USING GEO-SPATIAL TECHNOLOGY TO FLOODING POTENTIAL MODEL IN GAL OYA RIVER BASIN

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Abstract

Galoya River basin affected by flash flood during the north-east monsoon period. The Department of Irrigation, Metrological Department and Disaster Management Center to predict flash flood events. However, these programmes have a number of scarcities for several forecast areas in nation. Developing a GIS based model that integrates basin physiographic characteristics will allow the hydrologist to better predict flood events. In this study, I have developed geospatial model to establish the flooding potential for the upper Gal Oya river basin. The dynamic GIS parameters used to model development are slope and flow accumulation, land cover and vegetation, soil hydrologic, drainage classes and precipitation. All these layers were converted to raster datasets, using the basic attribute field responsible for flooding potential analysis each model parameter was assigned weights at the time of reclassifying, a rank of least flood potential (1) to most flood potential (9). Finally, each layers were overlayed with a weighted overlay analysis. For the weighted overlay analysis, each layer was given certain weights evaluated by their influence in flooding potential. The final flooding potential map was obtained as colored map with scale 1 to 9. This model can be easily simulated in any other basin in the nation by changing the input parameters. Study area under different flooding potential scale. More than 70% of the area is under the low to medium vulnerability with respect to flooding potential. Rest of is under high to very high flooding potential area.

Key Words: GIS, Spatial Analysis, Model Builder, Flooding Potential and Weighted Overlay

INTRODUCTION

Due to global warming, the ocean's thermohaline circulation pattern is changing. It is known as an El-Nino and La-Nina effect. Therefore, the ocean surface temperature is changing geographically. As a result, unlike earlier time, more than usual precipitation is happening in several parts of the world (Panda, 2008). Flash flooding induced by sudden surged storm events has recently become a norm in the world (Lee and Lee, 2003; Hudson and Colditz, 2003). In this present decade, it is a fact that most of the national disasters in Sri Lanka are due to Flooding. 2011 flood in northern and eastern region are few examples. Therefore, reliable flood models are a necessity to allow emergency managers and city planners to obtain advance warning in severe storm situations and get prepared for the eventuality (Knebl *et al*., 2005). Flood inundation modeling would also help planners and insurance people to take major decision to safeguard public's interest (Bates, 2004). Geographic information systems (GIS) are currently being used to help model flooding potential and inundation. Robayo *et al*., (2004), rainfall time series data with GIS in hydrological modeling. The Map-to-Map tool creates an ArcHydro model and an interface data model for all models that share data with GIS to output a floodplain map. Dyhouse, *et.al* (2008) have developed mechanism to model floodplain using HEC-RAS software. This study used the hydrodynamic modeling tool, which allows for a complete analysis of flooding impacts (Yang and Rystedt, 2002). However, all these software used to model floodplain are cumbersome and sometimes difficult to work with. The NBRO and DMC currently use the Flash Flood Monitoring to predict flooding events. Within each hydrologic basin is rainfall rates and accumulation is based on amount of reflectance. Then the average rainfall value is compared to the Flash Flood Guidance generating a flash flood index. When they venture into flood predictions in micro-watersheds, they face problem with basin connectivity and data authenticity. This study also have problem in identification of correct individual basin physiography.

Incorporating GIS into flash flood prediction will greatly improve the accuracy of the DMC warning system for any spatial area vulnerable to flash floods. Developing a geospatial model in ArcGIS ModelBuilder would also enhance the ability of layman with simple GIS know how to predict flooding probability in any area of concern. The preliminary GIS model contains intrinsic parameters of soil, vegetation, land cover, slope, and flow accumulation. Running a model based on these intrinsic parameters creates a static map of potential flooding. To make the map more dynamic and useful to the DEM precipitation data is added at the end of the model. The overall goal of this study is to generate a flash flood index ranging from least potential to flood (1) to greatest potential to flood (9) for Gal Oya River basin.

MATERIALS AND METHODS

Study Area

The study area for this paper is the Gal Oya River basin portions of Eastern region of Sri Lanka. It consists about 2000 sq.km and covered Mahaveli basin on the west, Maduru Oya, mundane Aru and Andalai Oya basin on the north, Ambalam Oya, pannal Oya, Karanda Oya, Heda Oya and Kumbukan Oya reven basin on the South and Indian Ocean on the East (Figure 01). Eastern part of the site of the study area has high populated.

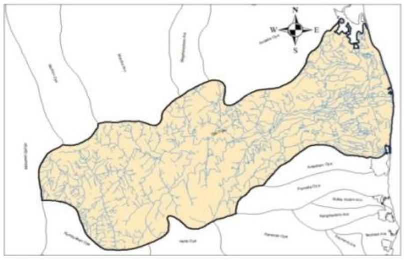

Figure 01: Study Area map of Gal Oya River basin

GIS and other Data Layers Used in the Study

Raw data sets used in this study include basin Digital topographic map (coverage file -scale 1:50000), Department of Survey, Sri Lanka, Soil map (shape file), Land Use Policy Planning Department. The annual average rainfall data was collected from the rain gauges inside and the adjacent areas by Metrological Department.

Spatial Layers Preparation for Analysis

Precipitation Data Preparation

Precipitation is a major player in flooding potential mapping (Chow *et al*., 1988). With high annual rainfall, there is potential for more flooding. Therefore using precipitation data is essential. There were five gauging stations around the study area. The annual average rainfalls for these five rain gauges were 164, 187, 213, 251 and 272 mm, respectively. A point shape file was created in ArcGIS with the average precipitation value as an attribute in its attribute table. Then the 'Inverse Distance Weighted' surface interpolation technique was used to create an interpolation raster from the point shapefile. Thiessen polygon technique can be used to obtain the distributed precipitation data for non-recorded locations. Then the Extract by Mask tool was used to clip the precipitation raster to the study area (Figure 02 to 04).

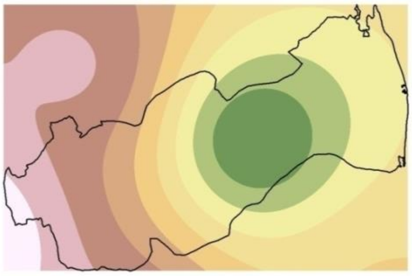

Figure 02: Interpolation Technique (IDW)

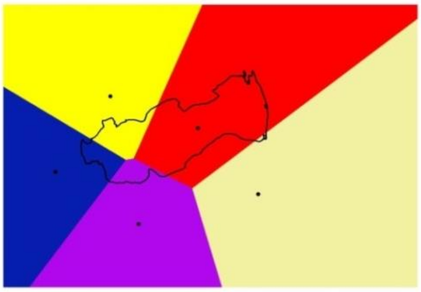

Figure 03: Thiessen Polygon Technique

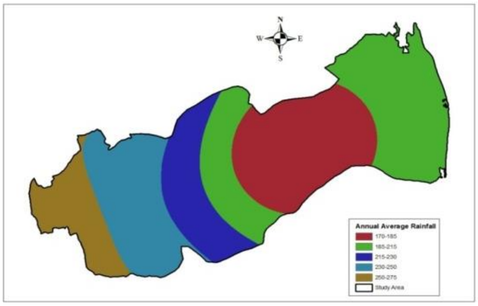

Figure 04: Reclassified Precipitation

Finally, the precipitation raster was reclassified into a scale of 1 to 9 with the class with the lowest rainfall amount getting a value of 1 and the highest one getting a value of 9. It was performed by classifying the precipitation raster with Equal Interval classification technique with nine classes while performing the reclassification on the raster (Figure 04).

Soil Data Preparation

Soil is another important factor in flooding potential mapping (Brady and Weil, 2004). Soil permeability and drainage ability are the important soil characteristics that determine the amount of runoff and overland water storage. Therefore, by using these soil characteristics are necessary. However, preparing data compatible to GIS spatial analysis is a delicate task. To make it simpler, a geospatial model was developed in ArcGIS 9.3 ModelBuilder so that with single click of Run button, the required soil characteristics layer would be created.As all the data layers should be in raster format to help in the model development, the soil vector data layer was converted to two different raster using the soil infiltration (hydrologic group) and soil drainage fields, respectively (Figure 05 and 06). While converting the soil feature layer to raster format, it was made sure that the raster cells were 10 meter to be compatible with the DEM. Each raster were reclassified to a rank from 1 to 9 (Table 01) based on the drainability and infiltration rate of the soil texture. Finally, the drainage and hydrologic rasters were combined based on the value (numeric) fields using the weighted overlay tool (Figure 07). Values were scaled from 1 (least potential) to 9 (most potential) to match the evaluation scale of 1 to 9 by 1

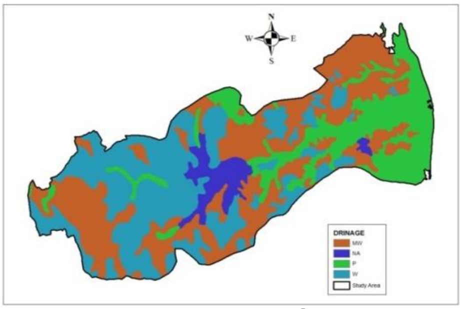

Figure 05: Soil Drainage

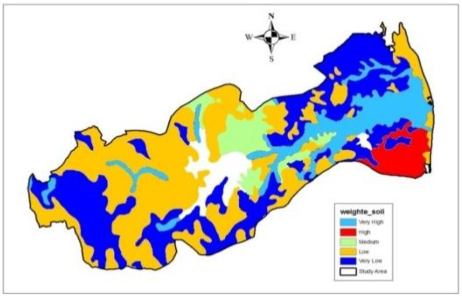

Figure 06: Soil Infiltration

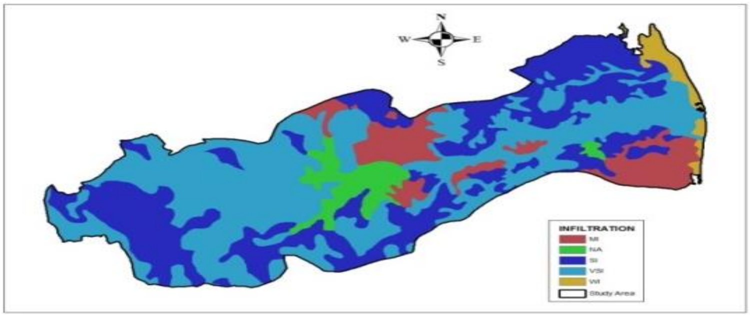

Figure 07: Reclassified Weighted Soil

Table 01: Reclassified Rank Drainage and Infiltration

Classification	Cell Value	Rank (1 to 9)
Drainage		
W(well, low water holding capacity)	1	5
MW (well, intermediate water holding capacity)	2	7
P (poorly, low hydraulic conductivity)	3	9
NoData	4	NoData
Infiltration		
D (very low infiltration rates, clay soils or impervious soils	1	9
C (Slow infiltration rates)	2	5
B (moderately infiltration rates)	3	7
A (well infiltration rates)	4	1
NoData	5	NoData

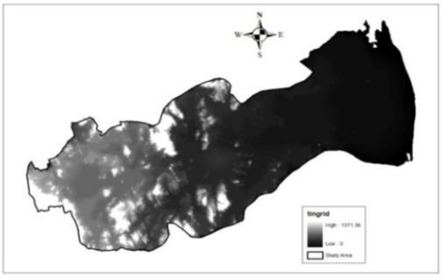

Figure 08: DEM of the Study Area

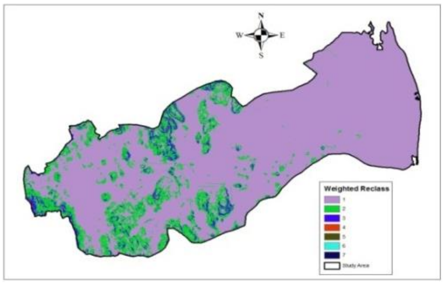

Figure 09: Reclassified Slope

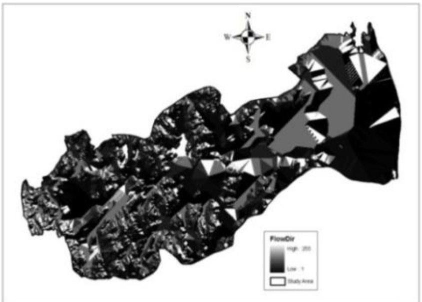

Figure 10: Flow Direction

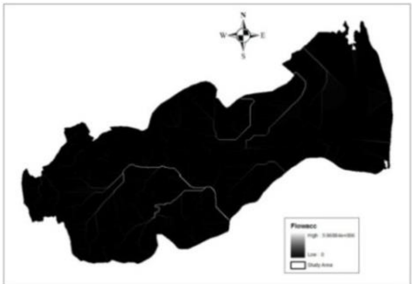

Figure:11 Flow Accumulation

Weighted Topography Raster Conversion

Slope and flow accumulation are the essential topographic factors that guide the flood potential of spatial areas. Slope and flow accumulation data layers can be generated using the digital elevation model of the study area.

The DEM raster was created to the study area using 3D analysis tool of ArcToolbox. Then the Slope and Flow Direction tools were used to develop slope and flow direction raster, respectively, from the DEM. Flow Accumulation tool was used with the flow direction raster as input to produce the flow accumulation raster (Figure 08 to 11). Each raster (slope and flow accumulation) was assigned Weights at the time of reclassifying, a ranking of least flood potential (1) to most flood potential (9).

When reclassifying continuous rasters (like flow accumulation and slope) the values were grouped into ranges using the equal interval classification scheme with nine classes. For example, the interval of greatest flow accumulation received a rank of 9 and the interval of lowest flow accumulation received a rank of 1. After the reclassification both were overlaid using the weighted overlay tool to get the weighted topography. Slope was weighted slightly more (60%) than flow accumulation because slope has a large influence on flood potential. Figure 12 is the geospatial model developed in ArcGIS 9.3 ModelBuilder to prepare the raster for the flood potential modeling.

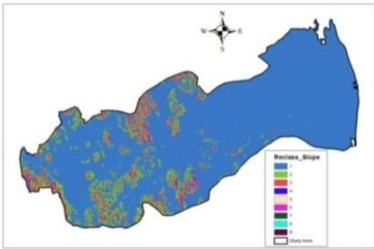

Figure 12: Reclassified Weighted Topography

Table 02: Weighted Vegetation/landuse Class Value

Classification	New Value
Forest	1
Scrub	1
Rubber	1
Homegarden	3
Paddy	9
Grassland	3
Built-up	5

Weighted Vegetation/Land Use Raster Conversion

The vegetation is a major restraint for flooding because it reduces the runoff and helps in percolation. Therefore, the land-use raster was reclassified into new values for the old values as given to vegetation class according to the Anderson's classification (Table 02). Forest classes and they were assigned with the new value of 1. Similarly, national park forest also was assigned with value 1. Similarly the land-use raster was reclassified with scores of 9 (highest for flood potential contribution). Thus, new raster, weighted vegetation/land-use was created. Again, the weighted vegetation/landuse raster was overlayed with the reclassed soil raster to create the weighted vegetation soil raster. Both got 50% of weight while conducting the overlay. Figure 14 is the geospatial model developed to prepare the weighted vegetation-soil raster.

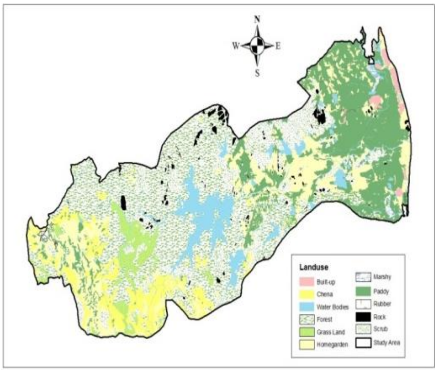

Figure14: Reclassified Weighted Vegetation/Landuse

Flood Potential Model Development

Once, all the four raster layers (i) Reclassified precipitation, (ii) Weighted topography, (iii) Weighted vegetation/landuse, and (iv) Reclassified land-use were created using the geospatial models developed, they were weighted overlayed together to produce the final flooding potential map of the Gal Oya River basin. These weighted layers were created in order to reduce the number of inputs in the final weighted overlay. The final output of a flood potential index was a result of equally weighting (25% each) the weighted topography layer, weighted vegetation/landuse layer, and precipitation data. The final comprehensive single geospatial model developed to obtain the flood potential map of the study area is given in Figure15.

Finally, once the flood potential map of the study area is produced, it was classified using the Natural Breaks classification technique into several classes according to the need of the user. In this study we have used five ranks, very low, low, medium, high, and very high potential areas, respectively, to represent the spatial areas of the watershed based on their vulnerability for flooding.

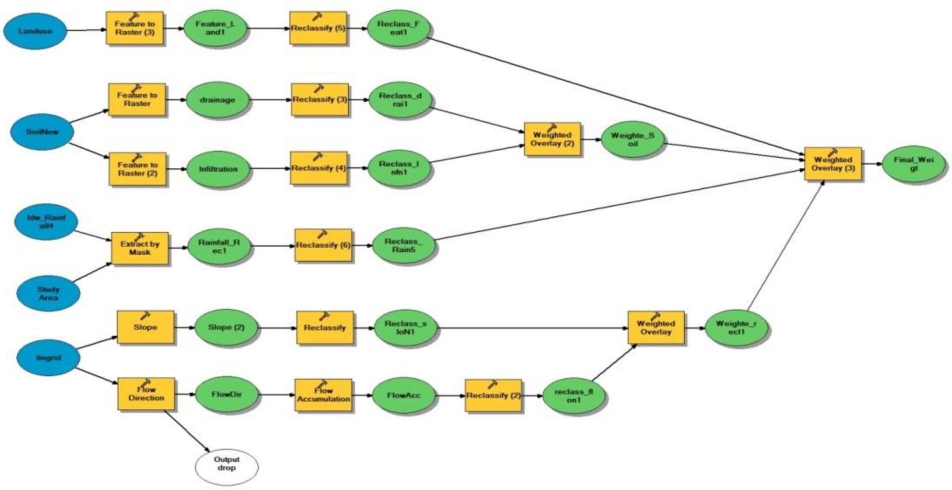

Figure 15: The Comprehensive Geospatial Model to Develop the Flood Potential Map

RESULTS AND DISCUSSIONS

Figure 16 represent the flooding potential map of the Gal Oya River basin. From the analysis of the result it was observed that most of the Western part of basin is of low flood potential area. The Eastern part of the basin is more flat than the Western portion. It is also closer to the city area and hence devoid of vegetation compared to the western part that is forest cover. There is not much area under the very high flooding potential category as observed from the image visual analysis. Table 03 shows the percentage of area of study area under different flooding potential scale. About 70% of the area is under the low to medium vulnerability with respect to flooding potential. Rest of the 30% area is under high to very high flooding potential area. Flood managers or insurance officers should be interested to develop these areas to decrease the flooding potential in the basin.

However, it is to be noted that the use of annual precipitation totals may be too coarse a resolution for accurate flood potential estimation, i.e., precipitation intensity on a given day and given period may vary dramatically at two locations of a basin. Therefore, it would have been more appropriate to use sub-annual high intensity precipitation records for accurate flood However, it is to be noted that the use of annual precipitation totals may be too coarse a resolution for accurate flood potential estimation, i.e., precipitation intensity on a given day and given period may vary dramatically at two locations of a basin. Therefore, it would have been more appropriate to use sub-annual high intensity precipitation records for accurate flood forecasting. One more note of this study is that the five gauging station in the basin may be not sufficient to reflect the actual spatial variability of rainfall in the watershed. Therefore, if possible more number of rain gauge stations should be used in analysis. We have developed a procedure for flood mapping in a basin through a developed geospatial model and the model can be modified with precise information as mentioned here.

Table 03: Different Flooding Potential Category

Flood Potential Score	Extent Sq.km	Per cent
Very High	301.71	16.60
High	273.31	15.04
Medium	970.32	53.39
Low	212.79	11.71
Very Low	59.19	3.26

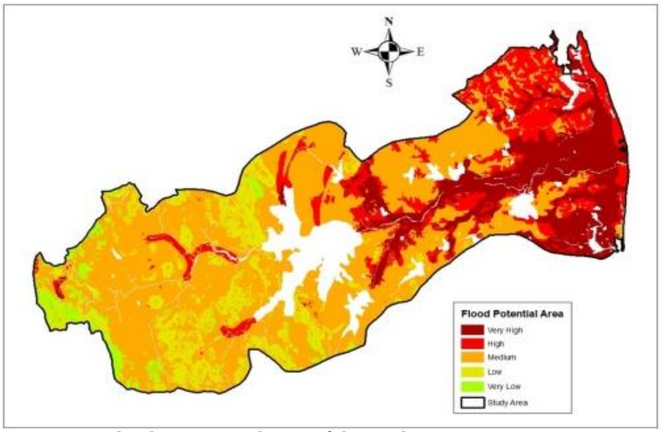

Figure 16: Flooding Potential Map of the Study Aea

In case of environmental analysis, weighted overlay with uniform weight allocations to spatial parameters may be not perfect for entire basin spatial locations. For example, slope may not be as influential under canopy or in grassed areas as it would be for bare ground, fallow pasture, or in urban settings. Therefore, a matrix of coefficients or weights for each raster layer can be used. However, the studied basin does not have that much variability in land-use, so individual weight factors for each raster were rightly used.

CONCLUSION

From this study, it was found that geospatial technology has the best potential to undertake complex environmental problems to analyze and provide results required for decision-making. This comprehensive flood potential model developed in ArcGIS ModelBuilder could be easily handled by novice GIS users for decision making. Again, as per advantage of the models developed in ModelBuilder can be easily by replacing inputs to obtained similar maps for other basin or study areas. Therefore, the models developed as part of this study could be easily replicated elsewhere.

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