Community Base Vulnerability Mapping for Lightning Strikes in Sri Lanka

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ABSTRACT

Lightning is one of the oldest observed natural phenomena on earth. An average of 40 people dies every year due to lightning strikes in Sri Lanka. Persons who engage in outdoor activities such as farmers, heavy machinery operators and players are more vulnerable for lightning strikes. Human or animals live in unsafe partly covered shelters, particularly shelters with galvanized roof which trend for casualty of lightning strikes. Reported deaths and casualties due to lightning in rural areas by using electronic or electrical appliances in rural areas are more as compared to urban areas where mitigation mechanisms such as lightning protection systems are used for their residences, factories and offices. Not only that, geographical features like terrain, soil type (soil conductivity) also enhance the impacts of lightning. According to the latest statistics and surveys, it is revealed that the people who do not have proper shelters particularly with galvanized sheet roofs are more vulnerable for the lightning and it cause more causalities and deaths.

The aim of this study is to identify the vulnerabilities from the lightning due to different socio economic conditions (ie. to identify community base vulnerable area). Socio economic conditions reflect from their wealth, daily wage, living condition etc. Hazard areas were identified using the population density and the frequency of lightning Poverty index is the most appropriate factor to measure the socio economic conditions. Therefore, the poverty index is considered to be measured as a factor to find the vulnerabilities from the lightning.

Correlation has been done for the number of deaths and the causalities from lightning with the number of lightning days, population density and the poverty index. Hence identified the weighting factor of each for deaths and causalities and accordingly vulnerability maps have been developed by combining all these factors.

1 Introduction

Human and animal deaths and property damages are frequent in Sri Lanka due to lightning activities. 51 deaths were reported in 2011 and only 19 deaths were reported in 2013. There are less countrywide statistics on deaths due to lightning, but Disaster Management Centre (DMC), Sri Lanka is maintaining statistics for deaths and causalities from lightning in each district in Sri Lanka (www.desinventar.lk) since 1974. This was developed in collaboration with United Nations Development Agency (UNDP). Death and injuries statistics due to lightning are collected from newspapers, information from the Police, *Grama Niladari* (grass route level government officer in a village or area) and hospitals. This study is based on the existing statistical data.

In Sri Lanka more deaths and casualties due to lightning are reported during the evening or night, because climatologically, more lightning are occurred in the afternoon, evening or night. Figure 1 (Abhayasinghe, 1998) shows the climatology of lightning occurrence in Sri Lanka and it clearly indicates the most risk duration for the lightning hazards in the evening.

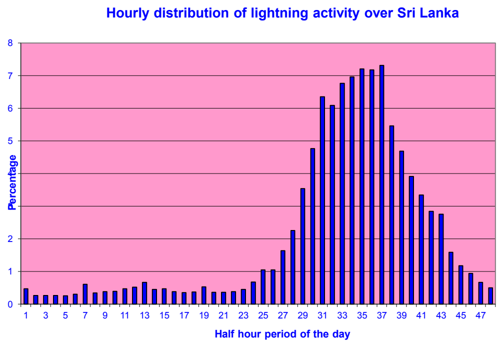

Figure 1 Lightning activity during a thunder day (Source : Abhayasinghe Bandara K.R)

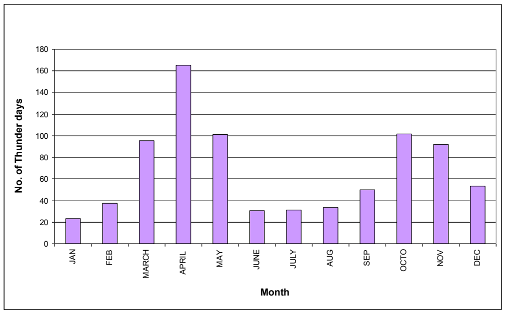

Figure 2 Average thunder days in Sri Lanka (1961-1990) (Source : Kumarasinghe.N)

Sri Lanka has four monsoon seasons , First Intermonsoon (March-April), Southwest Monsoon (May-September), Second Intermonsoon (October-November) and Northeast Monsoon (December – February). Figure 2 (Kumarasinghe, 2012) shows the average number of thunder days in each month. It clearly indicates that during two intermonsoon seasons, the probability of being a victim of lightning activity is high. There are two agricultural seasons in Sri Lanka namely, *Yala* from March to September and *Maha* from October to February. Farmers use rain water receives from the inter-monsoon seasons for their cultivation. They normally work until the evening. Therefore farmers are more prone to lightning strikes.

It is very common in Sri Lanka that, the rural people work in outdoors for their daily wages and the awareness about lightning hazards are less. Knowledge about precautionary measures for lightning strikes is less. Therefore, they continue their work even during the lightning. There is a habit especially among villagers, looking shelter under trees during showers with lightning. There are number of deaths and causalities and property damages due to improper earthing in their electrical systems. Knowledge on protection mechanisms is not much. Table 1 shows the reasons for casualties due to lightning strikes.
Identification of hazard areas and vulnerability areas with different socio economic conditions will be benefitted to decrease the death due to lightning, as the findings can be used to aware the people about more hazardous areas. Therefore this study is mainly focused to find out hazard and vulnerability area due to lightning.

No.	Reported Incident/Reasons	Year/Month	Location	No. of Deaths	No. of Causalities
1	While harvesting paddy in the evening	1997,April	Madawachchiya	2	11
2	While plucking tea leaves in the evening	1997, April	Kahaduwa	1	-
3	Looking shelter a large tree when raining, while a group of women collecting firewood	1998,October	Monaragala	5	-
4	A group of soldiers looking shelter a unsafe galvanized roof hut while raining after a march fast	2008, April	Minneriya	6	42

Table 1 Some examples of victims due to lightning strikes (Extracted from News Papers)

2 Vulnerability

2.1 Basic Components of Vulnerability

Vulnerability of communities due to disasters is defined in several ways. Generally, vulnerability of community is a measure of exposure to hazard. Chambers, 1989 defines vulnerability as exposure to contingencies and stress, and the difficulty of coping with these exposures. Adger, 1996 also identifies two components of vulnerability: the effects that an event may have on humans (referred to as capacity or social vulnerability), and the risk that such an event may occur (referred to as exposure). IPCC, 2001 defined as "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Also chapter 18 of IPCC, 2001 stated that vulnerability to climate change and climate variability is a function of exposure and adaptive capacity. Therefore it depends on the community and their socio economic conditions etc. Thus, vulnerability refers to both internal and external dimensions. The internal dimension relates to defenselessness and insecurity, as well as the capacity to anticipate, cope with, resist, and recover from the impacts of a hazard. The external dimension involves exposure to risks and shocks. Furthermore, Bohle, 2001 developed a conceptual framework of vulnerability named the "double structure of vulnerability," which comprises exposure and coping. However, measure of vulnerability is different for different hazards, but proper selection of adaptive capacities for the hazard is important to develop skillful vulnerability map. Figure 3 shows the flow diagram for the disaster, hazard and vulnerability. There may be more than one external factor which is in-cooperated in different weights for the vulnerability. Therefore, it is important to select better weight in each external factor to develop vulnerabilities. After introducing weighting factors, the outputs are standardized for comparison. Based on the method in the United Nations Development Programme (UNDP)'s Human Development Index (UNDP, 2002), all the variables in the vulnerability indices are normalized to a range of 0 to 100. The values of each variable are normalized to the range of values in the data set by applying the following general formula:

Normalized = ((X – Minimum)/ (Maximum – Minimum))* 100 **(1)**

X – Value to be normalized
Minimum – Minimum Value of the data series
Maximum – Maximum Value of the data series

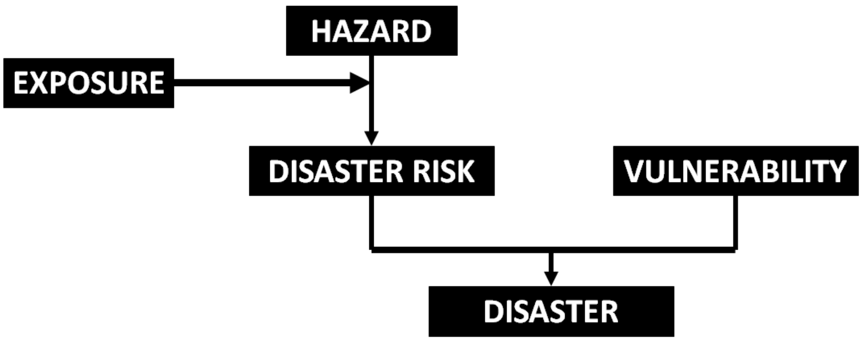

Figure 3: Schematic diagram for the Disaster, Hazard and Vulnerability

2.2 Importance of the vulnerability maps

The importance of basic vulnerability maps, help to reduce disasters. This is illustrated in figure 4 and 5. Even though a hazard cannot be stopped, there is a possibility of minimizing disaster associated with the hazard by reducing the vulnerability.

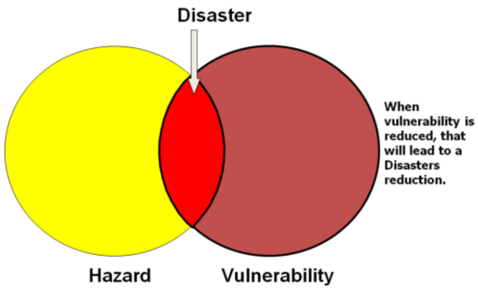

Figure 4 Disaster occurs due to a hazard incorporated with vulnerability

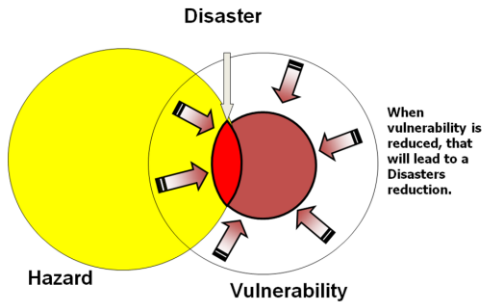

Figure 5 Less disaster for less vulnerability

Number of people in the hazard area are directly impact for hazards. In this study, population density is taken as the sensitivity feature of lightning and the poverty index is selected as the adaptive capacity for this study. Disaster can be minimized with the low population density and vulnerability can be reduced by introducing proper adaptive capacity according to the flow chart shown in the figure 3. Population density cannot be reduced at once, but poverty can be reduced by providing better socio economic conditions such as education for the people, good shelters, more awareness etc. Therefore population densities in each districts and the poverty indices are taken as inputs to compute vulnerably indices.

3 Data and Methodology

Department of Meteorology, Sri Lanka observes climatological data in 23 meteorological stations representing several districts. Three (3) hourly observations are done and observed lightning data are archived in hard copies. Data are extracted and analyzed monthly basis. Hence average number of lightning days has been calculated in each available district. Figure 6 shows the meteorological observation network and figure 7 shows the average number of lightning days for the period of 1961-2010. It can be shown that there is no meteorological office located in some districts in Sri Lanka. Therefore number of thunder days is interpolated using the *Krigging* technique. Hence the average number of thunder days in each district is shown in the Figure 7.

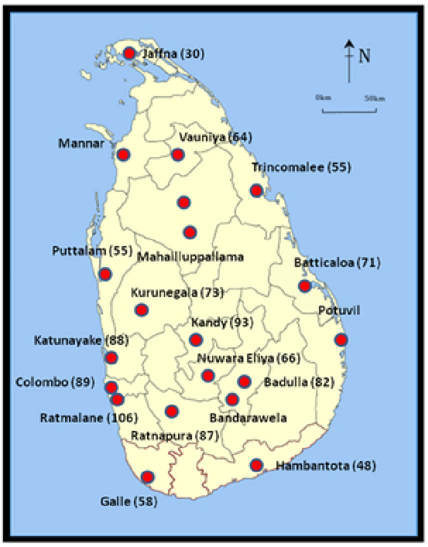

Figure 6 Meteorological observation network and the annual average number of lightning

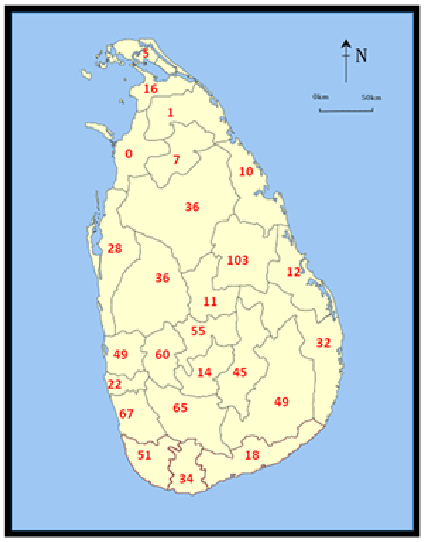

Figure 7 District annual average number of lightning days (interpolated)

Number of deaths and the causalities due to lightning strikes since 1974 were downloaded from www.desinventar.lk and shown in the figure 8.

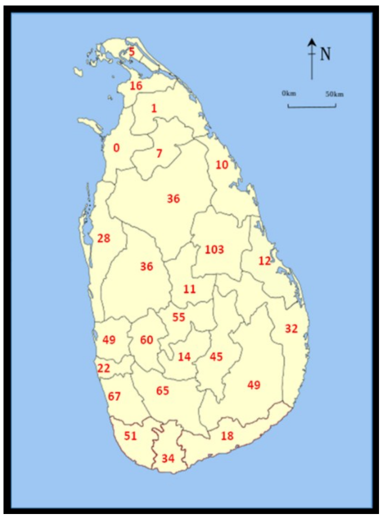

Fig. 8 Total Number of Deaths and Casualties in Each District (Source : www.desinventar.lk)

It is important to find a correlation between death and causalities due to lightning strikes and the lightning climatology. Therefore simple comparison has been done for the deaths and casualties with the average number of lightning reported in each district. Figure 9 shows the behavior of deaths and causalities due to lightning.

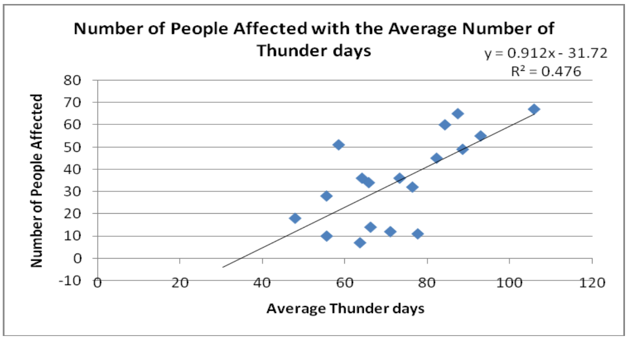

Fig 9: Relation between average thunder days and death and casualties

Average number of causalities are highly correlated with the number of thunder days (CC=0.476).

As explained in the introduction, the number of deaths and causalities due to lightning also depend on the population density and the poverty index. Population statistics of year 2012 published by Censors and Statistics Department in Sri Lanka were used for this study. Poverty of the people change rapidly and also it is not changing linearly. Therefore, the average poverty index for the period 1991-2010, available in the Censors and Statistic Department, Sri Lanka was used for the analysis. Figure 10 shows the relation between number of causalities and population densities in each district. It is clearly noticed that less correlation exits between the causalities and population density. The existence of some outliers (Polonnaruwa) may be the reason for the number of deaths and casualties. People in developed areas such as Colombo and Gampaha are much aware on lightning hazards and precautionary methods. Lightning protection mechanisms are used in certain extent in these developed districts may be due to income level. Therefore the number of deaths and casualties in districts like Colombo and Gampaha can be categorized as outliers. According to the available data it was found that 52 causalities (nearly 50% of the causalities and deaths for the period are reported in one day in Polonnaruwa and no deaths and casualties reported in Mannar district. These are extreme cases, hence they also can be categorized as outliers. Hence correlation has done for the other 21 districts. Accordingly, the modified graph for the behavior of number of deaths and casualties with the average number of lightning data is shown in the Figure 11. It can be shown that the correlation between those two are significant and the correlation coefficient is 0.391

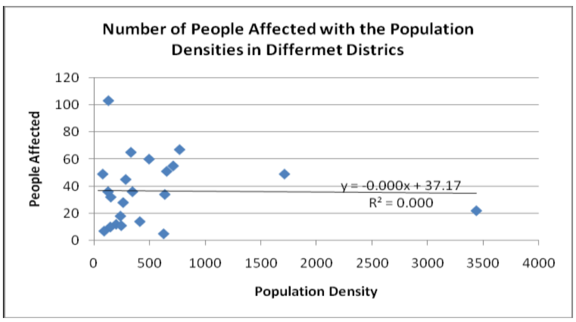

Fig. 10: Relation between average thunder days and death and casualties with outliers

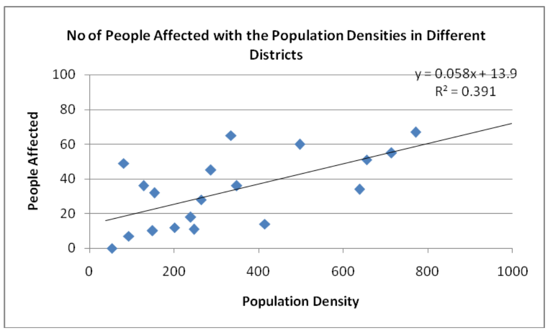

Fig. 11: Relation between average thunder days and death and casualties without outliers

Behavior of casualties and deaths due to lightning with poverty indices in each district is shown in the Figure 12. It also shows a slight correlation (CC=0.232). (Poverty indices are not available in, Mullative, Killinochchi and Mannar districts due to the prevailed war situation in those areas during that period).

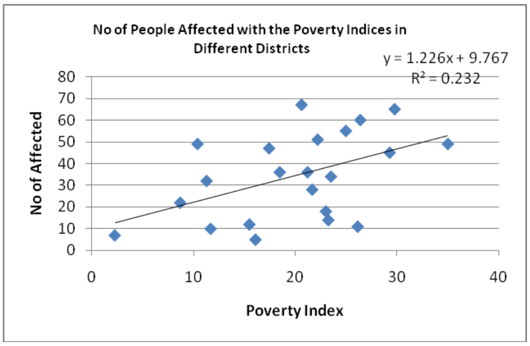

Figure 12 Relation between average number affected people with the poverty index density

It can be seen that the correlation of death and casualties due to lightning to the population density and the poverty indices are 0.391 and 0.232 respectively. It was found that all the factors considered for mapping vulnerabilities are correlated to some extend with the casualties and deaths due to lightning. However, the combination of number of lightning or thunder days with the population density and the poverty indices are important, because the aim of the study is to find community vulnerability to the lightning. Therefore, a better correlation can be found if number of thunder days, population density and the poverty index are combined and develop a multiple regression.

The regression equation for the number of affected people due to the population density and the number of lightning days is (Equation 2)

(Number of Affected People) = - 31.5 + 0.788 (Number of Lightning Days)+ 0.275 (Population Density) (2)

(Correlation coefficient is 0.644 and the Probability Value is 0.011)
This refers the possibility of disaster if there is no adaptive capacity. It can be referred as index for the disaster (disaster index) according to the flow chart given in Figure 3. Therefore, to compute disaster indices, weighting factors are considered as 0.2 for the population density and the 0.8 for the number of lightning days.

To find the vulnerability, poverty index should be in co-operated and hence the regression equation for the Number of affected people with population density, poverty index and number of lightning days are shown in the equation 3

(Number of Affected People) = - 35.4 + 0.673 (Number of Lightning Days) + 0.209 (PopulationDensity) + 0.699 (Poverty Index) (3)
(Correlation Coefficient is 0.634 and the probability value is 0.020)
This refers the vulnerability index according to the flow chart given in Figure 3. According to the equation 3, number of lightning days and poverty indices show equal weight and hence weighting factors are considered as 0.3 for the Number of Lightning days and Poverty Index. Weighting factor given to the Population Density is 0.2.
(Note: weighting factors are considered according to the coefficient of variables as poverty index etc.)

4 Calculation of Hazard, Vulnerability and the Results

Hazard and Vulnerability indices were calculated according to the weighting factors found using the regression equations for the number of lightning days, poverty index and the population density. Number of lightning days and population densities were considered to identify the hazard area and the indices were calculated using the weighting factors mentioned under the equation 2 and the results were normalized according to the UNDP, 2002 definition showed in the equation 1. The results are shown in the Figure 13.

Adaptive capacity was taken as poverty index for this study because it reflects many socio economic conditions. Therefore vulnerability indices were calculated using the weighting factors mentioned under the equation 3 and the results were normalized as above. The map of the Vulnerability indices is shown in the figures 14.

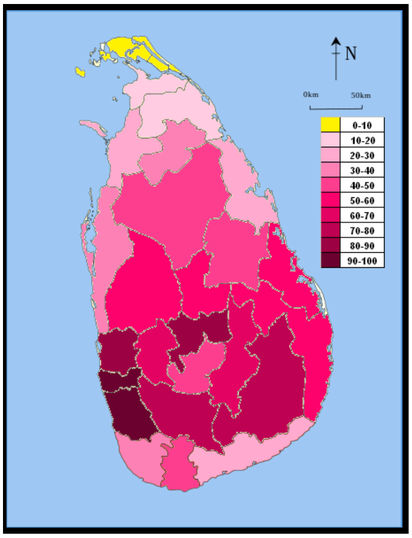

Figure13 : Disaster Index

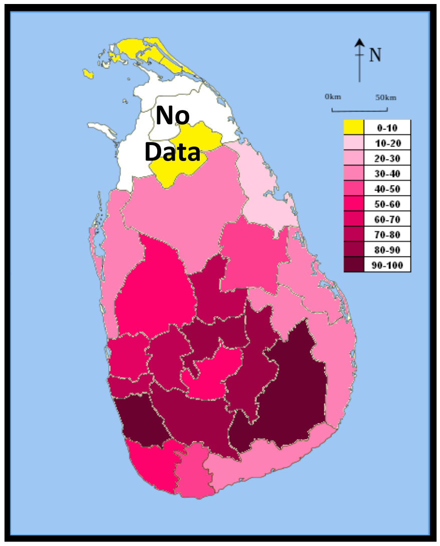

Figure 14: Vulnerability Index

Disaster Indices and Vulnerability indices in each district were graphed as shown in the Figure 15 and Figure16 respectively, for the convenience.

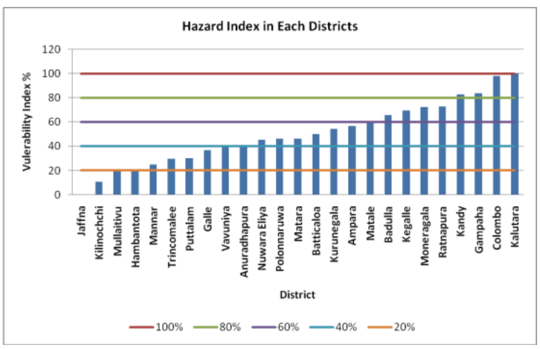

Figure15 : Disaster Index

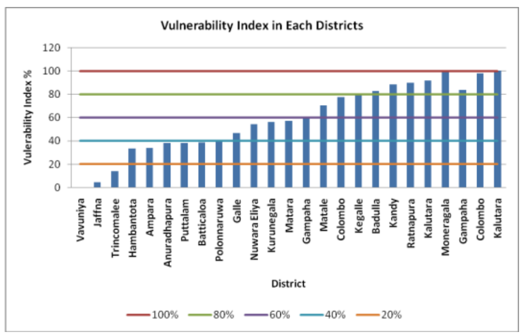

Figure16 : Vulnerability Index

5 Conclusion and Discussion

It can be found that more disaster areas are confined in the south western part of Sri Lanka. Out of those, Kalutara and Gampaha areas are the highest disastrous areas. Main reason for such situation is higher number of lightning days. Even though the highest number of population is in Colombo district, it categorized as the second highest for the disaster for lightning. Northern part of Sri Lanka shows the lowest disaster zones to the lightning strikes.

According to the statistics, highest poverty index is reported from Monaragala district. Even though the population is less, the vulnerability is much higher compared with the neighboring districts.

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