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Review Article

Digital elevation based flood hazard and vulnerability study at various return periods in Sirajganj Sadar Upazila, Bangladesh

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ABSTRACT

The objectives of the study are flood hazard mapping and crops and settlement vulnerability assessment in a low laying riverine flood prone area of Bangladesh for different flood magnitudes. Flood hazard maps have been developed for different flood magnitudes integrating the Digital Elevation Model (DEM) data of Shuttle Radar Topographic Mission (SRTM) and interpolation of water level height of different water stations. Frequency analysis has been carried out to determine the water level of 2.33, 5, 10, 20, 50 and 100-year return periods flood. Landuse or land cover map has been generated from the LANDSAT satellite images supervised classification. Vulnerability functions of risk elements and flood hazard maps are analyzed in GIS environment to develop vulnerability maps. Most of the settlement vulnerable areas were found in low laying lands from the settlement and crops vulnerability maps. This flood hazard vulnerability map can be used for selecting the type of crops and area for cultivation during the monsoon period on the basis of magnitudes of inundation of different flood zones.

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1. Introduction

Bangladesh is extremely vulnerable to flooding because of its geographical setting. It is a low-laying deltaic country with big inland water bodies, including some of the biggest rivers in the world. Flooding is an annual recurring event during monsoon and 80% of the annual rainfall occurs in monsoon. Due to intense rainfall during monsoon (June to September), about one-fifth to one-third of the country is annually flooded by overflowing rivers caused by heavy rainfall. Bangladesh is a flood prone country and very often experiences devastating flood during monsoon that causes damage to crops, settlement, fisheries, infrastructures and properties. This study assessed the flood hazard vulnerability of crops and settlement for different flood magnitude by integrating LANDSAT and SRTM digital elevation data with geographical information system (GIS) and remote sensing (RS).

2. Study area

There are two types of floods that occur in Bangladesh: annual floods and low frequency floods of high magnitude. Flood hazard assessment is carried out to identify the potential areas of a region for flood mitigation [15]. In this connection, in this present study, Sirajganj Sadar Upazila under Sirajganj District has been chosen for flood hazard and vulnerability study at various return periods. Sirajganj is located in north-western zone of Bangladesh and under the district Sirajganj Sadar Upazila with an area of 314.77 sq km, located in between 24°22 and 24°37 north latitudes and in between 89°36 and 89°47 east longitudes. It is bounded by Raipur Upazila on the north, Belkuchi Upazilas on the south, Kalihati and Bhuapur Upazilas on the east, Kamarkhanda, Raiganj and Dhunat Upazilas on the west (Fig. 1). The area falls in a major Agro Ecological Zones (AEZ), which is the Active Brahmaputra–Jamuna Floodplain (AEZ-8) [1]. The main cause of flooding in the area is the Tran boundary inflow from upstream catchment carried by the Jamuna River. Others Major important rivers, Bangali, Jamuneswari, Karatoa, and Hurasagar are flowed in and around the upazila.

3. Methods and data

Satellite Images with the integration of Geographical Information System (GIS) are used for historic flood hazard analysis. National Oceanographic and Atmospheric Administration (NOAA) and Advanced Very High Resolution Radiometer (AVHRR) data were used to analyze Bangladesh's historical flood event of 1988, which sets a hundred-year record for the inundated areas, with severe damage occurring throughout this region [9]. Several hydrodynamic models have also been developed such as HEC – RAS, MIKE44, SOBEK, ISIS, ONDA and FLUCOMP to study inundation at watershed level. Considerable skill is required to determine appropriate cross section locations for such models [12] and, in addition, bathymetric information with precise resolution, surface nature (topography, vegetation coverage, land use etc.) are not explicitly available especially in Bangladesh context.

Apart from hydrodynamic model application for developing inundation maps, Geographic Information System (GIS) Software can also be used. GIS has widely been used to map and model surface water and flood hazard (Aziz et al., 1998 (as cited in [6])). Digital Elevation Model (DEM) based flood extent with depth is an integral part of GIS can be adopted for flood hazard study. To get flood map of a study area, flood elevation generated from water level data, is subtracted from ground elevation data [6]. For obtaining flood extent it is necessary to have both interpolated water level and land elevation surfaces as flooding is a continuous phenomenon and interpolation is the procedure of estimating the value of properties at unsampled points or areas using a limited number of sampled observations.

In order to resolve the methodological gap, interpolation technique at GIS system has been applied using water level data of different stations in order to generate interpolated water level surface. There are number of interpolation techniques, designed for particular purpose are available in ArcGIS framework. One of is Kriging interpolation, which has been developed based on statistical models that include autocorrelation [7]. But for water level surface generation, the technique will not be appropriate as there is no statistical relation between the different stations in real scenario. On other hand, another interpolation technique, Spline is used for land surfaces generation, as the technique estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points [7]. But only Topo to Raster method is suitable for interpolating a hydrologically correct surface [7]. In the present study, Topo to raster interpolation tool of ArcGIS has been applied for generating interpolated water level surface. The point feature datasets can be converted to 4 m resolution ArcGIS grid format datasets using the Topo to Raster tool located in the ArcGIS Toolbox [14]. The Topo to Raster tool in ArcGIS 3D analyst results in a connected drainage structure and corrects representation of ridges and streams [4].

To analyze of how often particular flood intensity is likely to occur termed as Flood Frequency Analysis (FFA) is an important concept in flood hazard vulnerability study. FFA is a technique of statistical examination of the frequency – magnitude relationship [5]. It is an attempt to place a probability on the likelihood of a certain event occurring [5]. In FFA, return period (T) is used which have a statistical term meaning the chance of accidence once every T years over a long period [5]. Inundation maps at different return periods along with adjacent land coverage could be a useful analysis for flood hazard study. In this present study, yearly peak water level data of Brahmaputra–Jamuna, Karatoya and Bangali River has been used for FFA.