Flood Risk Assessment based on OpenStreetMap Application: A case study in Manmunai North Divisional Secretariat of Batticaloa, Sri Lanka

S. Suthakaran[1], and Amindika Withanage[2], M. Gunawardhane[3] and J. Gunatilake[4]
[1]The World Bank, Colombo 03, 00300, Sri Lanka
[2] Department of Medicine, Faculty of Medicine, University of Kelaniya, Ragama, 11010, Sri Lanka
[3, 4] Postgraduate Institute of Science, University of Peradeniya, Peradeniya, 20400, Sri Lanka
[4] Department of Geology, Faculty of Science, University of Peradeniya, 20400, Sri Lanka

Abstract

In the recent past, Sri Lanka has been experiencing an increase of intensity and frequency of natural disasters. Therefore, the study was carried out to introduce the Open Source application to collect the field level information and to identify the flood inundation areas through the 3D model. The case study area was 48 *Grama Niladhari* Divisions in Manmunai North Divisional Secretariat (DS), Batticaloa District. The study was conducted to analyze how far the role of OpenStreetMap (OSM) to support the mapping of the flood risk level of the study area. It's done by collecting exposure data through community participatory method using OSM. OSM data were integrated into Digital Elevation Model (DEM). Elevation points were collected using Google Earth and TCX Converter. Flood hazard maps were created using inputs such as water depth and flood extent of the DEM and clarified through local community participatory mapping exercise. Next, vulnerability maps were generated based on factors such as building characteristics of houses, population of the areas and the availability of assistance during the flood scenarios in 2010 and 2011. Finally, the flood risk map of the study area was prepared in combination with hazard and vulnerability maps. The study produced a user-friendly application of open source and GIS to develop a 3D flood risk model for identification of risk levels of floods. Exposure data have been uploaded into the OSM, therefore, it can be accessed anytime, anywhere and by anyone. The extent of study area is 2593 ha; where about 25,000 families live and there are more than 32,000 buildings. The building footprint database was established using JavaOSM and Bing satellite imagery. It was updated with the building attributes produced by the data collection exercise. This study showed that when the water level increases in the lagoon, nearly 25 GN Divisions (GNDs) out of 48 GNDs are under high flood risk. The developed online geospatial database in OpenStreetMap is an important asset since it is supported to prepare an emergency flood risk management plan, accelerate the emergency response and flood mitigation plan for the study area.

Keywords: Flood Risk Assessment, Community Participatory Mapping, OpenStreetMap, Sri Lanka

1. Introduction

Batticaloa District is located on the Eastern coast of Sri Lanka. It is situated on a flat coastal plain bounded by the Bay of Bengal in the East. The district accounts for 3.8% of the country's total land area (approximately 2,633 km^2) and with an elevation between 1.20 M - 15.0 M Mean Sea Level (MSL). The coastal undulating plain is between 5 and 50 M. The coastal uplands area is situated above 50 M.

Flood is the most impacting type of disasters world-wide and is expected to cause increasing damage in the near future. Therefore, effective assessment of flood hazard requires community participation because communities are the first responders in case of a disaster. It also requires the use of new or recently adopted technology with information and parameters modified to local context, resources and other needs.

Therefore, the new terminology of Community-Based Disaster Risk Reduction (CBDRR) has been coined to help communities in an organized way. The risk assessment should become the product of dialogue and negotiation between different actors with their perceptions. The use of adequate methods and skills that support what has been called community involvement and empowerment has been explored by many disaster risk researchers.

Currently, in Sri Lanka, local maps are not sufficient to create detailed emergency management plans, as well as mitigation plans to

[1]Corresponding Author: S. Suthakaran
ORCID: https://orcid.org/0000-0002-0159-2496
Email address: suthakaran70@gmail.com

reduce the loss of properties and life when disasters occur. Therefore, there is a timely requirement of building detailed maps across the country using OpenStreetMap (OSM) to help emergency responders and planners in the future.

This method for disaster reduction is now practicing by the World Bank in South Asia Region through Open Cities project which helps to prepare emergency preparedness towards natural disasters and managing crisis. The OpenStreetMap platform has been developed to bring the power of community mapping to support urban planning and disaster management investment.

Therefore, the present study was carried out as a case study, to explore the possibility of assessing flood risk and resilience in the coastal areas of Eastern Province of Sri Lanka through Community-Based Participatory Approach and OSM technologies.

1.1. Problem statement

Batticaloa Town is in Manmunai North (MN) DS Division, surrounded by Batticaloa lagoon. During the rainy season, all the natural drainages and streams begin to flow and end up in the lagoon as a result, lagoon water level rapidly increases.

Sri Lanka is at the risk for numerous types of extreme events for an instance, the 2004 tsunami, one of the deadliest disasters in human history, killed over 30,000 people and left over 5000 missing in Sri Lanka (Nishikiori *et al.,* 2006). According to Bureau for Crisis Prevention and Recovery in 2004 report, average annual flood exposure in proportion to population, Sri Lanka ranks 11th in the world. The vulnerability to flooding is increasing due to climatic changes, population growth and urban development in flood-prone areas (Barredo, 2009).

Manmunai North DS Division is multi hazards prone area which is located close by lagoon and the sea. Most of the GN Divisions in the study areas were affected by Tsunami in 2004. This makes flood risk management an important responsibility for governments and municipalities. In this context, number of Non-Governmental Organizations and Government Agencies are contacting the Disaster Risk Reduction (DRR) program in the areas, even though, there are no any emergency response plan if the heavy floods happened in the areas.

Therefore, as a case study, this study intends to introduce the Open Source application to collect the field level information and identify the flood inundation areas through the 3D model.

1.2. Objectives

This study will explore the possibility of assessing flood risk and resilience in the coastal areas of Eastern Province of Sri Lanka, by analysing a sample of one Divisional Secretariat (DS) Division (Manmunai) in Batticaloa District, which was affected by Tsunami in 2004.

The first part of the study will focus on the use of Community-Based Participatory Approach to introduce to exposure data collection method to find the building characteristics. It will assess the disaster exposure of the individual building in the study area through a flood risk assessment method using Open Street Map and Geographic Information System (GIS).

Secondly, the study will identify the elevation pattern and create a 3D model and find out the flood risk areas using results from community participatory mapping exercise.

2. Literature review

The first step in effective disaster management is the identification and profile of hazards (Smith, 2001). Hazards are generally classified as of natural, technological and human origin. To cope with these threats, the United Nations General Assembly adopted a global program in December 1989 to reduce the losses caused by natural hazards and proclaimed the 1990s as the International Decade for Natural Disaster Reduction (IDNDR).

Flood risk management is a subcategory of Disaster Risk Management (DRM). The purpose of the risk assessment is to establish a standard and comparable measure of the probability and consequences of the identified hazard in order to lessen the impacts of natural hazards (UNISDR, 2009).

In the past few decades, prevention and preparedness phases in DRM using ways to reduce the vulnerability of communities by strengthening their capacity to develop coping strategies were emerged (Birkmann, 2006).

Numerous studies have addressed the contemporary vulnerability of different communities in the world to flooding from the point of view of the natural hazards of understanding exposure, the number of people and structures affected (Roy *et al.,* 2001; Nirupama and Simonovic, 2007).

To promote sustainable development and minimize the effects of floods, it is essential to use spatial data and technologies because both hazards and vulnerable societies are changing in space and time. The development and use of spatial analysis for Flood DRM, is increasingly important, for several reasons (Newman *et al.,* 2017). These include natural hazards are having a significant impact on communities and economies, losses due to natural disasters are expected to increase into the future due to increasing concentrated urban areas, consequently increasing exposure and vulnerability (Neumayer and Barthel, 2011; Daniell *et al.,* 2016b). This is aggravated by cities often developing adjacent to rivers and oceans (McGranahan *et al.,* 2007).

The total economic losses from natural hazards over the period 1900–2015, approximately 40% were due to flooding (Daniell *et al.,* 2016b). Further, concerning factor is risk reduction which is broadly recognised as being more cost effective than response and recovery (Rose *et al.,* 2007). For an instance, Harper *et al.* (2013) investigated flood risk-reduction projects in Australia and found that benefit cost ratios were better than 1 and up to 9 where risk-reduction investments were made that target high-risk locations with appropriate strategies.

Knowledge of the local community has been considered as an important primary source of information related to flood risk assessment. These data can be used for the estimation of the risk and for the complete deviation of the frequency of the floods, the characteristics of the floods, the triggers and their consequences. Information on water propagation, duration and maximum water level can be obtained using local knowledge and participatory GIS (Craig *et al.,* 2002).
OSM is an open-source and open-access project founded in 2004 by Steve Coast. OSM project's hub contains four parts. There is a Google Maps style online mapping interface, which lets visitors can discover geographical areas. Users can use export function to download OSM information for further use or processing. The editing tab allows anyone to contribute to the project by digitizing, uploading GPX, or correcting errors in their local areas. The OSM community wiki, contains information about the project and offers guidance. We used the Java OpenStreetMap Editor (JOSM), also. It offers advanced functionalities such as linking OSM features to photos and audio notes, support data conflict resolutions.

Schelhorn *et al.* in 2014 studied and resulted that the identification of elements at flood risk from OpenStreetMap is a suitable and cost-effective alternative for supporting local governments and communities in risk assessment and emergency planning. OSM like collaborative maps can use as a potential source of Volunteered Geographic Information (VGI) for identifying elements at risk of a community including disaster management (Neis *et al.,* 2010; Schelhorn *et al.,* 2014 and Soden *et al.,* 2014).

By 2018, the OSM project had almost 4.7 million users who contributed almost 6.2 billion GPS points and 514 million lines, which are partially based on 4.6 billion notes and 5.9 million relations that have been uploaded (OSM stats, 2018).

The one of the best recent study, Pasi *et al.* (2015) studied the application of OSM. The authors have chosen to use free open source tools such as OSM, JOSM and GPS essentials with Field papers. Information to disaster risk management in the novel scope of risk assessment. Pasi *et al.* (2015) had compared flood risk assessment profiles produced using data collected by OSM against official geodata produced by local governments in two cities of Veneto, Italy. They found that OSM data present several advantages and have a great potential for improvement, suggesting that OSM should be integrated in future risk assessment processes.

Very few literatures are available for local knowledge compiled for flood risk and risk assessment (Elwood, 2006). OSM is used to find out the flood inundation areas, flood risk mapping, vulnerability mapping and risk assessment using participatory mapping and Participatory Geographic Information Systems (PGIS).

Disaster exposure data is an essential when Disaster Management Centre of Sri Lanka deals with pre disaster and post disaster events but in the Sri Lanka context is very challenging because Sri Lanka doesn’t have such data which is a big gap in Sri Lanka. However, Disaster Management Centre has implemented two main projects in collaboration with World Bank Sri Lanka to collect the exposure information of the buildings in Batticaloa and Gampaha Districts which could meet the future demand on exposure information for other areas. In Sri Lanka, government and academic volunteers mapped over 30,000 buildings and 450 km of roadways using OSM (GFDDR, 2018).

Recently Disaster Management Centre in Sri Lanka has launched a disaster risk information platform which is very important initiative for researchers, DRR workers, public, departments and academic institutions to extract the information freely.

In this present study also, collection of the exposure information and data sharing method through Open Street Map application are applied.

3. Method and materials

This study also used the free and open source software to collect the exposure data on the buildings and extracted elevation point from Google Earth to identify the flood inundation area. This research used the qualitative and quantitative methods to collect the field level information to measure the flood level, vulnerability level and risk level of the study area.

3.1. Data collection

Flow diagram of the data collection and entering methodology is shown in Figure 1. OSM was used as a platform to build a database on survey data for the Exposure Mapping Activities in the Manmunai North DS Division.

Community-Based Participatory Approach was adopted by National Housing Development Authority, Municipal Council of Batticaloa and community to exposure data collection method to find the building characteristics. The questionnaire of building characteristics survey is in the appendices.

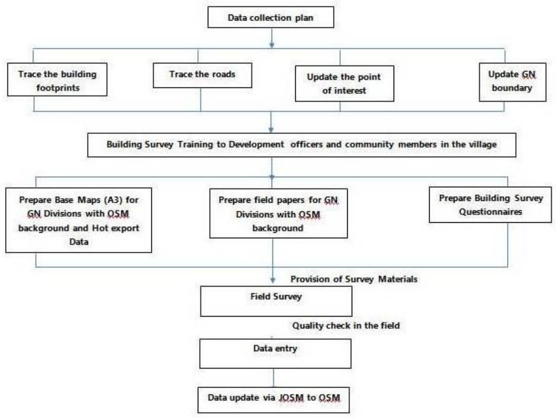

Figure 1: Flow chart of data collection and entering methodology to use the OSM

48 Enumerators (University Graduates from MN Divisional Secretariat) were provided by Divisional Secretariat, MN. They were trained to read the map, to find landmarks in the field papers, locating them perfectly on the field and to compare buildings on the field paper with ground situation. Forty-eight enumerators were divided into 5 groups for data collection based on geography of the study area. Base maps, field papers and questionnaires were used as survey materials.

Staffs from District Secretariat of Batticaloa and Municipal Council of Batticaloa entered building data. Bing satellite image which offered on JOSM was used create a preset (XML file) to upload all the information by a single interface and it was comprised of the questionnaire in digital form. Therefore, data updating task became more convenient.

JOSM, QGIS and Tasking Manager were used as digitizing tools. Digitizing activity divided into four tasks for the convenience such as tracing the building footprints using JOSM, tracing the roads, updating the point of interests and updating the GN Boundaries. During this process a number of new roads were traced and named.

Secondary data such as district disaster management plan, comprehensive land use plan, statistical profile of the district (2015), committee and village disaster plan and relevant maps from LUPPD were collected.

World Bank supported financially and technically to carry out the exposure mapping exercise.

3.2. Data scrubbing

Data scrubbing was the process of correcting the errors on OSM database which could be caused by mistake during the data entry process. The process of data scrubbing was as follows:

a) Data ripped off from the OSM server using ‘PostgreSQL’: Using PostgreSQL as a tool to download the updated data from the OSM server as shape files.
b) Using QGIS, attributes of the OSM data filtered: Downloaded data from OSM servers opened via QGIS, and filtered through attribute tables to get to know what are the fields contain ‘null’ value
c) Compression between JOSM and QGIS: The filter results containing ‘null’ value has been re-updated based on the data on questionnaire and re-checked survey results.

3.3. Community participatory mapping exercise and focus group discussion

The process of identifying, collecting previous flood records, community’s knowledge and perception about flooding was made through the intensive use of several participatory tools such as in depth interviews, focus group discussion and transect walk. The main theme was as follows:

a) Flood events experienced in terms of type, magnitude, duration and date.
b) Outcome of flood scenario by considering physical, economic and social aspect of the family.
c) Mapping exercise developed to manage flood risk
d) Use of resources available at divisional level
e) Influence of flood related issues in their life style

3.4. Flood hazard, vulnerability and risk mapping

Figure 2 shows the process of hazard mapping, vulnerability mapping and flood risk mapping.

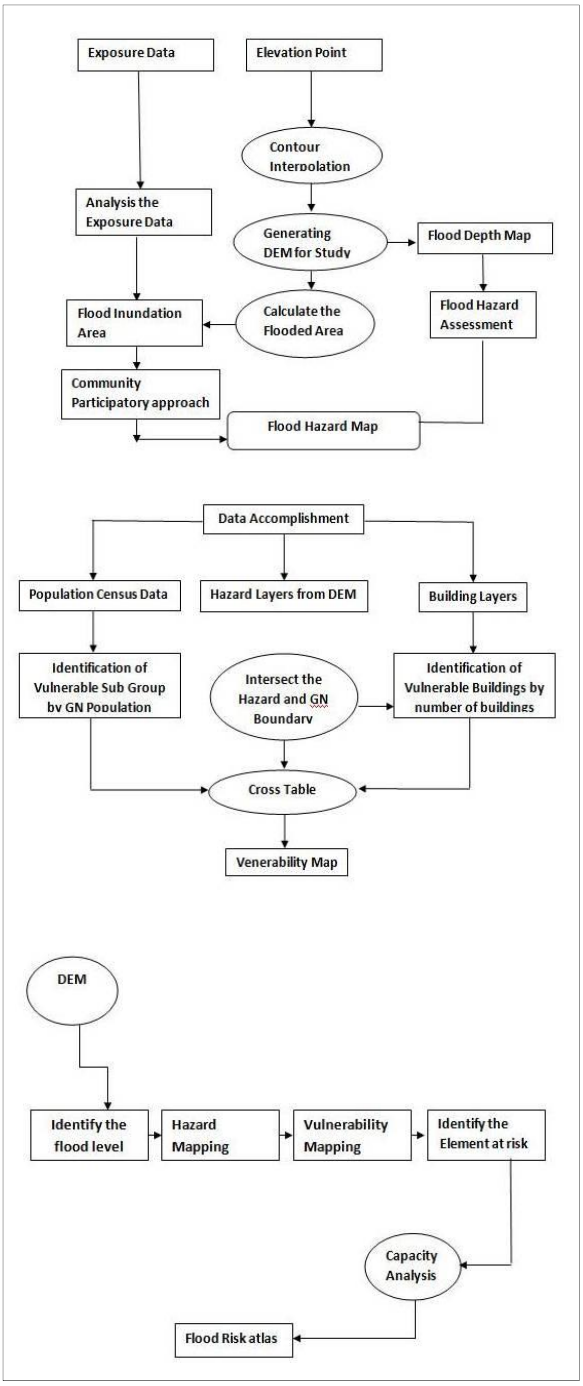

Figure 2: The flow chart of the Hazard, Vulnerability and Risk Mapping

Elevation point data were collected through the Google Earth Pro and (Base on SRTM data) converted into kml file. The elevation point is used with the 3D analysis tool to create Digital Elevation Model (DEM).

The mapping of the extent of the flood based on community participatory approaches with GIS analysis was done. The perceived perception of the hazard through a participatory focus group discussion and the DEM approach analysis were converted into risk categories that were then applied to the special results of distribution, depth and duration of the floods.

Flood hazard maps were classified according to flood inundation areas based on the depth of floods and elevation (categories: 0–2 m high hazard, 2-4 m moderate hazard and 4-6 m Low Hazard). The flood-prone portion of the village has been artificially surrounded by human interventions, such as settlements and fishing activities.

The characteristics of buildings, number of buildings by GN boundary was used to integrate with the population and flood inundation areas to identify the vulnerability of the areas.

In this approach, flood risk map was prepared in combination with the vulnerability of the flood, hazard level, identified elements at risk and capacity of the DRR team in the study area. The results of the risk maps helped to determine the area's most prone to flooding and where communities cannot cope with the disturbances caused by the floods.

4. Results and findings

OSM and participatory data collection methods were combined with GIS. This is a useful approach to improve the understanding of floods as a dynamic hazard for communities in the study area. The integration of local knowledge in GIS-based methods could interpret different aspects of flood risk. In addition, it has expanded the understanding of how floods become a threat faced by residents of these exiting settlements and local villages in their daily lives.

4.1. Flood inundations areas

The inundation areas for flood by assuming when the water level increased by 2 m interval (0-2 High Hazard, 2-4 m, Moderate Hazard and 4 -6 m Low Hazard) in the Lagoon.

In this village, with past experiences, it could be determined the number of families affected during the intense rainy season. The study also showed that there is a flood risk in the area when the water level increased in the lagoon.

Table 1shows that number of buildings faces the possible flood hazard. According to the building survey, five percent of buildings are built up in the high flood hazard area and 16% of buildings are built up in the moderate flood hazard area. This study clearly addressed the threat of flood hazard in the study area.

Table 1: Number of Buildings facing the possible flood threat

Building Usages	High	Moderate	Low
Residential	91	392	2021
Commercial	16	26	149
Government	5	27	108
Utility	7	18	64
School	2	6	9
Religious	3	22	93
Hospital	0	8	11
Other	50	28	119
Total	174	527	2574

4.2. Vulnerability level of the study area

The study showed that several buildings have accumulated in the vulnerable area. Multidisciplinary families and income-generating families are living in the vulnerable areas, although fisher families lose their income during the rainy season due to floods. Irregular and low incomes usually cause these families more vulnerable.

4.3. Risk level of the study area

Flood risk assessment identified that 25 GNs are under high flood risk. The indicators used to find the vulnerability of the areas and the risk of the areas.

Figure 3 shows all results maps hazard, vulnerability and risk maps of the study area.

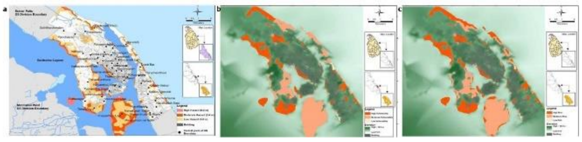

Figure 3: (a)Hazard map ; (b) Vulnerability map; (c) Risk map

4.5. Developed online geospatial web base system

Spatial data are very important to multi-disciplinary decision making analysis especially for post disaster and pre disaster activities. This study developed online geospatial data base which can be usable for anyone. It's open for everyone. Spatial data sets can be obtained from the Open Street Map application such as Hot Export tool, over pass turbo, OSM export and QGIS. There are, buildings, point of interest, land uses, water bodies and road networks.

5. Discussion and conclusions

MN is located in the urban areas, built-up the buildings in the flood prone area and these factors favor flooding, however, non-governmental organizations and government organizations have not seriously considered that these areas are located in the flood prone during previous floods. Therefore, results of this vulnerability assessment yield the recommendations to pay attention by the whole organizations working in DRR activities.

This article discusses the importance and possibility of assessing flood risk and resilience in the coastal areas of Eastern Province of Sri Lanka trough community-based participatory approach and OSM technologies.

Through community participatory flood risk assessment, mitigation measures have been addressed to reduce the risk level for the study area. Several mitigations measures are newly constructed of residential and public buildings need to be considered with the plinth level above 2m from surface especially in the high flood prone area and also renovation of drainages.

The study developed the road networks for the areas with the details of road name and the surface condition which can be used to prepare evacuation route with the concern of flood risk assessment. Also, the study has identified and located public buildings and the safe area for MN DS Division which can help to find the evacuation location to accommodate people when the disaster happens. These results can be used by the decision makers in the area.

Online geospatial data base is available to use everyone and can be updated by OSM users who are interested. In future, District Secretariat and Disaster Management Centre can utilize this online data base to prepare a DS Division Development Plan and make a monitoring mechanism.

Developed Online Geospatial Web Base System developed in this case study can be identify as a multi-disciplinary decision-making analysis especially for post disaster and pre disaster activities.

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10. Disclosure Statement

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11. Ethics and consent

This study received the confirmation from the District Secretary of Batticaloa to process the exposure mapping exercise in Manamunai North DS Division. Divisional Secretary of MN was approved and supported for primary and secondary data collection.

12. Appendix

Building Characteristics Survey

Ds Division Name:

GN name: GN code: Map Id:

1. General information:

1.1 References

Map Building ID: House Address Number (if visible): House number per voters list:

1.2 Building usage

Residential		School	
Commercial		Hospital	
Industrial		Religious	
Utility		Government	

Other specify: ....

1.3 Number of Stories

1		4	
2		5	
3		If more:	. .

1.4 Type of usage (do no collect for regular houses): . . . .

1.5 Name of the building (do not collect for regular houses): . . . .

2. Building characteristics:

2.1 Check only if applicable:

Roof without wall (hut)		Under construction		Abandoned	

2.2 Principal material of construction of the walls:

Plastered		Tin Sheet	
Exposed Brick		Clay wall / Mud	
Exposed Cement Block		Cadjan / Palmyrah	

Other specify: . . .

2.3 Foundation height:

Normal (1 foot or less)		Knee high (1.5 feet)		Waist high (3 feet)		Higher than 3 feet	

3. Principal material of construction of the roof:

Clay/ Ciment Tile		Permanent Zink Sheet	
Asbestos		Tin Sheet/Temporary Zink	
Concrete slab		Cadjan/Palmyrah/Straw	

Other specify: . . .

If applicable, number of faces for the main roof:

1 face (lean-to)		2 faces (pitched)		4 faces (hipped)	

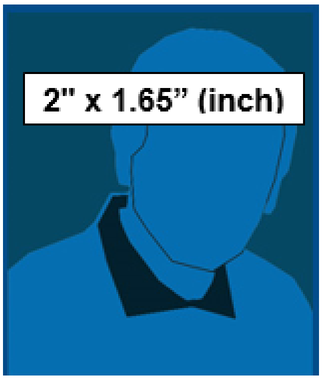
13. Authors biography-

[1] ST Consultant, The World Bank, Colombo 03, 00300, Sri Lanka

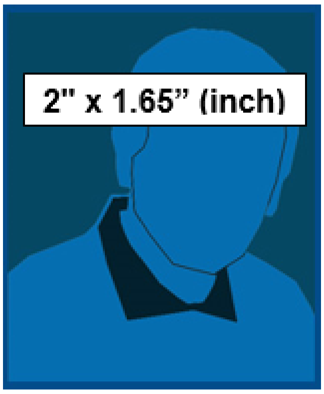
Suthakaran Sundaralingam graduated with the second upper class a B.A Special in Geography from University of Peradeniya. Also, he has a Postgraduate Diploma in Geo-informatics System from PGIA, University of Peradeniya. He is a member of OSgeo Local Chapter, Sri Lanka, Member of OSMF UK, GISCorps Volunteer and member of OSM Sri Lanka Community.
Contact him karansuthakaran@yahoo.com

[2]Department of Medicine, Faculty of Medicine, University of Kelaniya, Ragama, 11010, Sri Lanka

Amindika Withanage graduated from University of Peradeniya in 2015, currently working as the research assistant in the Ragama Health Study project on cardiovascular outcomes, its predictors and formulation of a prediction model. Her main research interest is application of geospatial data for health and disaster management.
Contact her amindika.kks@gmail.com



[3] GIS Officer, Western Region Maritime City Development Project
Ministry of Megapolis & Western Development.
Contact him malikagis@gmail.com



[4] Dr. Jagath Gunatilake, Senior Lecturer in Department of Geology, Faculty of Science in University of Peradeniya. PhD completed in the field of Geotechnical Engineering in Saga University, Saga, Japan. He earned a BSc [Honors-First Class] in Geology, University of Peradeniya, Sri Lanka. His research interests are Geographic Information System, Remote Sensing, and Engineering Geology etc.

Contact him jagathpgis@gmail.com