Assess the Level of Vulnerability to Climate Induced Disasters in Sri Lankan Coastal Areas: An Application of Open Source Geographic Information System

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Abstract
Sri Lankan cities have faced severe impacts of climate change over past years. Past records of daily temperature and rainfall data reveal significant changes of temperature and rainfall patterns during last two decades. Identification of level of vulnerability plays an important role in decision making process. Local and national level institutions in Sri Lanka face difficulties due to unavailability of cost effective methods for identifying these vulnerable areas. This paper presents a cost effective method to assess the level of vulnerability for climate induced disasters applying open source GIS (Geographic Information System) and AHP (Analytical Hierarchical Process). Open source GIS is growing in its use as a viable alternative to commercial GIS. AHP, the technique used to calculate the weights based on the vulnerability of each climate induced disaster on key sector groupings considered critical for national development. Result showed that Negambo, Batticoloa, Mundalama, Kalpitiya, Tangalle and Ambalantota are the DSDs (Divisional Secretariat Divisions) with highest level of vulnerability.

1. Introduction

"As a developing country; Sri Lanka, with a tropical climate pattern, has higher vulnerability for climate change impacts in extreme weather conditions such as high intensity of rainfall or extreme dry periods on unpredicted or unexpected periods of the year. Some of the cities in the country have already being experiencing the impacts of climate change specially which are located at the coastal region of Sri Lanka. As an island country, the coastal areas itself is an important environmental as well as economic resource to the country." Temperature data of past years, rainfall analyses reveal strong trend of changes and their impacts that cities are experiencing is clearly seen. (Bandara et al., 2013). While identifying these changes, their impacts and the magnitude of the problem, the need of adaptation measures to minimize the impacts of such natural disasters has arisen. Adaptation measures vary with the situation and the level of vulnerability of each location. Assessing the level of vulnerability is considered as a critical element in planning development activities. Identification of level of vulnerability would emphasize the precedent need in including climate change adaptation actions such as resource allocation, capacity development etc. for each sector to reduce the effect of vulnerability to climate induced disasters in the process of decision making. The term Disaster Management includes all these minor details in terms of urban planning perception. 'Disaster management is a multi-disciplinary activity. The most fundamental asset is the data itself that needs to be shared between different actors' (Aydinoglu and Bilgin, 2015). Actors basically include service providers, receivers, decision makers, officials engaged in disaster management etc. Sharing of real and accurate geospatial data on time is important in disaster management. Local Authorities (LA) have to face difficulties in access to accurate and updated database that has to be analyzed whilst making decisions. Many decisions need geospatial information and a GIS support for analyzing these information. To analyze natural disaster situations which are spatial phenomenon, use and application of geospatial information technology becomes a necessity. Geospatial information management and analysis play a crucial role in the various stages of the policy-cycle: identifying the agenda of a public entity (problem identification), setting policy objectives and formulating measures to be taken, implementing policy measures and finally monitoring and evaluating with the aim of assessing whether the measures taken are implemented and leading to the desired results (INTOSAI Professional Standards Committee , n.d.). However, in developing

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countries there are numerous barriers for effective use of geospatial information technology, especially at local level, including limited financial and human resources and a lack of critical spatial data required to support geospatial information technology use to improve disaster management related decision making processes (Herold and Sawada, 2012). Open source GIS development has been inspired by the increase of computer capacity (for storing and handling data) and increasing number of users. With the development, further its user friendliness has more and more improved. Open source software has also proven highly reliable as well, thanks to the continuing efforts of the programming community that develops it. Although free software provides unprecedented flexibility, stability, and freedom of choice, various distributions tend to compete and imitate one another. Camara and Fonseca (2007) identifies in their study that, open source software (OSS) is a good strategy to bring information and communication technologies to developing countries. "The open source process has the potential to empower developing country end users to customize applications for the very particular needs that often arise in different settings, and allows, through use, the natural evolution of information technologies and systems within unique and specific contexts" (Weber, 2003). Apart from that, many governments around the world have begun to consider the use of open source software as a key part of their strategic thrust in information technology, requiring that its use be considered when it provides a feasible alternative to proprietary software. Developing countries in particular, with the resource constraints they face, view OSS as a means of reducing the cost of IT investment and increasing its productivity (Weber, 2003). As a developing country, Sri Lanka too faces resource constraints in the field of Information Technology, especially regarding government sector. Although numerous proprietary software packages are in use, it is rare to find these institutions using Free and Open Source Software. Lack of awareness on countless advantages that one can get, has become the reason for the limited use of OSS in Sri Lankan context. Local Authority is the bottom level main service delivery body in Sri Lanka. Identification of level of vulnerability to climate induced disasters has become a key consideration under disaster management in present decision making and development plan preparation at local level. Although it has identified as a key consideration, Local Authorities are lacking the resources and technical requirements as they face difficulties in allocating financial resources for such analyses. Consequently, there comes a need of cost effective method for such institutions to fulfill their requirement. The objective of this study is to introduce the use of FOSS at a crucial point of disaster management in relation to urban planning and decision making. It proposes the application of FOSS in identifying the level of vulnerability which provides a cost effective methodology for those who face resource constraints.

2. Methodology

Level of vulnerability is calculated for coastal urban areas of Sri Lanka since coastal urban areas are considered as the most vulnerable areas for climate induced disasters. Coastal urban areas of Sri Lanka occupies about 3/4 of Sri Lanka's urban population and 80% of economic infrastructure networks. Both urban disasters and environmental hot spots are already located disproportionately in low-lying coastal areas (Pelling 2003). Further, 'the coastal zone accounts for 43% of the nation's GDP (Disaster management Centre, 2010 cited in Sector Vulnerability Profile, 2010). Thus, coastal Divisional Secretariat Divisions of Sri Lanka are subjected to select as the case study area of this study. Since Local Authorities are the main service delivery body at the bottom level, they are dealing with people, data and hardware. Using different tools, techniques with the knowledge we have this study proposes a methodology to analyze the level of vulnerability. AHP and GIS are the main tools and techniques used here. Identification of key sector groupings considered critical for national development and climate induced disasters, it was done based on a study carried out by Ministry of Environment, Sri Lanka. AHP was used to calculate the weight for each sector vulnerability to climate induced disasters and the calculated weight was assigned spatially by using GIS. Required data on above mentioned key sectors were as arranged based on exposure to climate change vulnerability of each different sector. To determine the weight of each sector, they are compared together in a 1-9 ordinal scale as depicts in Table 1. This weight factor is determined based on collected opinions of professionals in each relevant field. A sample of 50 professionals were engaged in this task. Selected number of professionals regarding their field of expert is shown in Table 2. Based on publicly available data sources, sector specific vulnerability index for each sector was identified. Vulnerable areas have been classified according to the type of vulnerability under five categories.

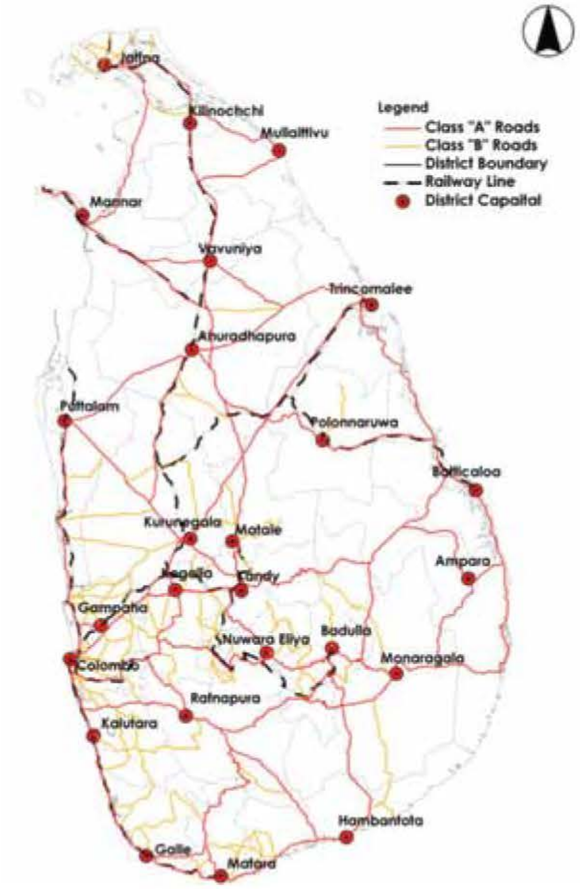

Figure 1: Road network of Sri Lanka – Source: National Physical Planning Policy and Plan

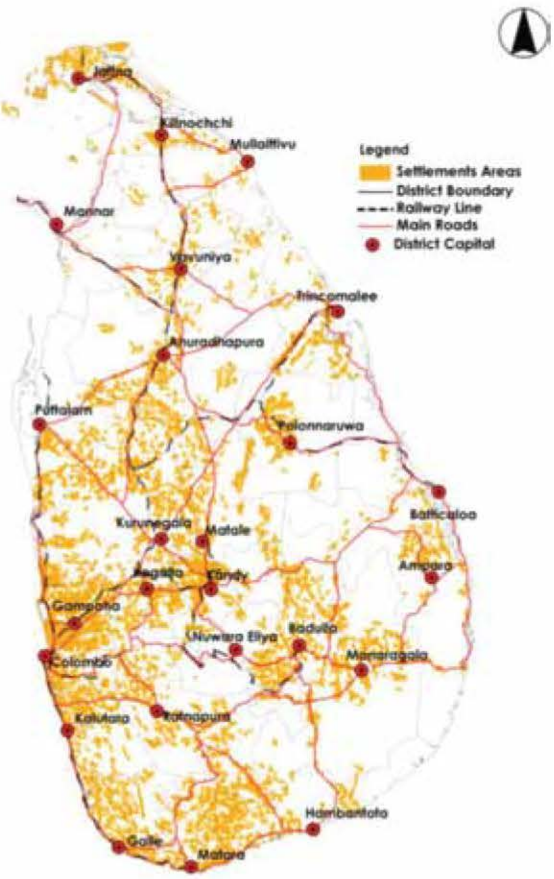

Figure 2: Settlement pattern of Sri Lanka– Source: National Physical Planning Policy and

Figure 3: Conceptual diagram of integrating people, knowledge and technology

Table 1: Nine level scale for binary comparison of different factors

Importance	Weight
1	equal weight
2	equal – moderate
3	moderate
4	moderate – strong
5	strong
6	strong-very strong
7	very strong
8	very strong- extremely strong
9	extremely strong

Table 2: Selected Professionals regarding their field of expert

Experts Area	No of participants
Urban Planning	10
Housing	8
Transport Planning & Engineering	7
Disaster Management	10
Agriculture & Livestock	8
Tourism	7
Total	**50**

Table 3: Summary Results of Pair-wise comparison on climate exaggerated disasters

Factors	Drought	Flood	Landslide Exposure	Sea Level Rise
Drought	1.00	0.20	3.00	5.00
Flood	5.00	1.00	3.00	7.00
Landslide Exposure	0.33	0.33	1.00	3.00
Sea Level Rise	0.20	0.14	0.33	1.00
Total	**6.53**	**1.68**	**7.33**	**16.00**

1-9 sectoral ordinal scale has been used to measure the pair-wise comparison of climate induced disasters. Pair-wise comparison has done on Sector as same as the climate induced disasters analysis. Values were assigned based on expert's opinion and supervision. Table 3 shows the results of Pair-wise comparison on climate induced disasters. Then, Normalized Percentage of Climate Induced Disasters (NPCID) is calculated and it is multiplied by Normalized Percentage of Sector (NPS) to identify the priority and to calculate the weighted value of the factors. Further, to calculate the weight value (Wi) it has been converted into percentage. Calculated weight values for each sector under climate induced disasters were assigned to DSD's. Resulted 36 layers and weighted values are shown in Table 4. Although it is important to determine the sector specific vulnerability, decision making in disaster management is largely depend on one specific vulnerability index for a selected area. These 36 layers are combined together and overlapped using QGIS. Spatial representation of this index determines the attention which needs to be paid in disaster management and it is an important and effective way of identifying the level of vulnerability in decision making process comparing different geographic locations. QGIS is an open source Geospatial platform which allows the user all the available facilities and tools as same as the commercial GIS platforms. The purpose and the objective of this study is to introduce an user friendly, easily accessible and cost effective methodology for Local Authorities to use by their own without having a expertise knowledge or technical assistance by outside parties.

3. Result

The resulted output map shows the most and least vulnerable DSDs along the coastline. Resulted final map (Figure 4) shows the level of vulnerability of Sri Lankan Coastal DSDs to climate exaggerated disasters. Analyses revealed that Negambo, Batticalo, Mundalama, Kalpitiya, Tangalle and Ambalantota DSDs showed very high level of vulnerability compared to other DSDs.

Table 4: Resulted 36 layers and weighted values

Layer Number	Layer Name	Weight Value
1.	Human Settlements Sector Vulnerability to Drought Exposure	6%
2.	Human Settlements Sector Vulnerability to Flood Exposure	8%
3.	Human Settlements Sector Vulnerability to Landslide Exposure	4%
4.	Human Settlements Sector Vulnerability to Sea Level Rise	3%
5.	Transport Infrastructure Sector Vulnerability to Drought Exposure	5%
6.	Transport Infrastructure Sector Vulnerability to Flood Exposure	7%
7.	Human Settlements Sector Vulnerability to Landslide Exposure	3%
8.	Transport Infrastructure Sector Vulnerability to Sea Level Rise	2%
9.	Tourism Sector Vulnerability to Drought Exposure	1%
10.	Tourism Sector Vulnerability to Flood Exposure	2%
11.	Tourism Sector Vulnerability to Landslide Exposure	1%
12.	Tourism Sector Vulnerability to Sea Level Rise	1%
13.	Drinking Water Sector Vulnerability to Drought Exposure	4%
14.	Drinking Water Sector Vulnerability to Flood Exposure	6%
15.	Drinking Water Sector Vulnerability to Landslide Exposure	3%
16.	Drinking Water Sector Vulnerability to Sea Level Rise	2%
17.	Irrigation Sector Vulnerability to Drought Exposure	3%
18.	Irrigation Sector Vulnerability to Flood Exposure	4%
19.	Irrigation Sector Vulnerability to Landslide Exposure	2%
20.	Irrigation Sector Vulnerability to Sea Level Rise	1%
21.	Paddy Sector Vulnerability to Drought Exposure	3%
22.	Paddy Sector Vulnerability to Flood Exposure	4%
23.	Paddy Sector Vulnerability to Landslide Exposure	2%
24.	Paddy Sector Vulnerability to Sea Level Rise	1%
25.	Plantation Sector Vulnerability to Drought Exposure	2%
26.	Plantation Sector Vulnerability to Flood Exposure	2%
27.	Plantation Sector Vulnerability to Landslide Exposure	1%
28.	Plantation Sector Vulnerability to Sea Level Rise	1%
29.	Fishery Sector Vulnerability to Drought Exposure	3%
30.	Fishery Sector Vulnerability to Flood Exposure	4%
31.	Fishery Sector Vulnerability to Landslide Exposure	2%
32.	Fishery Sector Vulnerability to Sea Level Rise	1%
33.	Livestock Sector Vulnerability to Drought Exposure	2%
34.	Livestock Sector Vulnerability to Flood Exposure	2%
35.	Livestock Sector Vulnerability to Landslide Exposure	1%
36.	Livestock Sector Vulnerability to Sea Level Rise	1%

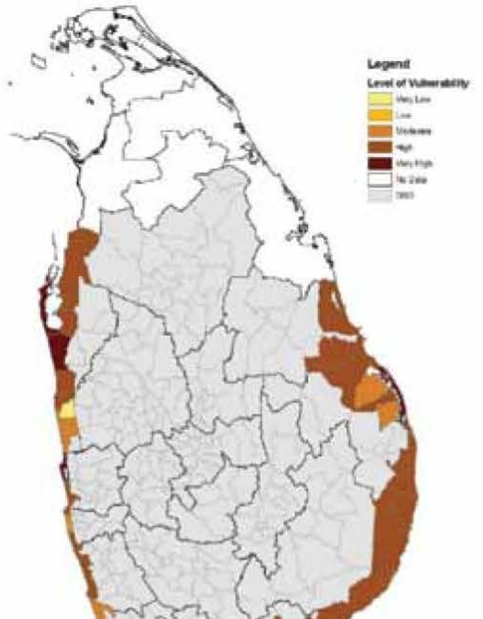

Figure 4: Map of level vulnerability to climate exaggerated disasters in Sri Lankan Coastal DSD's

Madampe showed very low vulnerability, since it does not have a direct contact with the sea. When all DSDs were taken in to the account most of the coastal DSDs showed comparatively moderate level of vulnerability for climate exaggerated disasters. Accordingly, this study proved that there is a significant vulnerability for coastal areas of Sri Lanka on climate exaggerated disasters and their level of impacts.

4. Conclusion

Conventionally Sri Lankan practice is to analyze location specific vulnerability in terms of one specific disaster at a time. Basically, these studies are not focused on the level of vulnerability compared to other locations. Apart from that majority of government institutions are using commercial GIS software packages where they face large number of limitations such as data feeding. The objective of this study is to propose a cost effective methodology for those who face resource constraints using FOSS to identify the level of vulnerability in terms of all sectors which were identified as critical for national development. This study has identified the level of vulnerability to climate induced disasters in coastal DSD's of Sri Lanka. It shows a clear understanding and a comparison between each DSD in which position they held and what kind of an attention they need to pay for disaster management. This kind of a study is an obligatory requirement for a Local Authority for decision making. A most critical issue that Sri Lankan bottom level government institutions face is the lack of resources including financial, physical and human, skills and knowledge, technical assistance etc. Use of FOSS is introduced for them in order to overcome these issues and follow an easy method to do such analyses by their own. This is the initial step to introduce OSS for bottom level decision makers and institutions. This step is to open up their minds to get use of OSS since they can expand their knowledge by joining with discussion forums, sharing experiences with professionals who have done similar studies and to renew the knowledge by following case studies which are freely accessible and try to develop context specific analyses according to the needs etc. Contribution of this study is opening up the minds towards reducing high costs for geo-spatial analyses in disaster management and to introduce FOSS in Local Government set up especially to overcome inadequate skills, knowledge, resources in GIS use for decision making due to financial barriers.

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