Development of a Flood Hazard Zonation Map for "Kalu Ganga" Basin by GIS Modelling

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Abstract: "Kalu ganga" (river) is one of the major rivers in Sri Lanka situated in south-western part of the country. Kalu ganga basin area is a highly populated area comprising urban centres and agricultural fields. River floods frequently occur in this area resulting severe damage and destructions. Local planers, decision makers and disaster relief organizations lacks accurate information on the spatial distribution of flooding and the land-use types. Only minimal efforts and resources have been allocated to deal with this problem. The objective of this research is to develop flood hazard zone maps for the Kalu ganga basin area in a Geographic Information Systems (GIS) environment. The applied methodology is comprised of 5 phases. They are preparation phase, fieldwork and data acquisition phase, modelling and flood hazard map generation phase, validation phase and reporting phase. According to the generated flood hazard map, Kuruvita, Elapitiya and Rathnapura divisional secretariats have the highest risk of flooding. Most divisional secretariats in the western province exhibit low or moderate risks of flooding. According to the analysis of flood hazard map with land-use classes, 2307 hectares of residential areas and 5568 hectares of agricultural fields were found to be at high risk of flooding.

Keywords: ArcHydro tool, Digital elevation model, Flood modelling

1. Introduction

Flood is defined as extremely high flows or levels of rivers, lakes, ponds, reservoirs and any other water body, whereby water inundates outside of the water body (Marfai, 2003).

In many regions and countries floods are one of the most damaging phenomenon, which adversely affects the socio economic establishments of a population. Each year floods cause hundreds of deaths and property damage in billions (Marfai, 2003).

Destruction due to floods in developing countries like Sri Lanka will continue

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unless reliable coping mechanisms are well established in advance. However, due to the lack of awareness, resources and suitable approach, the problem couldn't be solved. This particular vulnerability of developing countries underlines the urgent need to promote relatively fast, technically tolerable, environment friendly and socially accepted cost effective structural as well as non-structural countermeasures that should be planned and implemented.

Flood hazard zonation map developed in GIS environment can provide information about communities and infrastructure which are at risk of flooding. Since making Flood hazard map (FHM) is inexpensive and quick, it would be the best way to develop social resilience and to cope with extremities in mentioned areas. The "Kalu ganga" basin was chosen as the focus of this research due to high population density of the area. The objective of this research is to identify areas which have a high risk for flooding.

2. Methodology

2.1 Initial data utilized for the research

i. SRTM DEM (Shuttle Radar Topography Mission Digital Elevation Model)
ii. 1:100000 Digital Soil map
iii. 1:100000 Digital Geology map
iv. 1:50000 Digital Landuse map
v. Flood data records in the area of interest from 1980 to 2008

2.2 Software tools utilized for the research

i. ArcGIS-ArcMap software
ii. ArcHydro tool extension in ArcMap
iii. MS-Excel

2.3 Processing SRTM DEM

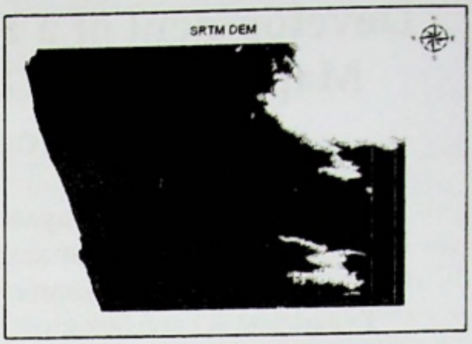

Figure 1. SRTM DEM of study area.

SRTM DEM was used extensively throughout this study. This digital elevation model is readily available to download from their official website http://srtm.csi.cgiar.org. The area covering whole Sri Lanka exists in sheets 52 and 53 as TIFF images with WGS 1984 coordinate system. These two sheets were merged together and clipped to extract the DEM for the area of interest.

Table 1. ArcHydro Tools and Functionality

Tool	Description
Fill Sinks	Fill sinks for an entire DEM (grid).
Flow Direction	Create flow direction grid from a DEM grid.
Flow Accumulation	Create flow accumulation grid from a flow direction grid.
Stream Definition	Create a new grid (stream grid) with cells from a flow accumulation grid that exceed used-defined threshold.
StreamSegmentation	Create a stream link grid from the stream grid (every link between two stream junction gets a unique identifier).
Catchment Grid Delineation	Create a catchment grid for segments in the stream link grid. It identifies areas draining into each stream link.
Catchment Polygon Processing	Create catchment polygons out of the catchment grid.
Drainage Line Processing	Create streamlines out of the stream link grid.

After extracting the DEM for the study area, it was further processed using the ArcHydro terrain processing tool kit. Each function was executed sequentially because each consequent function uses the output from the previous function.

Finally ArcHydro tool kit produce "Catchments Polygon" and "Stream links Polyline" shape files. Using these 2 maps, drainage density map of the area was produced. For each sub-catchment, drainage density classes were assigned according to their level of drainage density in 3 categories as: 1) High, 2) Moderate, 3) Poor.

Further, the SRTM DEM was used to develop the Slope map of the study area using 3-D analyst in ArcMap. This slope map was classified according to the slope percentage as 1) Flat, 2).Gentle and 3) Steep.

2.3 Processing Soil Map

A portion of the map was extracted from the entire soil map of Sri Lanka provided by DMC (Disaster Management Centre). Based on soil types, the infiltration levels were classified as 1) Very high, 2) High, 3) Moderate and 4) Poor.

2.4 Processing Geology Map

Geology of Kalu ganga basin area was covered by the Sri Lanka 1:100000 Geology Provisional Map series, sheets number 16, 17, 19 and 20. We acquired these maps relevant to study area from Geological Survey and Mines Bureau (GSMB) in digital DGN format. These 4 maps were exported in to shape files and merged together and afterwards Kalu ganga basin area was extracted.

2.5 Processing historical flood records

Historical flood records relevant to divisional secretariats in the area of interest were downloaded from www.desinventar.net website. The average number of flood events was calculated for timeframes of 1, 5, 10 and 25 years. Using that data the flood frequency was categorized as 1) Very high, 2) Moderate, 3) Slight, 4) Sudden and 5) None flooding.

2.6 Flood Hazard map generation by GIS modelling

After all initial maps were processed, a numerical weighting system was introduced for their classification. In assigning weightings to maps priority was given to which mostly influence flooding as follows.

Table 2. Weighting system for modelling

Priority	Property	Maximum Weighting
1	Slope	50
2	Drainage density	40
3	Soil type	30
4	Geology	20
	Total	**140**

Finally, the flood hazard map for the Kalu ganga basin was developed by combining all the maps. It was compared with the historical flood data. The risk analysis was done by overlaying and comparing the Landuse map with the developed flood hazard map.

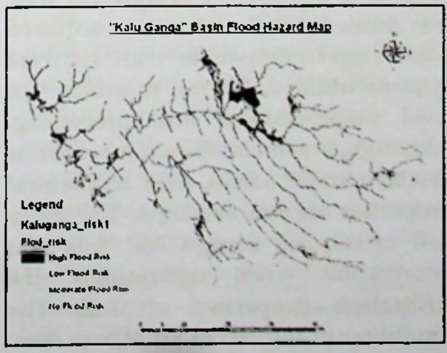

Figure 2. "Kalu Ganga" basin flood hazard map

3. Results

The total area of the basin is approximately 364608 ha, out of which, 57832.7 ha are human settlements and 203484.0 ha are agricultural land. From the analysis of the landuse map with the flood hazard map the areas under threat for flooding were extracted (Table 3).

Table 3. Area under threat by Flooding (in ha)

Risk category	Human settlement	Agricultural
High	2306.6	5567.4
Moderate	17525.8	35789.6

According to the Flood hazard map (FHM), in the Sabaragamuwa province, Kuruvita, Elapatha and Rathnapura divisional secretariats are found to have high risk of flooding. In the Western province, Kaluthara and Panadura divisional secretariats are also at risk.

4. Discussion

GIS modelling was preferred over numerical modelling techniques for this project because the study area was very large and the project completion time was limited. Most of the time acquired data wasn't compatible with software systems utilized, forcing to utilize low level manipulations and processing. Although, a soil classification system is available in Sri Lanka, their mechanical properties are not available. The study had to rely on foreign soil data and information when determining the infiltration properties of soil. The resolution of the SRTM DEM was 90m. This resolution was acceptable for the present research, because the study area was comparatively large. However, if more accurate DEM is available, the accuracy of results can be improved. For the risk analysis phase, the study used the digital Landuse map developed by the survey department prepared in year 2000. Therefore, there might be some discrepancies in the final results.

5. Conclusions

The study reviled that approximately 2.6% of residential areas and 3% of agricultural fields are at high risk of flooding. The study identified that most of the high risk areas are situated in Rathnapura district. These high risk areas should be subjected to further studies using techniques such as numerical flood modelling. Also, residents living in high risk areas should be educated as how to cope with these hazards.

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