Real Time Flood Inundation Modeling for Midnapore-Kharagpur Development Authority (Mkda) Planing Region of West Medinipur District, West Bengal (India)

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Abstract

Natural disaster like flood and water logging is a worldwide phenomenon. In India, during intense monsoon, not only the rural areas but the urban areas are also badly affected by water logging. Midnapore Kharagpur Development Authority (MKDA) planning region of West Bengal is not an exception. This research is a fundamental step to assess flood inundation and water logging vulnerability of MKDA and their real time display on map, which can aid the decision making process of MKDA authority during heavy downpour. FLO-2D - a two-dimensional flood routing model, has been used to simulate runoff (channel flow, unconfined overland flow, street flow etc.) over complex topography. Spatial information on land use land cover, elevation, slope magnitude, slope direction, soil condition, and sewerage condition were incorporated in the model design; finally rainfall duration and amount are used as input to get the inundated areas as output. Model generated inundated areas of a real storm have been compared with actual inundated area extracted from microwave imagery (RADAR SAT-1) of the same date and with primary field survey map for validation of the model.

Keywords

Natural Disaster, Flood and Water Logging, Remote Sensing and GIS, FLO-2D Simulation Modeling, Real Time Display.

1. Introduction

Midnapore Kharagpur Development Authority (MKDA) was formed in the year 2003 in West Midnapore district of West Bengal (Fig.1). Basic objective behind the formation of MKDA was to provide better public amenities including construction of roads and streets, open spaces, park and recreational zones, new potential residential and commercial sectors etc. but rapid unplanned urbanization around Midnapore-Kharagpur and its consequent sewerage problem has led to extensive waterlogging throughout the rainy season. Total planning area of the development authority is 596.76 sq. km. consisting of 464 Mouzas (cadastre) with 14 Village-Panchayet Samiti of Medinipur, Kharagpur-I, Kharagpur-II, Salboni block and 54 wards of Kharagpur and Medinipur Municipal area. The general relief of the study area varies between 20m-60m above the Mean Sea Level. Kangsabati is a perennial river passing from west to east dissected the region into two parts north and south and created two converging slope pattern i.e. north west to south east and south west to north east (ref2).

In the year 2008, annual rainfall in the West Medinipur district was about 2594 mm. Most of the rainfall occurred during monsoon season (mainly in June, July and August) which was 400-500mm above the normal rainfall and most rainfall occurred mainly in three days i.e.16^{th}-18^{th} June which was about 607mm that badly affected the normal life style of Medinipur- Kharagpur Development Authority (MKDA) as well as the whole district (ref[1]). Many parts of the Midnapore and Kharagpur town were inundated. The above condition is the main motivation behind the study and for that reason some scientific approach related to realtime flood inundation simulation modeling has been adopted to find out the propensity of water logging. There are many factors responsible for this situation viz. 1.poor sewerage condition like absence of drainage, blockage of sewerage system, 2.unplanned development, 3.elevated road network, 4.expansion of settlement in lowlands etc. Application of GIS for real time rainfall runoff modeling is rapidly advancing and soon will be the frame work of a predictive early flood warning system. This research is a fundamental step to assess flood inundation and water logging vulnerability of MKDA and their real time display on map, which can aid the prioritization process of MKDA authority in their emergency sewerage clearance and mechanical water ejection during heavy downpour.

2. Objectives

The main objective of this study is to assess the water logging propensity of different parts of MKDA and its instantaneous display on map. This main objective can be divided into following sub-intents:

1. Estimation of the amount of runoff or total amount of water generation from a single storm.
2. Estimation of the out flows of water through the existing sewerage system.
3. Identification of the direction of water flow and zone of concentration.
4. Real time display of the spatial extension and depth of water logging.

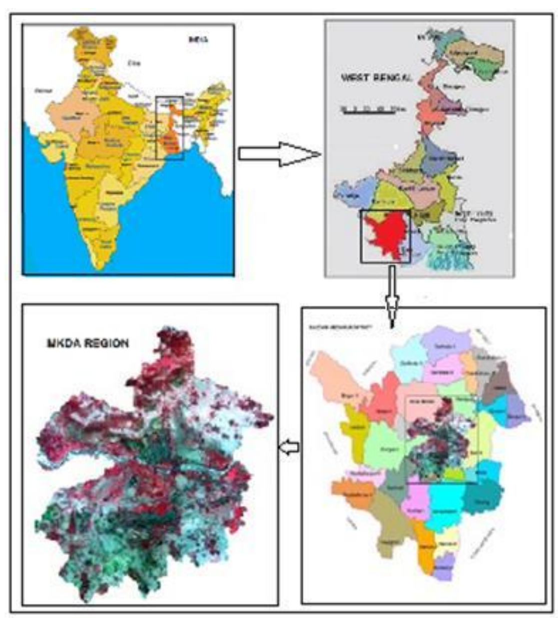


Fig.1 - Location map of the study area

3. Methodology and data used

The first and foremost step of this study was to scan and register all the base maps in digital environment. SOI Topographical sheet No. 73 N/3, 73 N/6 and 73 N/7 at 1:50,000 scale covering the study area were collected from Survey of India office – wood street, Kolkata. District map, MKDA planning map, Block maps are collected from MKDA office, 2nd floor, Sahid Khudiram Zilla Parikalpana Bhaban, Midnapore. Municipality maps of Medinipur and Kharagpur are collected from respective municipality offices. Sewerage condition map of the region is created by primary field survey with GPS. IRS LISS-IV satellite imagery (resolution 5.8m) used for land use land cover mapping, RADAR SAT-1 data (L-band), 2008 (Resolution 102 meter) used to find actual inundation, ASTER DEM (Digital Elevation Model) downloaded from reverb/ECHO website, with spatial resolution 90m is used for slope magnitude and slope direction, Hydrological Soil map of the study area is collected from NBSS & LUP – Salt Lake, Kolkata and rainfall data collected from Directorate of Agriculture, Govt. of West Bengal and Irrigation Department of Paschim Medinipur District.

3.1 Inundation Modeling

FLO-2D simplified the process of analytical solution in inundation modeling. It is a two-dimensional flood routing model that has been used to simulate runoff (channel flow, unconfined overland flow, street flow etc.) over complex topography (ref[3]). Spatial information on land use land cover, elevation, slope magnitude, slope direction, soil condition, and sewerage condition were incorporated in the model design; finally rainfall duration and amount are used as input to get the inundated areas as output. Shape files for importing results to GIS are automatically generated for most of the Mapper plots. By importing the DTM ground elevation points into Mapper and subtracting the ground elevation from the FLO-2D predicted maximum grid element water surface elevation, flow depths are computed for every DTM point.

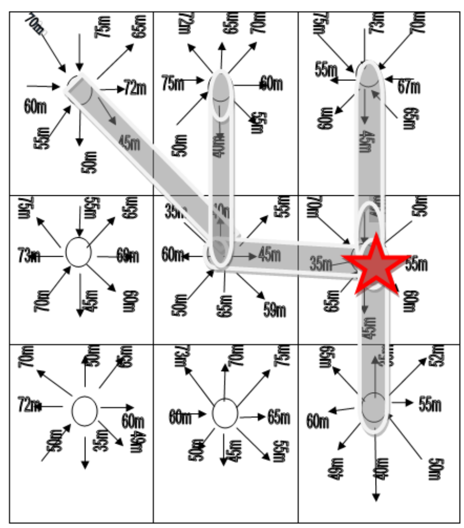


Figure 2. Simulation model architecture

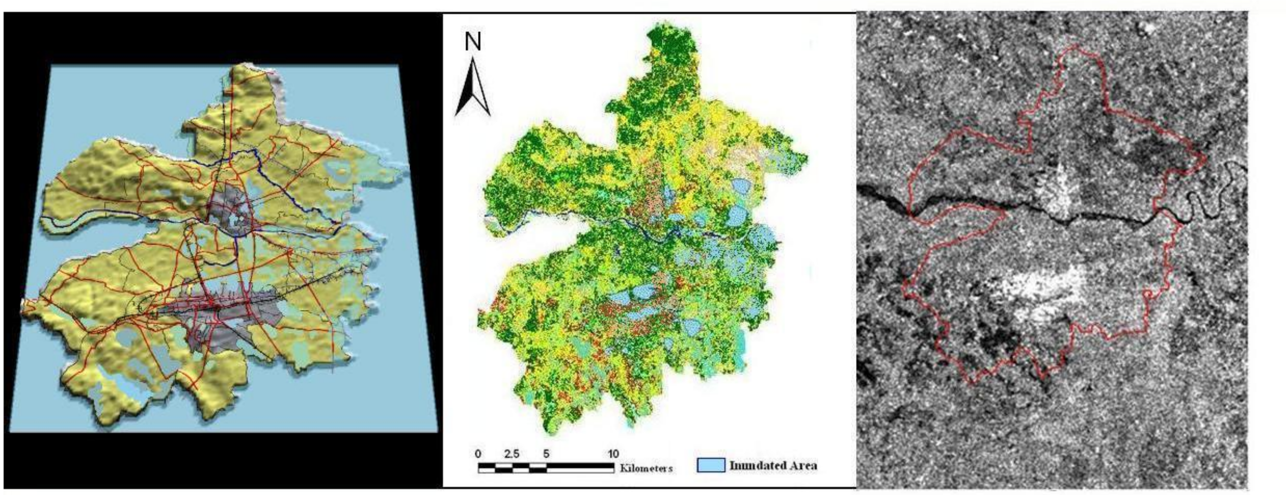
3.2 Functionality of the model

FLO-2D routes flows in eight directions as shown in Fig.2. The four compass directions are numbered 1 to 4 and the four diagonal directions are numbered 5 to 8. The grid element boundaries create an octagon shape. For a lucid description of the model architecture, the inundation model is summarized into 3x3 pixel format and arrows are denoted as slope direction. Firstly model consider first pixel which is XY. Water flows from this pixel to maintain slope height and slope direction to X+1,Y+1 pixel. Then model consider next pixel X+1,Y. In this process we get the zone of concentration of water (ref[3]).

4. Results and discussion

FLO-2D results include the maximum area of inundation (maximum flow depth), temporal and spatial hydraulic results, channel or floodplain cross section hydrographs, peak discharge and other hydraulic output. The 3D MAPPER program has been used to graphically review the model output. The flow depth results have been plotted as shaded contours in MAPPER. This integrated simulation model was used to predict the areas of flooding. For experimental basis we have given the actual rainfall (607mm) the 16^{th} to 18^{th} June of 2008 as input and we have got the 75.376sq km. area of inundation in municipal wards, Village Panchayets and Mouzas.

In Kharagur municipality ward no. 3,4,5,7,24,25,28; in Medinipur municipality ward no. 1,5,6,9,18,19 and Shrirampur, Chherua, Bishripat, Hatiholka and parts of Harispur, Kuldaha in Panchkhuri 6/2 Village Panchayat; Manguchak, Biji and parts of Anandaagar in Tantigaria Panchayat; Ghorachak, Keshpal, Gokulpur, Narayanpur, and part of Barcola, Jinsar in Barkola Panchayat are shown as inundated areas (Fig-3a). In monsoon season due to cloud cover standard FCC images are not available. This model generated inundated areas have been compared with the actual inundated areas extracted from microwave imagery (RADAR SAT-1) (Fig-3c) and primary field survey map (Fig-3b) of nearest date (28^{th} June, 2008). This model validation process is done by calculating the common inundation area using “union” tool of Arc GIS software. Outside this common region there were Juarhati, Paikarapur, Benasol ,Tentulia, Maheshpur in Kolaikunda Panchayat; in Kharagpur municipality



a. Simulated inundation map b. Field survey report c. RADAR SAT-1 Imagery

Fig.3. Model generated water logged areas and their corresponding ground truth (28th June, 2008).

ward no. 6 and 23; and in Midnapore municipality ward no. 2 and 3 which were actually inundated but not shown by this model. The accuracy level is found to be 67%.

5. Conclusion

Above result depicts that this model is capable of predicting the probability of inundation instantaneously but the accuracy level is not that high. Therefore it may be accepted as a partly successful model but introduction of few more factors like geological condition, ground water potentiality, may enhance the accuracy level up to 80% and in that case it would be very useful for assessment of the probability of inundation in other urban, sub urban and semi urban units of India.

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