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HYDRO DYNAMIC SIMULATION OF FLOODS IN KUSHABADRA RIVER USING REMOTE SENSING AND GIS

S.L.J. Fernando
Department of Geography, University of Ruhuna, Matara, Sri Lanka
E-mail: jagathferna@gmail.com

Abstract: Floods constitute the major disaster affecting many countries in the world year after year. They are inevitable natural phenomena occurring from time to time in all rivers and natural drainage systems, which not only damage lives, natural resources and environment, but also cause tremendous losses in the economy and health sectors. In this study an attempt has been made to develop an integrated methodology for flood mapping using satellite images, Geographic Information System (GIS) and Hydrodynamic modeling for the September 2003 flood incidence in Puri District, Orissa in India. Analysis from RADARSAT data by visual interpretation and digital interpretation portrays quite a reliable and stable inundation extent. A comparative analysis of the inundation extent was done and calculated in the flood ravaged area. Comparison of flood inundation maps has been made between the MIKE 11model output and the degrees of flooding which was detected by RADARSAT imagery. Based on the DN values of the RADARSAT imageries a model was developed to generate the condition to determine the flood pixel values and non-flood pixel values by using the ERDAS Imagery itself and ultimately, categorised into three as Deep , Moderate and Shallow floods. It is hoped that the use of GIS will provide supplementary data in Hydrology for such analysis and will lead to easier and better interpretation and understanding of flood phenomena and characteristics.
Keywords: Floods, satellite data, remote sensing, GIS.

INTRODUCTION

Floods represent the major disaster causative factor affecting many nations of the world all year round. As earlier indicated they constitute inevitable natural phenomena ravaging continents and regions with devastating to time in all rivers and natural drainage effects on human lives, natural resources and environment; one by implication on national economies. The impact of floods has increased due to among other factors, rising sea levels and increased development on flood plains (Sander & Tabuchi, 2000). Recurring flood losses have handicapped the economic development of both developed and developing countries.

Damage and devastation from flooding have been increasing each with subsequent year resulting in loss of lives, property and production as well as paralysis in the activities in flooded areas. Large and long duration of flooding could lead to great economic loss for any

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country. The non-structural methods of mitigation of flood hazards are very cost effective as compared with structural ones (dams and dikes). Among non-structural methods, modern flood forecasting and its association with real-time data collection systems have increasingly found favour with countries prone to flood hazards. Flood risk mapping is required to provide information concerning flood risk areas to residents in flood prone areas and to establish flood protection and evacuation systems. Shailesh Kumar (2004) has listed the causes of flood as follows,

- Steams carrying flows in excess of the carrying capacity within their banks, thus overflowing adjoining areas.
- Heavy rainfall synchronizing with river spill.
- Heavy local rainfall.
- Backing up waters in the tributaries at their outfalls into the main river with or without synchronizes of peak floods in them.
- Typhoons and cyclones.
- Synchronization of upland floods with hide tides.
- Inadequate drainage to carry away surface water with the desired quickness etc (Shailesh Kumar, 2004).

OBJECTIVES

Main Objective:

The general objective of this study is the analysis of flood inundation area using Remote Sensing and GIS techniques and flood inundation extent derivation using MIKE 11 hydro-dynamic model.

Specific objectives:

1. To map the flood inundation area by using the multi-temporal RADARSAT -1 Images;
2. To generate the flood inundation maps by using the Hydrologic Hydraulic Model of MIKE 11;
3. To classify and calculate the flood extent area by slicing method.

STUDY AREA

For this study, Kushabhadra River in Puri District of Orissa State in india was selected. The geographical location of the study area lies between at 19° 51’ 12” N and 20^0 21’ 25”N Latitude and 85^0 51’14” E with 86^0 06’ 20”E Longitude. The location of the study area is shown in figure 1.

The district of Puri is located in the coastal track of Orissa, known as Holy land of Load Jagannath. Its boundaries extend in the north to Jagatsinghpur District, in the south to Bay of Bengal and Ganjam District, in the west to Khurda District and in the east to Bay of Bengal. The entire Puri District is covered with plain alluvial track and coastal belt, mainly utilised for their high fishery potentiality. It has a sprawling beach line of about 150 kilometres.

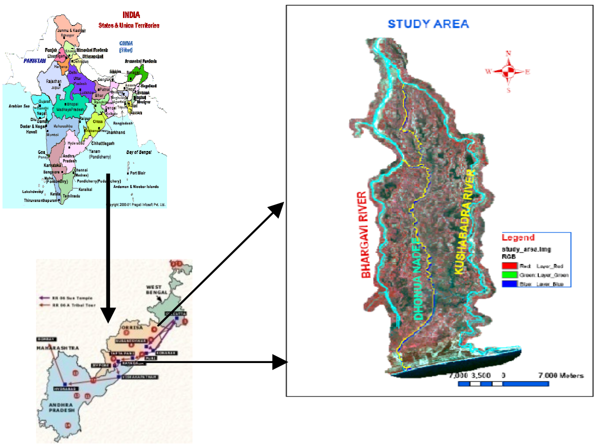

Figure 1 – Geographical location of the study area

MATERIALS AND METHOD

Methodology has been undertaken to achieve the above desired objectives for this study. Mythodology is consists of three major components namely, acquisition of data and processing of data and analysis of data.

Acquisition of Data

Primary and secondary sources were used this study for collecting data. Remote Sensing data, ancillary data and field data are collected to fulfill the objectives of this study. Remotely sensed data are used in this study with various sensors. RADARSAT images were helpful to demarcate land water surface in the study area. Multi-temporal RADARSAT imageries during pre-flood and post-flood of $4^{th}11^{th}$, 13^{th}, and 20^{th} September 2003, 50 meter resolution data are used for the interpretation of the flood ravaged area. Digital and visual interpretation process were applied by using the above motioned data sets. ASTER imagery from TERRA satellite system. ASTER (Advanced Space Born Thermal Emission and Reflection) is provided by Japanese Ministry of International Trade and Industry (MITY) programme. ASTER Digital Elevation Model is a product that is generated from a pair of ASTER level IA images. This level IA input includes Band 3N (Nadir) and 3B (After viewing) from the visible NIR with the resolution of 15 m. ETM PAN Data from LANDSAT series. ETM PAN Image with path 245 and row 139 dated 23 October 2003 data has been used to delineate the drainage network with stream. That could be useful to analysis with MIKE 11 Model as an input file.

Ancillary Data

Data of daily and hourly flood reports have been used to reveal the fluctuation of water level by flooding duration (Flood Cell, Bhubaneswar, 2003). Cross section of Kushabadra River at Balianta and Nimapara from 2000 to 2005 data were collected from Hydrometric_Office, Bhubaneswar (Hydrometric Office, Bhubaneswar, 2003). These data constitute input data in MIKE 11 Model. Gauge and Discharge data are used for analysing the dynamic behaviuor of the river in relation with the various magnitudes of flood. Data is obtained from Data Centre of Hydrometric Office, Bhubaneswar (Hydrometric Office, Bhubaneswar, 2006).

The Processing of data

In this study, main analytical processes were carried out in the MIKE 11 Hydrodynamic Model. The processing of data for simulation in MIKE11 Hydrodynamic Model involves preparation of Network file, Cross section file, Hydrodynamic file and Boundary parameters. There are four major input parameters which I had to use for this simulation according to the four editor modes. Network files are fefererred to as Dhonua*_re.nwk11,* Cross section files are mentioned as *crosssec_1.sns11***,** Boundary files called as *Bnd_dhonua.bnd11* and HD parameter files named as *Dhonua_HD.hd11*. Discharge data could be converted to the time series in the MIKE 11 Time series environment as an input of the model. The hourly and daily water level and Discharge data were created into compatible MIKE 11 time series in a separate input file.

Visual and Digital Interpretation

The objective of the visual interpretation is to generate the flood inundation map by using multi- temporal RADARSAT data of 4th, 11th, 13th and 20th September 2003. It was carried out by onscreen digitization in ERDAS Imagine 8.7. Moreover the Swiping option in ERDAS Imagine is employed to check whether there is any differentiation in land and water boundary. After digitization of datasets the vector layer was cleaned with built topology for converted to shape file. Digital interpretation was done based on threshold classification. Input maps were multi-resolution and multi temporal RADARSAT imagery of 4th, 11th, 13th and 20th September 2003.The range of pixel values studied was between inundated and disseminated areas. Based on the DN values of the RADARSAT imageries built a model was built to generate the condition to determine the flood pixel values and nonflood pixel values by using the ERDAS Imagine itself. Then classified map imported to ILWIS environment to reclassify for three classes. It has been divided into three classes as **"Deep Flood", "Moderate Flood"** and **"Shallow flood".** So, DN values are dependent factors for classifying into three classes (See figure 3).

ANALYSIS AND DISCUSSION

Visual interpretation and Digital image processing techniques are adopted to extract the flood inundation extent of the study area in the flood maps using RADARSAT data. This analysis is focused on two ways as namely,

1. Mapping of Flood inundation
2. Flood areal extent using hydro dynamic model

Digital Analysis

Digital interpretation method helped to find the quick and accurate area of flooding. The flood maps of the inundation area were extracted by using the threshold method with the help of Digital Numbers. It is seen observed that the threshold based classification gives fairly good results in determining the inundation extent compared with the visual interpretation. Result from above techniques is applied to different dataset with multi dates during the flood period corresponding with 4th, 11th, 13thand 20th of September 2003.

The range of threshold value is assigned to extract the flood level from other features present in the imagery. In case of db image of 50 m, the threshold map corresponds to 04th, 11th, 13th and 20th September and gaves an accurate level by using Digital Interpretation techniques. Initially the whole area was divided into two classes namely "Flood Area" and "Non Flood Area". Then by using the slicing techniques of the ILWIS environment again it was classified threshold into four as,

i. Non_ flood area
ii. Deep flood area
iii. Moderate flood area and
iv. Shallow flood area.

Initially misclassification is also seen on 20th September image in small pockets in the upper north western part of the study area which is mainly due to the presence of speckle and noise in the RADARSAT imagery. Table1 is showing how much area were inundated with the respect of flood classes mentioned above.

Table 1- Area calculation with flood classes

Date and months	Total Area Km^2	Deep flood area Km^2	Moderate flood Km^2	Shallow flood Km^2
4th September	245.95	44.31	99.36	102.26
11th September	195.22	39.43	71.17	84.62
13th September	195.17	28.71	74.73	92.21
20th September	107.81	19.18	36.50	52.12
Total	744.66	131.65	281.77	331.22

Source: RADARSAT data September, 2003

Though basically inundation trend of flood of this area is same as from 4th to 20th, there are some little differentiations visualised in the maps as well as in Table 1. Flood area extension has been changed owing to distributional patterns of features and intensity of rainfall. According to Table 1 mentioned above the highest inundation was observed on 04th of September and the lowest inundation area was on 20th September 2003. It can be visualised in the Figure 2.

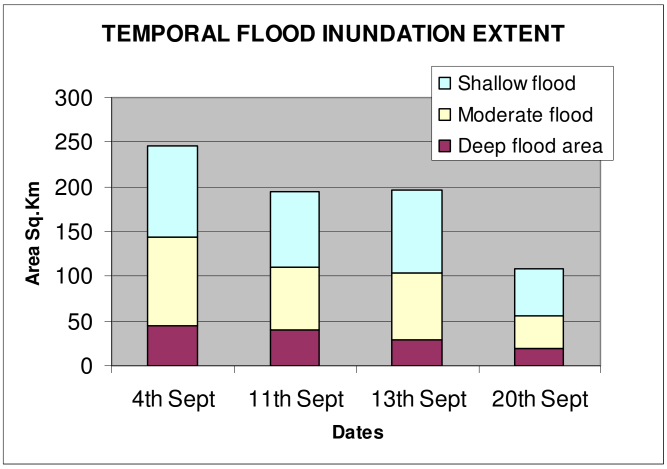

Figure 2- Temporal flood inundation extent

According to the Figure 2, of 04th of September, stags are relatively higher than the 20th September 2003 area inundated. Not only the interchanges, but within single day flood inundated area also changes itself. This relative trend can be identified on the visual interpretation maps shown above. The highest and the lowest flood inundation level can be identified by referencing the discharge data. Minimum discharge data at Balianta gauging station recorded 93.890m^3 on 26th August 2003. After that day it increased daily with great rapidly. The discharge level of 31 August was 3476.103 m^3 at the same station and it again increased 4051.112 m^3, on 01st September 2003.That was the highest discharge data reported at the Balianta gauging station. Even the highest inundating level observed on 04th September, where discharge level was little, decreased compared with the previous duration at the same station. However early rainfall triggered much of inundation which occurred in this area.

The main reason for the highest flood level of this area was related to the discharge level of Jogishahi Escape which is one place for the discharge of overflowing water from the left bank of Kushabadra River to the Dhonua Nadee. Therefore attention is concentrated on the discharge level at Jogishahi Escape. The highest discharge level at the Jogishahi Escape has been reported on 2nd September 2003 as about 1507.84 m^3 and the day before, it has been reported as 1418.65 m^3 at the same centre. Application of threshold techniques and their results can be shown by figure 3.

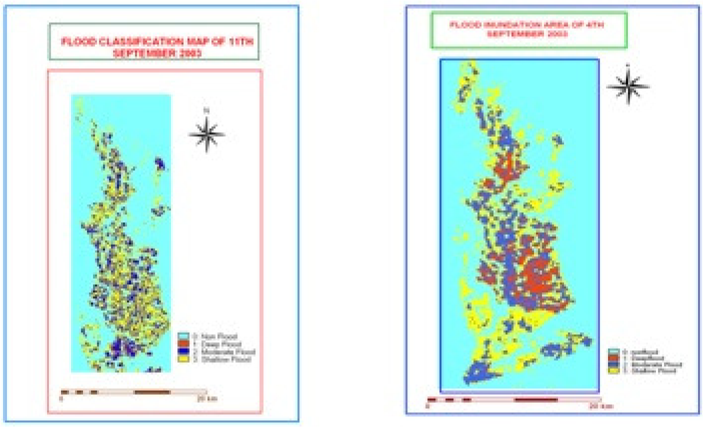

Figure 3 – Flood classification of the study area

In addition to that, proceding water of the Dhonua Nadee increased, after joining with the water from Achutpur Escape. From left bank of Bhargavi River where discharge level was higher than the previous time. The discharge level on 30th August was 981.81 m^{3}and on the 31st of August it became 1008.92 m^{3}at the Achutpur Escape. Even though, the discharge of the highest inundated period of 04th September was reported as a little bit decreased, the maximum inundated area can be seen. After two days of the highest discharge level at that centre; on 4th September, the inundated level became more severe as the flood inundation map shows above in Figure 3.

Profile analysis

Behavior of the flood level and fluctuation of the discharge level is discussed with this analytical part. Water surface profiles are shown at each water level at each cross-section at a particular time. The behaviour of flood level and discharge level have direct relationship which can be delineated by Figure 4, and sub diagram inserted here as A, B and C shows the results for each river and cross-section on 29th Aug 2003 at different times. Using ASTER DEM, the longitudinal profile of the stream, which is investigated in this study, has been generated. The Figure below shows the longitudinal profile details of the left and right flood plain, the initial water level and the maximum water depth reached during the peak discharge derived by MIKE 11 model. According to the longitudinal profile of Dhonua Nadi, the water level of Dhonua Nadee was normal on 29th September, 2003. It was nearly two meters from the bed level of the river.

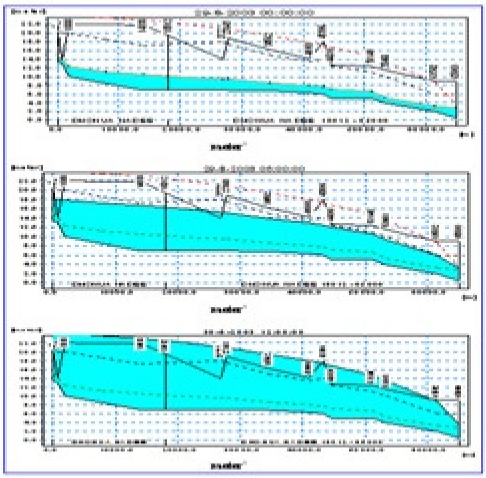

Figure 4: Longitudinal profile with water level in Dhonua Nadi at different times

Figure 4 is showing how to fluctuate the water level from the bed of river. It can be identified from diagram A of Figure 4. The water level of the Dhonua Nadee was being fluctuating from 20th September to 29th September 2003. So, on the first quarter of the day on 29th August, the water level of the river sequentially increased corresponding with 4m above from normal water level due to abnormal behavior of discharge in Kushabadra River and Bhargavi River. As a consequence the discharge level of Dhonua increased from 37 m^3/sec to nearly 1000m^3/sec. on 29th September. So manipulation of flood level was dependent on the fluctuating discharge in the rivers. When the discharge level was 1000 m^3/sec the flood level continuously increased around 15m to 21m at 12.00 hr on 29th August. It also varied from place to place.

The discharge level at Dhonua Nadee at 12.00 hr on 29th September was 2650 m^3 /sec. It was the highest discharge level on that day. It was 1650 m^3/sec compared with discharge level which was recorded at beginning hours on 29th September .As a result , the flood level subsequently increased to 21.5 m at 1.8 Km ,18.5m at 27.8 Km and 16.5 at 41.0 Km along with the river.

At one instant, the discharge level has been near to the highest from 2650 m^3/sec to 3900 m^3/sec level at 6.00 hr on 30th September. So, the water level of the river was beginning to increase up to a severe level of 23 m at 1.8 Km, 22.5 at 18 Km and 19.4 m at 41.0 Km in the stream from starting point. In respect of that, the flood level has prevailed at 22.5 m near the first portion of Dhonua and 6.3 m at 44,6 Km from the same point. It was the 40% increment of the flood level which we can see at 12.00 hr. before the same day.

According to the flood inundation results of this study, it was discovered that the highest flood level occurred at 12.00hr on 30 September 2003. It can be observed easily with longitudinal profile of **C** in figure 4. It indicates that, the highest flood level with dotted line is completely covered with flood water. The place from the beginning point to another particular point situated in study area has been inundated around 24m flood in the 2003 flood in Orissa state. With the distance of 41 Km along the stream, it became a 6m flood level. The day when peak flood was occurring discharge level of the stream also rose to top level. It was recorded as 1418.32at Jogishahi and 1008.92 at Achutpur Escape. While the discharge level was increasing, the flood extention phenomena was ongoing striking on the river bank and overflowing them. This can be seen in Figure 5.

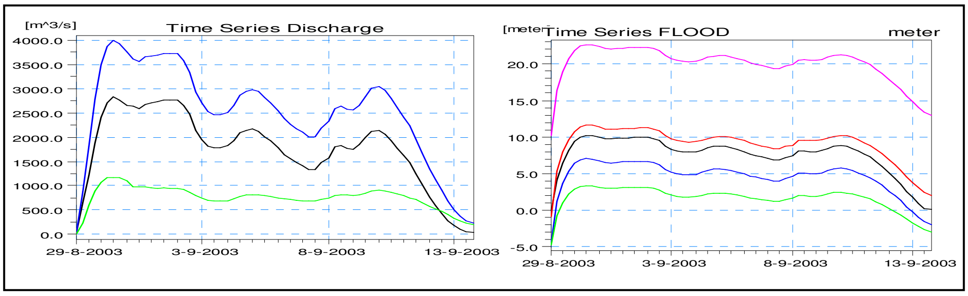

Figure 5: Flood level and discharge level in Dhonua Nadee

When the discharge level of 3960^{m3}/sec was reported in Dhonua Nadee as highest level, it increased up to 23.5 m of flood level at 1.8 Km from Jogishahi Escape. In addition to that from 14 Km distance from upper stream one can observe the 20.5 m flood level and the 41.0 Km flood level 18 m far from H point. It is the highest flood level which is observed in the downstream from 29th August to 13 September 2003. Therefore it can be seen that the highest flood height of this period was reported on 30th September at 12.00 hr as 23.5 levels in Dhonua Nadee.

CONCLUSION

Maximum flood inundation level is determined out on 4th September 2003. The highest flood inundated area is 245.95 Km^2, out of which 48% was out of deep flooded area. Deep flood areas would be the most vulnerable zone in the study site. The lowest flood extent on 20th September 2003 with an aerial extent of 107.81 Km^2 and Left bank of the Dhonua River was highly inundated in this study area in 2003 flood. The whole flood area has been classified into three groups as mentioned above and out of them shallow flood extent is higher when compared with others. However the interpretation results and flood simulation results are most probably super imposed with the help of simulation results file and interpretation file.

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