discovery of the most significant environmental factors for the elephant habitat of the study area. Wijekoon et.al (2011) considered the spatial pattern of human-elephant conflict in Sri Lanka. The study identified the spatial pattern of the conflict and the identified hotspots and developed a plan to minimize human-elephant conflict. One hundred eighty-six villages in seven provinces were selected for the study. The judgment sampling method was used for the sample selection.

The literature by Roy Brouser (2006) has highlighted the human-elephant conflict and the rural poverty in Sri Lanka. This research paper indicated that conflict management methods can benefit elephants as well as the rural poor. Data was collected using four different methods, such as special expert interviews, spatial analysis using GIS, household surveys, and indeterminate assessments. A Geographical Information System has been used to identify the magnitude and intensity of human-elephant conflict in Sri Lanka at the national level. A study by Roy Browser (2006) shows that human-elephant conflict has always been high in the North-Western part of Sri Lanka due to severe deforestation. Girabola, Galnewa, Galgamuwa, Ehetuwewa, and Lunugamvehera are identified as areas viewing high levels of human-elephant conflict and poverty.

Ratnayake (2011) conducted a study on spatial distribution patterns of human-elephant conflict in Sri Lanka. The death, injury, and property damage by the elephants have been mapped using the Geographical Information Tool. The study concluded that these maps assist Sri Lankan administrative agencies in mitigating, recovering, responding, and preparing for the human-elephant conflict of Sri Lanka.

Gunaratne (2006) evaluated the effectiveness of electric fences in reducing human-elephant conflict in Sri Lanka. The questionnaire method has been used to collect relevant information. Socio-economic information before and after the construction of electric fences, land ownership, elephant behavior, death toll, property damage before and after the construction of electric fences, people's perceptions about electric fences have been collected through questionnaires. Although electric fences have made a positive contribution in reducing human-elephant conflict, studies have shown that they do not reduce human-elephant conflict as a whole.

Samaraweera et al. (2011) studied HEC in the Thanamalwila DS division. This data was collected through interviews and questionnaires. Kemf and Santiapillai (2000) studied elephant mortality in Sri Lanka. De Silva and Attapattu (1997) report human deaths caused by elephant attacks. Bandara et al. (2002) examined land use issues involved in the conservation of elephants in Sri Lanka. Kotagama (1977) studied important actions taken since the mid–1970 by the Department of Wildlife Conservation (DWC), the primary agency in charge of conservation in Sri Lanka, to mitigate HEC in affected areas. A large number of papers on human-elephant conflict and strategies have been reviewed by Shaffer et al. (2019). This was used only literature review for finding suitable strategies and solutions. Fernando et al. (2005) discussed insights and patterns of human-elephant conflict in Sri Lanka. Two settlements in the study area were selected for the study. For that, an old settlement and a new settlement were selected as the study area. This study mainly used questionnaires and surveys for the data collection of the study. The survey collected information on attitudes of humans about elephant trespassing onto villages and mitigation of conflicts, especially in the selected areas. This study has used the Participatory Rural Appraisal (PRA) method for finding solutions for the HEC of the study area.

Considering literature, many researchers have utilized questionnaires, interviews, spatial analysis using GIS and statistical methods to study human-elephant conflict. But the PRA method has not been used to address human-elephant conflict. Participatory Rural Appraisal (PRA) can be used as one of the popular and effective approaches to gathering information on the human-elephant conflict in rural areas of Sri Lanka. The PRA tools play a very significant role in analyzing non-spatial data. The application of PRA tools in analyzing the issues has greater potential to help to determine good

decision-making. The identification of the high risk, moderate risk, and no risk areas, types of land used, elephant routes, most appropriate areas for elephants, and identifying the mitigation methods can be done through the PRA tools and the results will be significantly helpful in decision making. Therefore, this study is very important for future studies of Sri Lanka.

METHODOLOGY

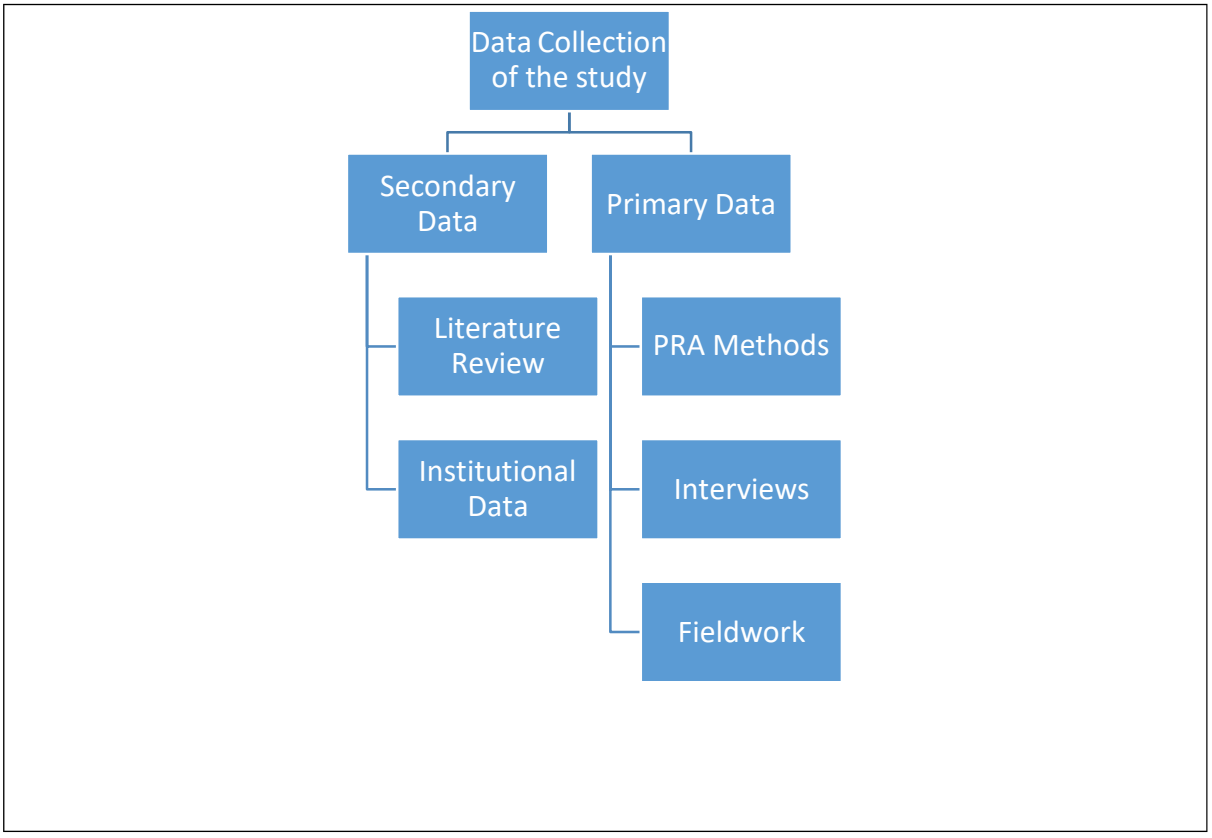
This study focuses on finding out human-elephant vulnerability and the risk in the Thambuttegama Divisional Secretariat Divisions. Data for this study was collected mainly using secondary and primary methods (Figurer 1.1). Secondary data was collected through reports and literature surveys and information on population, human death, elephant death, property damages, etc; was collected from the Department of wildlife, Sampathpathikada, and relevant reports.

Focus group interviews and field observation methods were used to collect primary data. This study focused on finding the human-elephant vulnerability and risk situation in the two Gramaniladari divisions (GN) namely Kuda Bellankadawala and Kelegama that were located in the Thambuttegama Divisional Secretariat Division. In addition, hazard map (resource map), risk quadrant, historical map, and problem tree were used to identify HEC vulnerability and risk of the study area. All these maps were created by selected villagers. Finally, HEC risk was calculated using the risk calculation method.

Field observations were important in collecting information about the human-elephant conflict of the study area. This method was used to identify elephant trails, crop and property damages, and elephant habitat areas. Photographs of some important places were taken, and they were used to show visual information about the real HEC situation in the study area. These sources of information assisted in clarifications and study of the factors by comparing the photographs.

The interview method was used to collect relevant information about HEC of the study area. Information was collected from 10 respondents, including GN officers, the Director of the disaster management center, offices of the agrarian development center, and farmers. The main objective was to get information about HEC of the study area such as HEC areas, social, economic, and human impacts, physical and man-made damages due to HEC in the two particular GN Divisions. Those areas were given distinct attention during these interviews.

Figure 1: Data collection methods of the study area



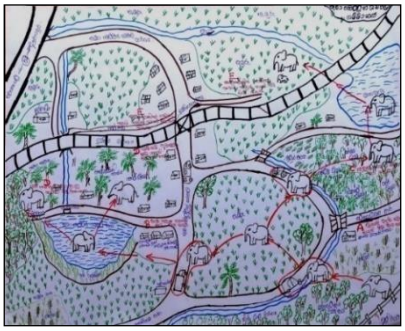
Hazard map of the study area

The hazard map can be described as one of the most important tools in the PRA method. A hazard map can be simply defined as a means by which the hazards in a particular location can be clearly represented. It provides a visual presentation of the study area containing HEC information. Hazard map has not been made to scale. But labels and symbols were used for describing different facilities, features, infrastructure, and HEC situations and vulnerability of the study area. Through this map, anyone will identify the spread of the human-elephant conflict and find solutions to prevent the damage caused by it.

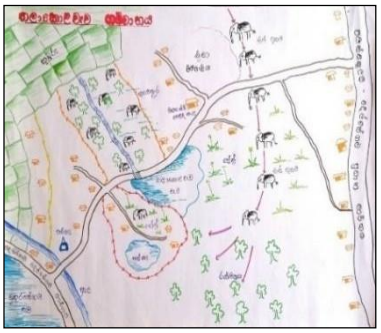
This map was produced by a team and has been described in that all physical and HEC vulnerability and risk information

of the study area. Two hundred fifty people have been selected from Kuda Bellankadawala (50), Sadagirigama (50), Kalegama (50), Phethiyagama (50), and Nawaganga Siripura (50) villages and they made separate hazard maps for each GN Division. Selected participants have mapped land and land use patterns, road information, settlement patterns, elephant corridors, water resources, forest areas, and strategies for minimizing human-elephant conflict and hazard zones on their hazard maps. They have made separate maps, as shown in figure 2.

Figure 2: Hazard map information of the Kuda Bellankadawala and Kelegama GN Divisions

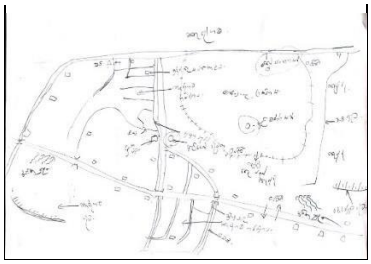


Kuda Bellankadawala Village

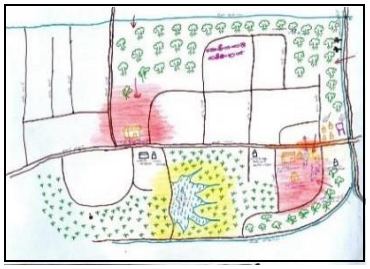


Thalakolawawa Village

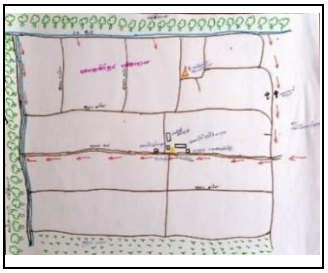
Sadagirigama Village



Kelegama Village



Pethiyagama village



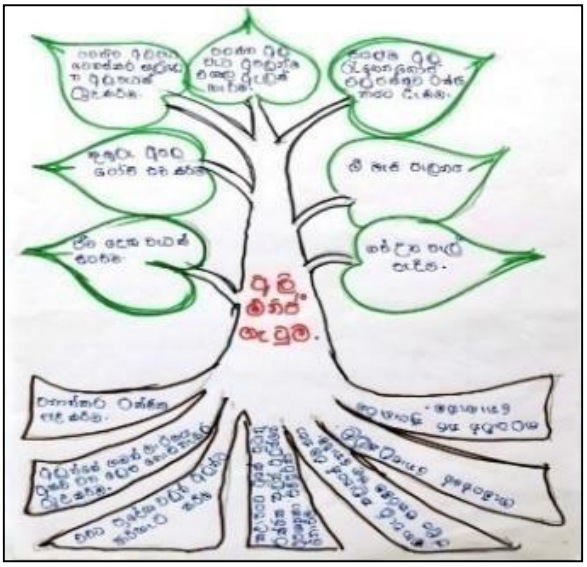
Nawaganga Siripura Village

Source: PRA Survey, 2020.

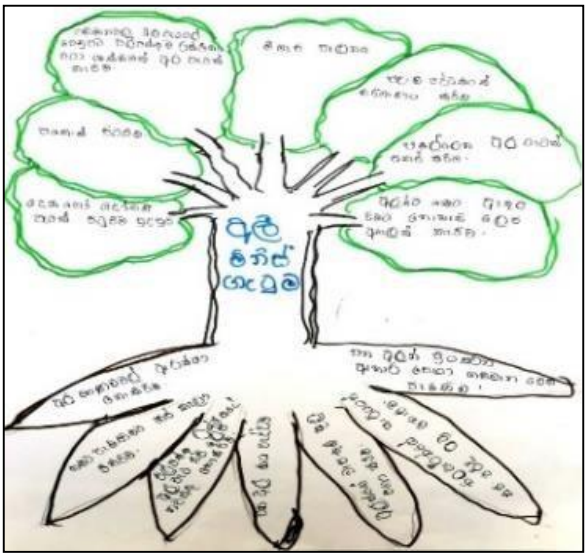
Problem Tree

The problem tree was used by the selected team to gather information related to HEC in the study area. The causes, solutions, and strategies of the human-elephant conflict have been identified by this problem tree. The completed problem trees of the study area are illustrated in figure 3.

Figure 3: Problem tree information of Kuda Bellankadawala and Kelegama GN Divisions



Kuda Bellankadawala Village



Thalakolawawa Village

Source: PRA Survey, (2020).

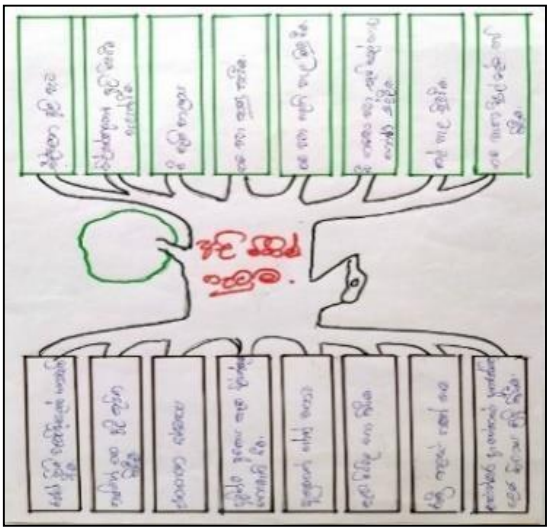
Seasonal Calendar

The study showed the hazard situation that occurred each month in the area. Accordingly, the seasonal patterns of hazards in the Kuda Bellankadawala village, Thalakolawawa, Sadagirigama village, Kelegama village, Pethiyagama village, and Nawa Gaganga Siripura village are shown in figure 4. Furthermore, the frequency of seasonal patterns of HEC in the study area is also shown.

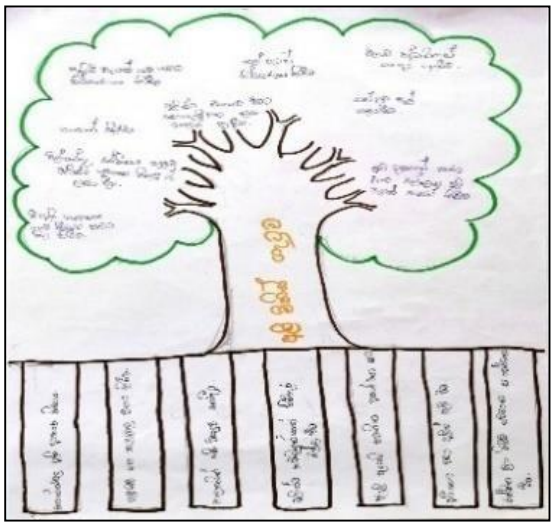
Risk Quadrant:

Risk Quadrant technology was used to study the probability of human-elephant conflict in the study area. HEC probability situations were collected under four categories, namely (figure 5). Low probability of occurrence low impact (LI) (bottom left), Low probability of occurrence high impact (HI) (top left box of the quadrant), High probability of occurrence low impact (LI) (bottom right box of the quadrant), and High probability of occurrence high impact (HI) (top right box of the quadrant).

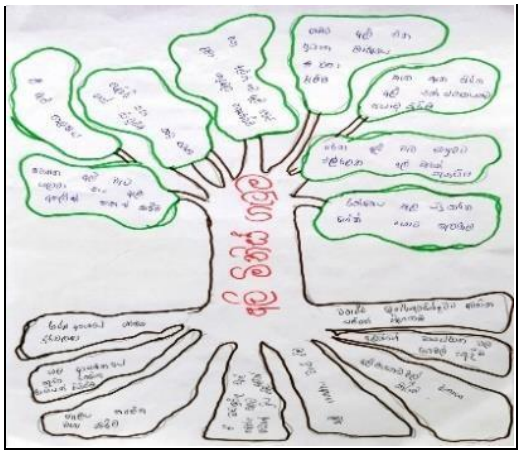
Figurer 4: Seasonal calendar information of the Kuda Bellankadawala and Kelegama GND.



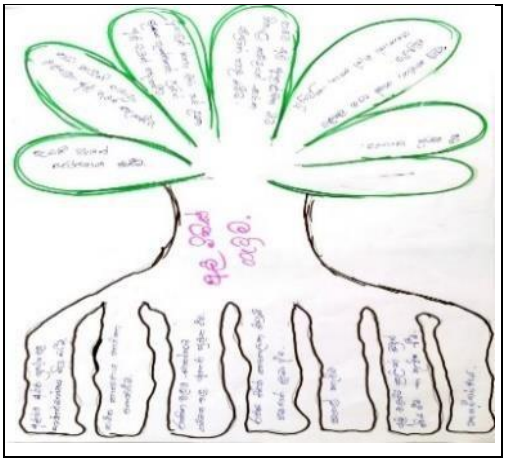
Sadagirigama Village



Kelegama Village



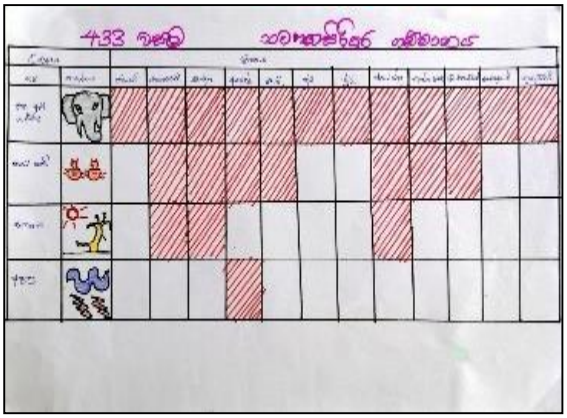
Pethiyagama village

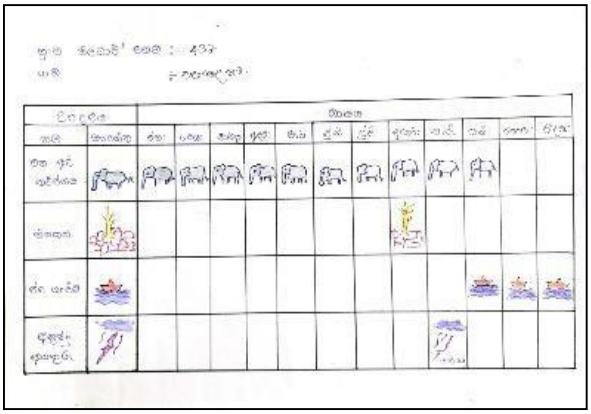


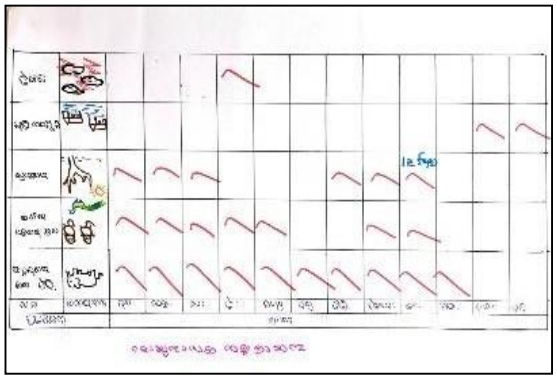
Nawaganga Siripura Village

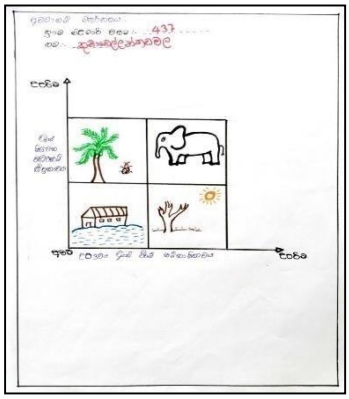
Source: PRA Survey, (2020).

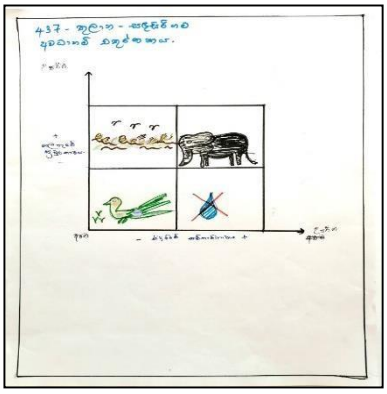
Figurer 5: HEC probability information of the Kuda Bellankadawala and Kelegama GND

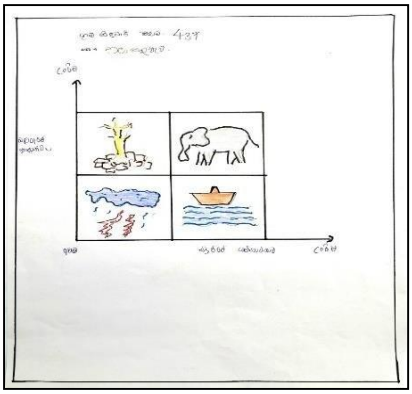












Source: PRA Survey, (2020).

Risk analysis

Risk indexes have been used for the analysis of human-elephant conflict risk in the study area. The formula is describing the following;

$$R = \frac{H \times V}{C}$$

R means risk, H means hazards, V means vulnerability, and C means capacity.

Using this formula, the risk of human-elephant conflict was analyzed in two GNDs, including all the villages. The hazard of HEC was calculated based on 10 years of incidents in the study area. The vulnerability of the human-elephant conflict was evaluated using the following parameters. Namely, number of houses located in 100m distance from the forest, number of disabled people, number of elderly people, and number of children less than 5 years, several clay houses, number of pregnant mothers, and number of houses without electricity. All these parameters were showing high-risk conditions in the study area. The following factors were used to identify the potential for human-elephant conflict in the study area. A scoring system was used for this. The factors and the allotted marks are as follows. Number of active elephant fences (Given marks 10), number of guns with the license (Given marks 02), number of village security guards (Given marks 05), types of quality roads (Given marks 05) (carpet roads, concrete roads, sand roads, etc) and number

of hospitals (Given marks 02). Relevant information was obtained from the community and the risk levels were calculated for each selected GND using the risk formula. Accordingly, high-risk areas of human-elephant conflict in the study area were identified. Geographic information systems (GIS) and SPSS techniques were used for the data analysis and visualizations of HEC information. The geographic information system can be defined as a set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a particular set of purposes. Burrough, 1986). Arc GIS 10.8 software was used for the visualization of the findings. This method is useful for future studies because it will be helpful in the development of planning and mitigating the HEC of the study area.

RESULTS AND DISCUSSIONS

The results of the study are explained under the following categories: Socio-Economic Information, Hazards, and Risk Reduction Methods.

Socio-Economic Information of the Kuda Bellankadawala and Kelegama GN Divisions

Kuda Bellankadawala GN Division consists of three villages, namely Kuda Bellankadawala, Sadagirigama and Thalakolawawa. The area of GN section of Kuda Bellankadawala is 3.32 square kilometers. According to the topography, the GN Division of Kuda Bellankadawala is located on a plane and 80% of those lands have been used for paddy cultivation. The total population of the Kuda Bellankadawala and Kelegama GN were estimated at 3735 (Sampath Pathikada, 2019, Thambuttegama DSD). As shown in Table 1, Thalakolawawa and Nawaganga Siripura villages have recorded 25 percent and 20.8 percent of the population, respectively.

Table 1: Total Population of the Kuda Bellankadawala GN Division

Name of the GN Division	Village Name	Total Family	Total Population	Total Population %
Kuda Bellankadawala GN Division	Kuda Bellankadawala	125	530	14.1
	Sadagirigama	155	646	17.0
	Thalakolawa	166	653	25.2
Kelegama GN Division	Kelegama	146	518	13.9
	Pethiyagama	184	614	16.4
	Nawaganga Siripura	225	774	20.8

Paddy cultivation is the main source of income in the field of study. In addition, people cultivate other mixed crops, such as chena and home gardening. But 5% are employed in education, public health, and other public sector jobs. The income levels of the people in the study area are relatively low. Sixty percent of PRA respondents said that their monthly income was less than 15,000 rupees. Sixty-two percent of women and 42 percent of men have participated in the PRA survey.

Analysis of HEC problem of the Kuda Bellankadawala and Kelegama GN Divisions.

The hazard, physical, and environmental conditions of the study area are clearly shown in Table 2.

Table 2: Hazard, physical, and environmental conditions of the study area

Village Name	Major cultivations %	Other cultivations	Number of Tanks	No, of elephant routes	No of railways	Main Hazards
Kudabelankadawala	Paddy 70%	30%	01	02	01	HEC
Sadagirigama	Paddy 80%	20%	01	03	01	HEC
Thalakolawa	Paddy 75%	25%	01	01	00	HEC floods
Kelegama	Paddy 60%	40%	01	02	01	HEC
Pethiyagama	Paddy65	35%	-	01	-	HEC
Nawaganga Siripura	Paddy 55%	45%	-	01	-	HEC

Source: PRA survey, 2020.

Table 2 confirms that the human-elephant problem is a major hazard in the study area. There are several potentials in study areas to increase human-elephant conflict. Tanks, railways, elephant roads, and canals are the main potential factors in the study area. Figure 5 describes the information in the risk square. Accordingly, it has described the probability of major hazards in the study area. Elephant attacks, droughts, and floods have been identified as major hazards in the study area. Risk has been categorized by participants according to the risk status and impact of the hazards. Accordingly, the human-elephant conflict has been identified as a major hazard of the study area. The seasonal calendar was used to analyze the events of the human-elephant conflict that occurred in the Kuda Bellankadawala GN division. The results reveal that the human-elephant conflict of the Kuda Bellenkadawala GN division is high in all the months. (Figure 4). This problem is most common during the months from January to March and from May to September. The risk of flood incidents is very low at the level of the Kuda Bellankadawala GN Division.

The problem tree analysis method has been used to find the causes and solutions to the human-elephant conflict in the GN section of Kuda Bellankadawala. Participants created the tree with these problems. Destruction of natural forests and

protected areas, altering of elephant routes due to construction of buildings, development of the Mahawali H Zone, negligence of the people, and shortcomings in government policies have been cited as the reasons for the human-elephant conflict in the area. These reasons are shown in Figure 3. The following proposals have been made to minimize human-elephant conflict in the study area. Construction of a hanging fence, construction of a moat near the suspended fence, relocation of all elephants to the Wilpattu reserve, installation of night lights in paddy fields, installation of bee control in villages, construction of biology, construction of fences and small huts on trees around farms.

High HEC hazards have been reported in the Sadagirigama village, and it is located at the Kuda Bellankadawala GN division. A small area of land has been used for chena cultivation. It has also been explained by people that the village of Sadagirigama has a good irrigation system. They mention that this irrigation system will supply water to several small tanks which are located in Sadagirigama village. In addition, the PRA map shows the settlement distribution of Sadagirigama village, and most of them are located on either side of the minor road of Sadagirigama village.

The PRA map shows the hazard situation in Sadagirigama village. This map shows that this village is at high risk of human-elephant conflict. They are further described using the seasonal calendar. The seasonal calendars show that the village of Sandagirigama faces human-elephant conflict every month. Furthermore, it is described using symbols. They point out that the main reason for the human-elephant conflict in the Sadagirigama village is the location of the Oruyaya forest. It covers an area of nearly 200 acres.

The PRA map shows four hazard zones. One hazard zone is located near Mr. Sunil's house. People who participated in the PRA survey said that this place is very dangerous as it is the main entrance to the village. People always pass through this place. The second hazard zone is located near the lake. They say that elephants often come and go through this place. There is a water shortage problem in Sandagirigama village. Therefore, the water of this lake meets the drinking and bathing needs of the people of this area. The third hazard zone is located near the railway line in Sandagirigama village. People said that the elephant had died when it was hit by a train on its way to the village from the forest. Also, risk analysis has pointed out the common hazards in Sandagirigama village. Meanwhile, the problem of peacocks has been identified as another menace in the Sandagirigama village. People said that peacocks would come to their fields and gardens and destroy their crops, especially in January, February and March.

Thalakola Wawa village is located in the Kuda Bellankadawala GN Division. The total population of this division was recorded at 1,821. It is reported that about 21% of the people in the study area have an income level between 25,000-50,000. Over 36% have electricity facilities in their permanent houses. According to the hazard map, this village is located near Padiyankulama main road. The PRA information revealed that the majority of people are engaged in agricultural activities in the area. Their main income source is paddy. Like the village of Sadagirigama, this village does not have a water shortage problem. However, the hazard map shows that the area is prone to floods during the rainy season. Human-elephant risk zones have been identified in the Talakola Wawa village. Forests, locations of lakes, paddy lands, and the main road have been identified as risk points in the village.

According to the risk quadrant analysis, high vulnerabilities of the human - elephant's conflict are found in Thalakola Wawa village. In addition, hazards like floods and droughts have been identified, but their risk is lower than the human-elephant conflict in the area. According to the seasonal calendar, human-elephant clashes have been reported in the village of Thalakola Wawa, except in November and December. The HEC problem is most prevalent in the villages of Kelegama and Pethiyagama. In addition, four elephant routes have been identified from the Nawaganga Siripura village. This is because this area is located in an isolated area away from other areas. Seventy-three percent (73%) of the participants have revealed their experience of the negative impact of HEC over the last five years of the study area. The most commonly identified types of negative impacts of the elephants were property damages (70%) and destroying cultivations (25%). Thirty-five percent (35%) of the participants declared that they saw elephants transitory by paddy fields, around the tanks and railway crossings, and other roads. All the PRA participants revealed that elephants would destroy crops such as bananas, mangoes, watermelons, corn, pumpkins, and sugarcane at least once a month.

Analysis of HEC risk of the Kuda Bellankadawala and Kelegama GN Divisions

According to the Risk Analysis Index, Kuda Bellankadawala and Kelegama GN divisions reported a high risk of HEC. The risk value was calculated using risk equations. The risk equation is described in Section 3.2. Thus, Table 3 shows all the risk information.

Table 3: Main characteristics of the HEC risk of the Kuda Bellankadawala and Kelegama GN Divisions

GN Name	No, of HEC Hazard incidents	No House distance 100m from the forest	Disable people	>60 years age people	< less than 5-year children	Pregnant ladies	Houses without electricity	Clay houses
Kuda Bellankadawala	41	105	19	135	189	70	13	11
Kelegama	53	127	17	175	111	57	34	08
Total	94	232	36	310	300	127	47	19

Source: PRA survey, 2020

Table 3 illustrates some of the main characteristics of the HEC risk of the Kuda Bellankadawala and Kelegama GN Divisions

It provides an overview of the HEC risk situation in the study area. Accordingly, 56% HEC hazard situation has been identified in the Kelegama GN division. Two hundred thirty-two houses are located within 100 meters of the forest of the Kuda Bellankadawala and Kelegama GN Divisions. It will support HEC problem to be increased in the Kuda Bellankadawala and Kelegama GN divisions. In addition, 300 adults over the age of 60 have been reported from the study area and 58% of them were recorded from the Kelegama GN division. Fifty-seven pregnant ladies have been recorded from the Kuda Bellankadawala GN division.

* Describe the scoring system: 10 marks for 1 electric fence, 2 marks for 1 licensed gun, 2 marks for 1 government house, 5 marks for security services, quality roads (3 marks for carpets, 3 marks for concrete roads, 2 marks for other roads, number of hospitals (within 3km- 5marks, more than 3km– 2marks)

The following formula was used for the evaluation of the HEC risk level of the Kudabelankadawala and Kelegama GN Divisions.

$$R = \frac{H \times V}{C}$$

Kudabelankadawala GND HEC risk = $\frac{41x\ 105+\ 19\ +135+\ 189+\ 70+13+11}{25+02+92+0+9+6}$

R-value is 165. 84.

Kelegama GND HEC risk = $\frac{53x\ (\ 127+\ 17+175+111+57+34+08)}{30+14+190+15+15+15}$

Kelegama GND HEC risk is 100.17

Accordingly, the HEC risk value of Kuda Bellankadawala village is 165.85 and the HEC risk value of Kelelama village is 100.17. Comparing the above two results, it appears that the Kuda Bellankadawala Grama Niladhari Division is at a higher risk of human-elephant conflict. The PRA survey has identified the following factors as contributing to the increase of human-elephant conflict in the Kuda Bellankadawala Grama Niladhari Division. They are the use of inappropriate methods by the government to reduce human-elephant conflict, people generating loud noises, population growth in the study area, agricultural activities being carried out around tanks, and illegal methods of chena cultivation and constructions around the forests.

Mitigation methods of HEC problem of the Kuda Bellankadawala and Kelegama GN Divisions

The Kuda Bellankadawala and Kelegama GN divisions have used short-term and long-term strategies to reduce human-elephant conflict. All utility methods and their efficiencies are described in Table 4. They have used various short-term and long-term strategies to prevent human-elephant conflicts in the study area. Table 4 states that the most common method used by PRA participants to prevent elephant poaching is elephant clock towers. Currently, eighty-five elephant clock tower systems are considered being the most effective. Seventy of the participants used fireworks, which are highly regarded for preventing elephants (79%) from using the area. Bio-fencing (20%), bee noise (3%), and cultivated chile (8%) were less effective but were considered moderately effective. People believe that the elephant does not like the sound of bees. People believe that chilli cultivation is another good way to reduce the HEC. They think chili damages elephants' nerves. So they do not want to come to Chilean growing areas. Also, they think that this crop will bring in extra income. Other methods used to reduce HEC in the study area include corrosion bags (30%), elephant corridors (0%), trenches (8%), and electric fences (25%).

Table 4: Human elephant mitigation methods and efficiency in Kuda Bellankadawala and Kelegama GN Divisions.

Long term & short term mitigation Methods	% using Methods	Efficiency		
		High	Medium	Low
Elephant watch-towers	85%	53%	35%	22%
Firecrackers	70%	79%	12%	09%
Flash-light	22%	87%	11%	2%
Noise	66%	35%	41%	24%
Bio- fencing	20%	33%	54%	13%
Beehive sounds	3%	6%	72%	22%
Cultivating chili	8%	4%	63%	33%
Hanging of the kerosene bags	30%	2%	28%	70%
Elephant corridors	0%	79%	10%	11%
Electric fencing	25%	49%	28%	No
Trench	2%	34%	20%	No

Source: PRA survey, 2020

CONCLUSION AND RECOMMENDATIONS

Human elephant conflict has become a major problem for many communities in the Thambuttegama DS division. The main aim of this study is to mitigate the human-elephant conflict and find the best solutions for the HEC using a Participatory Rural Appraisal (PRA). For this, Hazard map, seasonal calendar, problem tree, and risk quadrant methods were used to collect important information related to the human-elephant conflict of the study area. Study findings

based on these methods have recorded that Kuda Bellenkadawala GN was at high risk of human-elephant conflict. Also, this study found negative impacts of the human-elephant conflict of the Kuda Bellenkadawala and Kelegama GN divisions. Eighty percent of PRA participants said that their crops had been damaged by elephants, 58 percent said that their homes had been damaged, and 5% said that humans have died because of the elephants. Also, the study identified long-term and short-term mitigation methods such as elephant watch towers, firecrackers, flashlights, noise, bio–fencing, beehive sounds, elephant corridors, electric fencing, and trench. All these methods are very important for recovery, mitigation, response, and preparedness of the human-elephant conflict in the study area. In light of the above findings, it is recommended to demarcate buffer zone surrounding the high-risk areas, make awareness programmes, use improper electric fences, make the public as well as the political leadership aware of the issues related to mitigation aspects of HEC.

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