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Flood hazard mapping in Urban Council limit, Vavuniya District, Sri Lanka- A GIS approach

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Abstract

Several areas in the Vavuniya Urban Council (UC) are being experienced to inundate during every rainy seasons frequently, thus it is crucial to assess the flooding incidents in this area in order to derive the proper planning and policies to overcome the impacts this hazard. The objectives of this study were to analyze the flood prone areas and to produce flood hazard index map of the Vavuniya district in a GIS platform. The study area is Vavuniya UC which consists 11 GN divisions. Required secondary data were collected from the Vavuniya UC, meteorological department and disaster management centre of Sri Lanka. Flood hazard map was produced by using flood incidents, population density, flood prone areas in percentage and distance from river as variables. Knowledge based ranking system was exploited to produce flood hazard index. Each variable was assigned equal weights. The developed flood hazard map revealed that 2 GN divisions out of 11 in safer zone. While 9 GN divisions were in threat zone. In this context it is critical to develop appropriate preventive strategies in the flood prone zone to protect the people from potential disaster threat.

Keywords: Flood hazard index, Flood prone area, Knowledge based ranking.

Introduction

Flooding is considered as one of the major natural hazard around the globe. Flooding occurs when water overflows and tend to inundates the dry land It is destroying the landscape of mankind over the years and resulted to loss of properties, lives, destruction of farmlands etc. in most cities in the world[1].

Vavuniya district is endowed for its rich cascade system in Northern province Sri Lanka. It is one of the district which frequently affected by flooding with following heavy rain during rainy seasons. In this context there have been hardly any investigations conducted in Vavuniya district related to flooding incidents.

Unplanned urbanization, extensive encroachment and improper management of tanks during past decades have made the flood inundation more severe in Vavuniya UC (Urban Council) limit. This study attempts to identify the immediate and indirect factors causing flood in this region and to map out the area which are more susceptible to flooding with using GIS platform.

In this study flood hazard map was developed based on the UC limit boundary. Flood hazard map based on administrative units would be more beneficial for the administrators for implementing effective of flood management strategies and resource allocation[2].

Objective of this research is to produce flood hazard index map for study area.

Materials and Methods

Vavuniya district is located in the low country dry zone of Sri Lanka. It covers of an area about 1967.00 Sq.Km. The mean temperature is 28°C and annual rainfall is 1400 mm. The majority of the resident's livelihood is agriculture. The UC limit is located in western part of the Vavuniya district. It lies in between geographical coordinates longitudes 80°28' – 80°32' and latitudes 8°43' - 8°48'. Vavuniya district is predominantly an agricultural district with unique cascade systems. There are 1 major (1674 Ha), 22 Medium (3905 Ha) and 711 Minor irrigation tanks (11,312 Ha). The soil of the district can be characterized as reddish brown Earth, low humid clays and alluvial soil where the permeability is low[3].

Vavuniya receives rainfall in a bi-modal pattern, obtained during October to late January (*maha* season) and from late April to late May (*yala* season). Geo-morphologically, it is a flat plain having undulated topography with broad valleys and small rock ridges forming cascade based agriculture[4].

There are 5 Local Bodies functioning in this District including one Urban Council and four Pradeshiya Sabhas. Total land area of UC limit is 23.5 Sq.Km and the total population is 35000. Vavuniya UC limit includes 11 GN (Grama Niladari) divisions[3].

For this study, Secondary data such as population census data, frequency of flood incidents from 2007 to 2014 were collected from Vavuniya UC and Disaster Management Centre (DMC), Sri Lanka for all GN divisions. The Aster DEM was used to identify the flooding prone areas. The generated DEM map

(ASTER DEM) was overlaid on the land use map of Vavuniya UC. Percentage of area below 25 m elevation were identified and mapped as high flood prone area.

The variables used to develop the flood hazard index (FHI) map were frequency of flood incidents, percentage of flood prone area, population density and proximity to river. Flood incidents were chosen as an indicator of the risk of flooding in each GN division while flood prone area as availability of potential flood shelter. Population density was used as a indication of economic assets under potential flood threat. These variables are considered as influential to determine the rate of flood impacts both individually and collectively[5].

Knowledge-based ranking scheme is a widely used technique by scholars in multiple criteria decision making analysis (MCDM). This technique was exploited in this study to determine the influencing priority of the variable by assigning the ranks (R) where high level of impact across the GN division were given more ranks. Final flood hazard index map was produced by summing all the scores.

Final FHI for GN scale was calculated as additive model by using all the specified variables. The final composite flood hazard index was calculated as follows:

Flood hazard index = (R_flood incidents + R_ population density + R_flood prone % + R_Proximity to river).

Table-1 shows, the knowledge based ranking used for the development of flood hazard index. Each variables were assigned equal weights to produce final composite map.

Final hazard values were classified into four classes on the basis of natural breaks (Jenks) scheme. All the spatial analysis was performed using ArcGIS 10.2.2.

Results and Discussion

Flood prone areas (Shelter): The potential flood shelter was assumed with a critical threshold elevation of 25 m above which the flood is improbable to rise. Due to undulating topography of this area, it can be assumed that at elevations below 25m, the flood threat could be increased in a nonlinear manner. Therefore, the GN divisions falls in the highest percentage of elevation below 25 m were assigned with high hazard rank as they would be more susceptible in a moderate flood event. The graphical illustration was given in Figure-1.

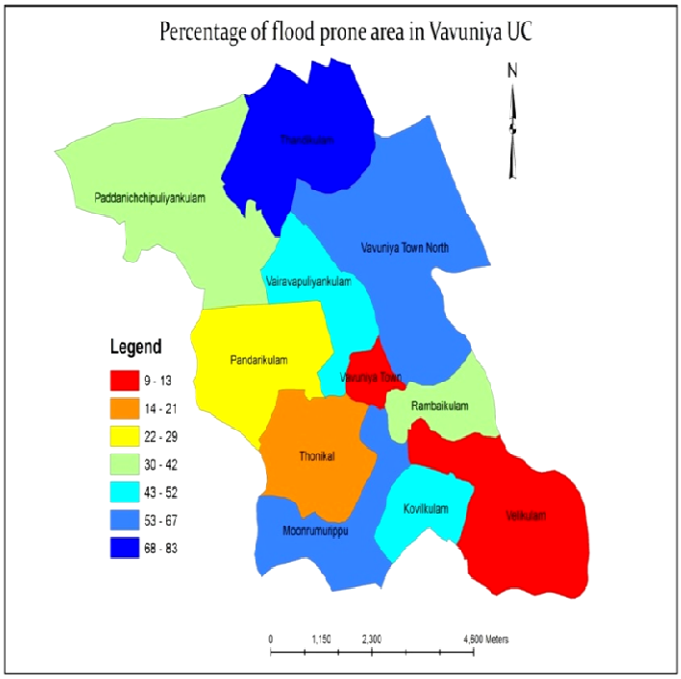

Figure-1
Distribution of flood prone areas in percentage

Table-1
Knowledge based ranking

Distance (m)	Rank	% of flood prone areas	Rank	Flood Occurrence	Rank	Population Density	Rank
124-177	6	9-13	1	0	0	0	0.25
178-510	4.5	14-21	1.5	1	1	2-3	1
511-556	3.5	22-29	2.5	2	2.5	4-7	1.5
557-950	2.5	30-42	3	3	4	8-16	2.5
951-1290	1.8	43-52	3.5	4	6	17-21	4
1291-2100	1.2	53-67	4.5			22-38	6
2101-3010	0.25	68-83	6				

GN divisions where the percentage of flood prone areas considerably high is an important variable in flooding hazard assessment.

Flood incidents (Risk of flooding): The most important factor in determining flood hazard is flood frequency which gives the better understanding of the risk by flooding. Flood occurrence in each GN division for the period of 8 years was shown in Figure-2.

Vavuniya town north GN division has recorded high (4) flood occurrence from 2007 to 2014 while Vairavapuliyankulam and Thandikulam has recorded 3 times flooding. However the whole area had affected by flooding at least once in 8 years.

Distance from rivers (m): The midpoints of the GN divisions were considered for the proximity analysis from the adjacent streams or rivers. The rivers and mid points of GN divisions shown in Figure-3. The proximity was found and extracted using Near Function of Analysis Tools.

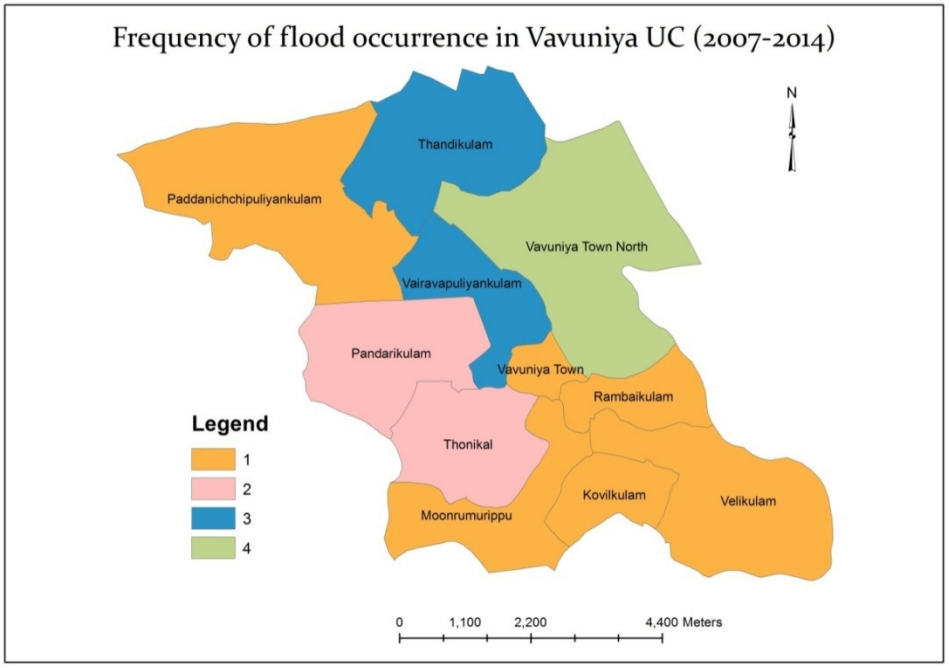

Figure-2
Flood occurrence in UC

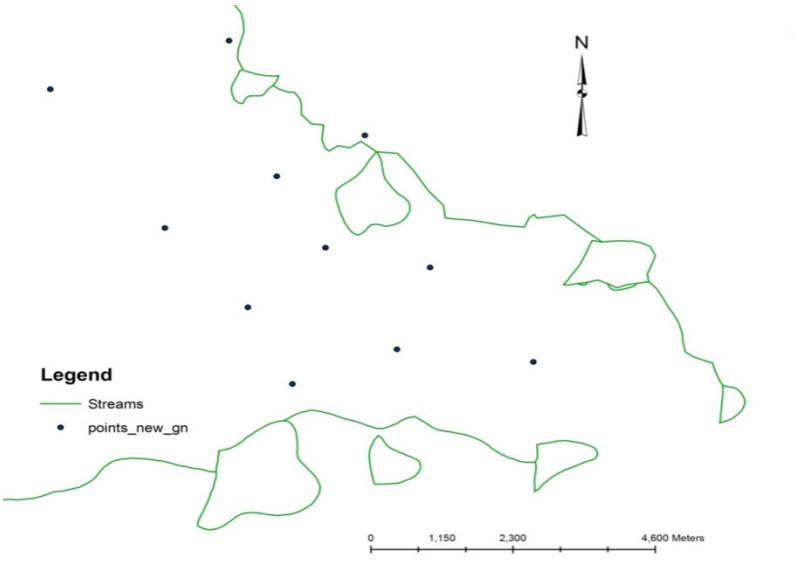

Figure-3
Distance from adjacent rivers

Proximity from adjacent rivers in meter is shown in Table-2.

The variable proximity to the river has been assigned high importance because where the risk of inundation is very low. Almost all the villages were within 124 to 3010 m distance from the rivers. Vavuniya town north and Thandikulam GN were much closed to rivers when compared with others.

Population Density (persons/Hectare): Population density of Vavuniya UC limit was shown in Figure-4. Incorporating population density in flood hazard index facilitate the corresponding relief measures required. In order to quantify the population under potential flood threat, population density of each was considered as another significant variable. Vavuniya town and Vairavapuliyankulam GN can be considered as high population density areas.

Flood Hazard Mapping in GN wise: The final map on flood hazard in Vavuniya UC is depicted in Figure-5 by using derived equation of FHI.

Table-2
Proximity from adjacent rivers in meter

GN Divisions	Distance from river (m)
Vairavapuliyankulam	935
Paddanichchipuliyankulam	3010
Kovilkulam	1298
Velikulam	1700
Moonrumurippu	556
Thonikal	2100
Rambaikulam	958
Vavuniya Town	510
Pandarikulam	2945
Vavuniya Town North	124
Thandikulam	177

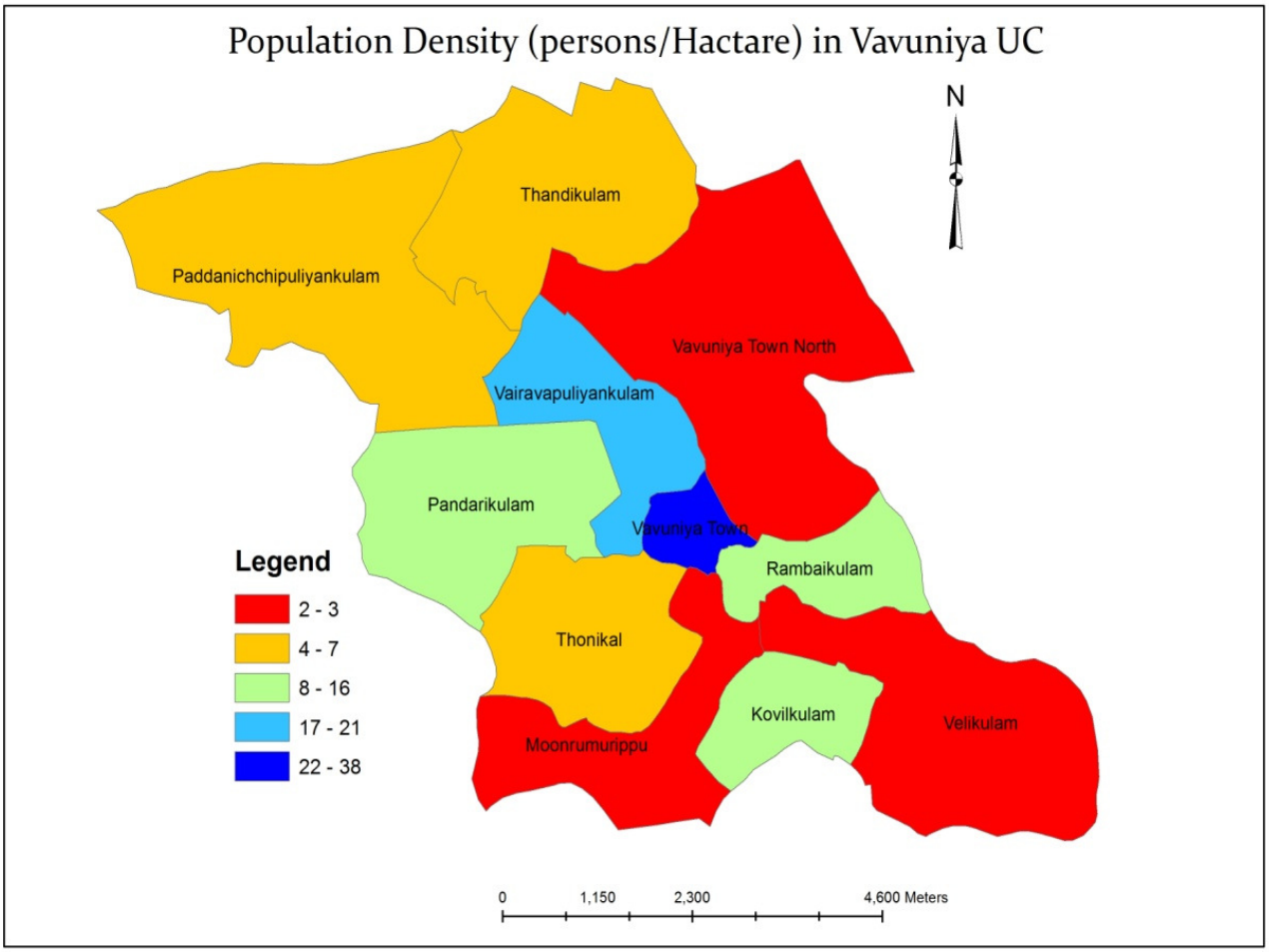

Figure-4
Population density in UC limit

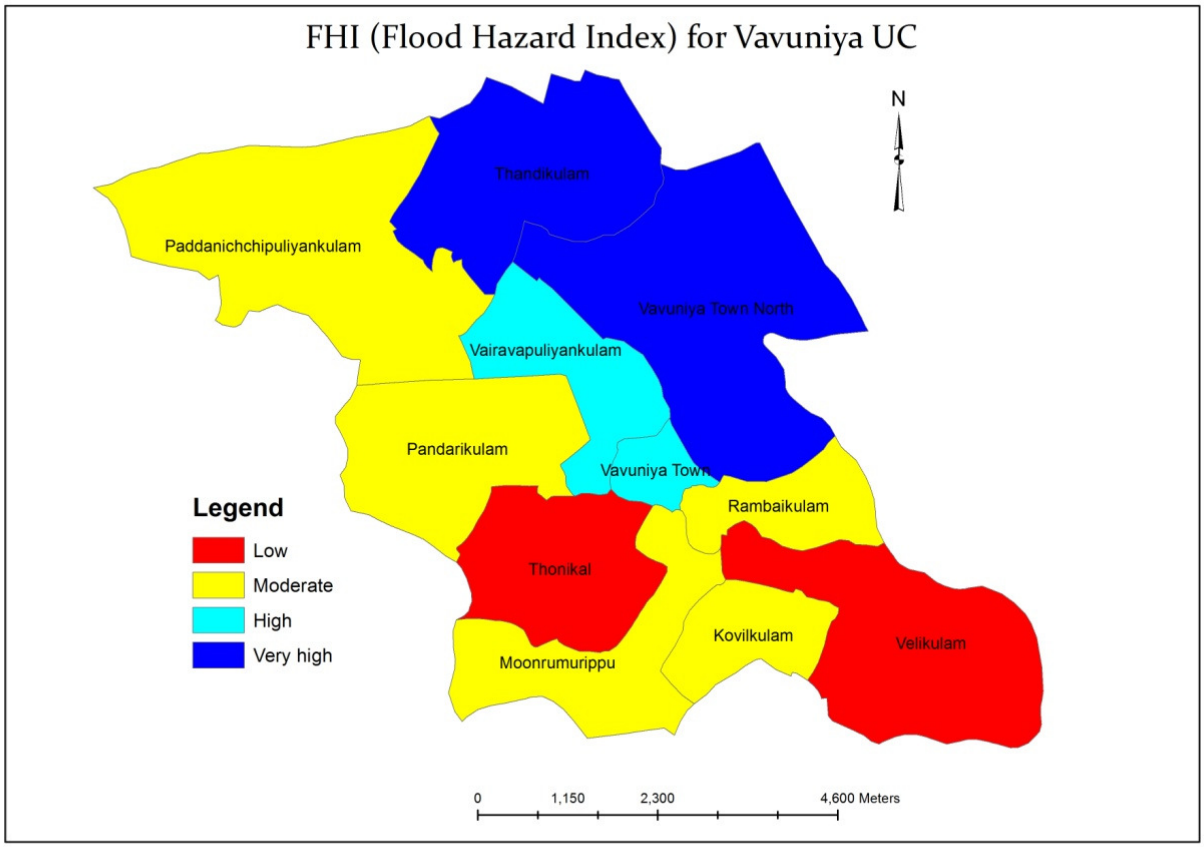

Figure-5
FHI in GN divisions of Vavuniya UC

Resulted Hazard category showed that only 2 GN divisions out of 11 in Vavuniya UC limit have classified as low. Thus the immediate strategy should be taken to overcome the flooding issues.

Conclusion

An attempt was made to identify the flood hazard zone in Vavuniya Urban Council in the GIS platform. Vavuniya, one of the district in Sri Lanka frequently affected by the flooding. The objective of this study was to produce flood hazard index map of the study area. FHI was derived with using knowledge based ranking system. The variables used in the development of FHI were Flood incidents, flood prone area, distance from river, population density. From the FHI derived FHI map, it can be concluded that only 2 GN divisions out of 11 in safer zone while others were in danger zone. Thus, it is necessary to implement appropriate preventive strategies for the flood prone GN division villages in order to avoid the potential flood disaster threat.

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