Hydro Dynamic Simulation of Floods in Kushabadra River Using Remote Sensing and GIS

S. L. J. Fernando
DEPATRMENT OF GEOGRAPHY, UNIVERSITY OF RUHUNA, MATARA, SRI LANKA
jagathferna@gmail.com

Abstract

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which is not only damages the lives, natural resources and environment, but also causes the loss of economy and health. In this study an attempt has been made to develop an integrated methodology for flood mapping using satellite images and Geographic Information System (GIS) and Hydrodynamic modeling for September 2003 flood phenomena of Puri District, Orissa in India. Analysis from RADARSAT data by visual interpretation and digital interpretation gives quite a reliable and stable inundation extent. A comparative analysis of inundation extent was done and calculated the flood extent area. Comparison of flood inundation maps has been made between the MIKE 11model output and flood extent, which was detected by RADARSAT imagery. Based on the DN values of the RADARSAT imageries built a model and generated the condition to determine the flood pixel values and non-flood pixel values by using the ERDAS Imagine itself and ultimately, sliced in to three classes as Deep , Moderate and Shallow floods. Use of GIS will provide supplementary data in Hydrology for such analysis and will lead to easier interpretation and understanding of flood phenomena and characteristics.

***Key words**: Floods, satellite data, remote sensing, GIS.*

INTRODUCTION

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which not only damages the lives, natural resources and environment, but also causes the loss of economy and health. The impact of floods has been increased due to a number of factors, with rising sea levels and increased development on flood plain (Sander & Tabuchi, 2000). Recurring flood losses have handicapped the economic development of both developed and developing countries.

Damage from flooding has been increasing each year resulting in loss of lives, property and production as well as affecting activities in the flooded areas. Large and long duration of flooding can be considered as the economic loss of the 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 the association with real-time data collection systems have increasingly found favor 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 system. 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 OF THE STUDY

Main Objective:

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

Specific objectives:

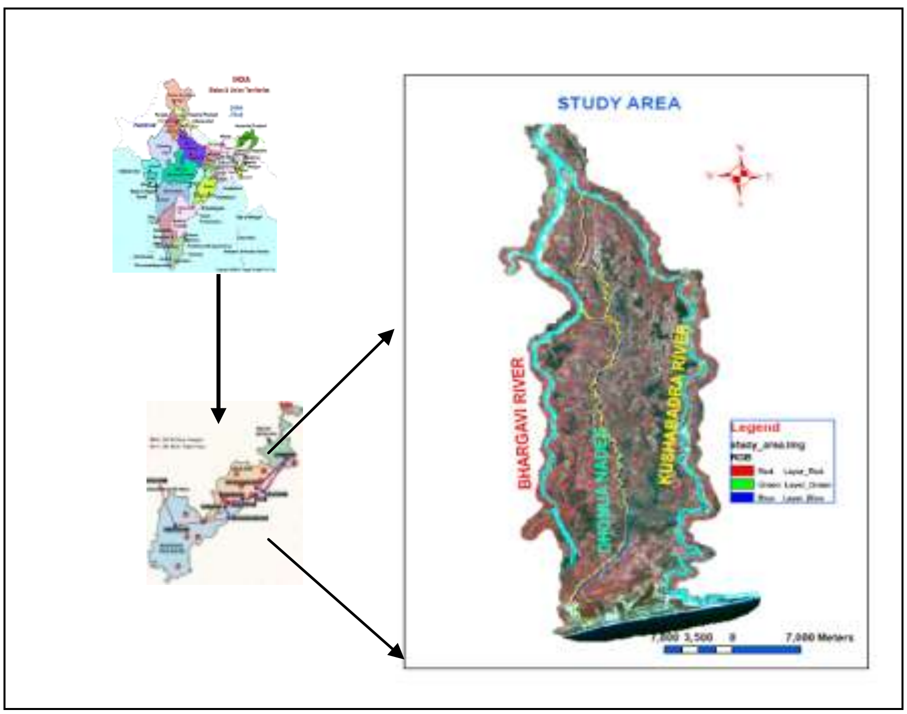
1. To map the flood inundation area by using the multi-temporal RADARSAT -1 Images;
2. To generate the flood inundation maps by using the Hydrologic Hydraulic Model of MIKE 11;
3. To classify and calculated the flood extent area by slicing method.

STUDY AREA

For this study, Kushabhadra River in Puri District of Orissa State was selected. The geographical location of 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 where 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 utilized for them high fishery potentiality. It has a sprawling beach line of about 150 Km.

Figure 1 – Geographical location of the study area.



METHODOLOGY AND MATERIALS

Methodology has been undertaken to achieve the above desired objectives for this study. Mythology is consist with three major components as, acquisition of data and processes and analysis of data

Acquisition of data

Primary and secondary sources were based on this study for collecting of data. Remote Sensing data, ancillary data and field data could be collected to fulfill of my objectives of this study. Remotely sensed data are used in this study with various sensors. RADARSAT images were helpful to discriminate of 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 to interpretation of flood extend area. Digital and visual interpretation process has been done 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 of 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 has 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 was collected from Hydrometric_Office, Bhubaneswar (Hydrometric Office, Bhubaneswar, 2003). This data had to use as an input data in MIKE 11 Model. Gauge and Discharge data are used for analysis the dynamic behavior of the river and are corresponding with various magnitudes of flood. So that, data 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, and 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 name as Dhonua*_re.nwk11,* Cross section files name as *crosssec_1.sns11***,** Boundary files name as *Bnd_dhonua.bnd11* and HD parameter files name 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 how to generate the flood inundation map by using multi- temporal RADARSAT data of 4^{th}, 11^{th}, 13^{th} and 20^{th} 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 and 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 4^{th}, 11^{th}, 13th and 20^{th} September 2003.The range of pixel values studied between inundated and disseminated areas. Based on the DN values of the RADARSAT imageries built a model and generated the condition to determine the flood pixel values and nonfood pixel values by using the ERDAS Imagine itself. Then classified map imported to ILWIS environment to reclassify for three classes. It has been sliced in to three classes as **"Deep Flood", "Moderate Flood"** and **"Shallow flood".** So, DN values are depended factor 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 with two ways as follows,

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

Digital Analysis

Digital interpretation method helped to find the quick and accuracy 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 that the threshold based classification gives a fairly good results in extraction out the inundation extent compare with the visual interpretation. Result from above techniques which is applied to different dataset with multi dates during the flood period corresponding with 4^{th}, 11^{th}, $13^{th}$and 20^{th} of September 2003.

The range of threshold value is assign to extract the flood extend 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 gave an accurate extent by using Digital Interpretation techniques. Initially whole of the area were threshold into two classes as "Flood Area" and "Non Flood Area". Then by using the slicing techniques of the ILWIS environment again threshold into four classes as,

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

Initially misclassification is also seen on 20th September image in small pocked 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. The table1 is showing that how much of area were inundated with the respect of flood classes mentioned above.

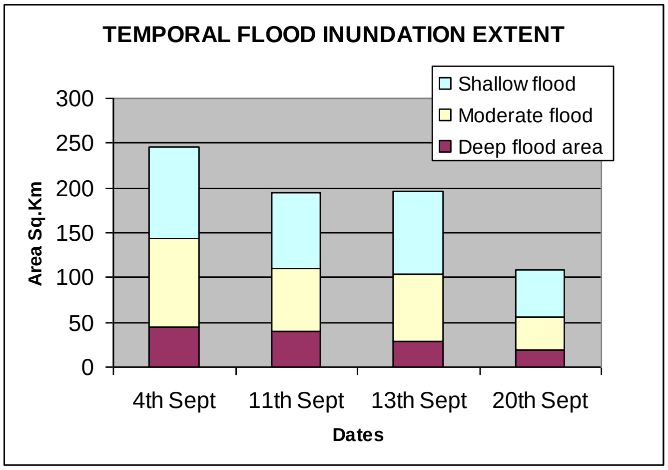
Table 1- Area calculation with flood classes

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 visualize in the maps as well as in the table 1. Flood area extension has been changed owing to distributional patterns of features and intensity of rainfall. According to the table 1 mentioned above the highest inundation observed on 04th of September and lowest inundation area represent on 20th September 2003. It can be visualized the figure 2.

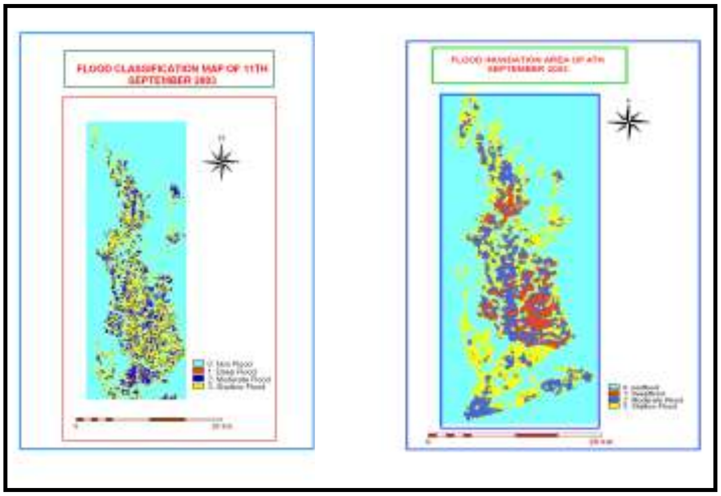
Figure 2- Temporal flood inundation extent



According to the figure 2, on 04th of September stags are relatively higher than 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 showing above. The highest and the lowest flood inundation level can be proved by referencing the discharge data. Minimum discharge data at Balianta gauging station recorded that 93.890m^3 in 26th August 2003. After that day by day it has increased with rapidly. The discharge level of 31 August was 3476.103 m^3 at the same station and it has 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 compare with the previous duration at the same station. However early raining was affected to that much of inundation had occurred in this area.

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

Figure 3 – Flood classification of the study area

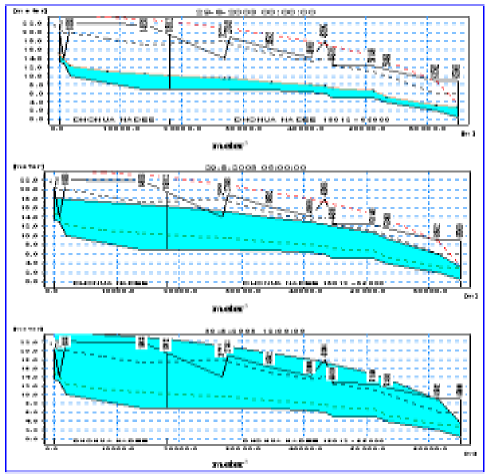


In addition to that, antecedent water of the Dhonua Nadee became more, after coherent with water from Achutpur Escape which is belonging with the left bank of Bhargavi River where discharge level too higher than the previous time. The discharge level on 30th August was 981.81 $m^3$and 31st August it became 1008.92 m^3at the Achutpur Escape. Even though, the discharge of the highest inundated period of 04th September was reported as 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 more severe as if the flood inundation map showing above figure 3.

Profile analysis

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

Figure 4 – Longitudinal profile with water level in Dhonua Nadi at different Time



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

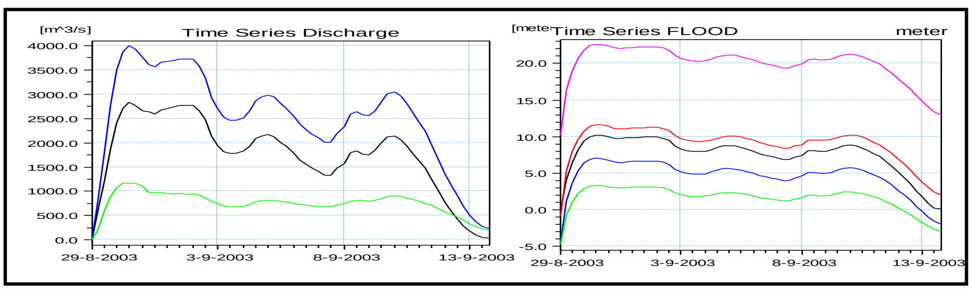
The discharge level at Dhonua nadee at 12.00 hr on 29th September was 2650 m^3 /sec. It was the highest discharge level on that day. It considered with 1650 m^3/sec compared with discharge level which was recorded at beginning hours on 29th September .As a result , the flood level has subsequently increased as 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 river was begging to increase up to severe level as 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. With respect of that, the flood level has prevailed at 22.5 m near to the first portion of Dhonua and 6.3 m at 44,6 Km from 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, I found that the highest flood level was occurred at 12.00hr on 30 September 2003. It can be observed easily with longitudinal profile of **C** in figure 4. It is indicating that, the highest flood level with dotted line which 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 2003 flood in Orissa state. When the distance from 41 Km along the stream, it became 6m flood level. The day when peak flood was occurring discharge level of the stream also risen up to top level. It was recorded as 1418.32at Jogishahi and 1008.92 at Achutpur escape. While the discharge level was increasing the flood extending phenomena has ongoing with striking on the river bank and overflowing from them. It 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 has been increased up to 23.5 m of flood level at 1.8 Km from Jogishahi Escape. In addition to that 14 Km distance from upper stream can observe 20.5 m flood level and at the 41.0 Km flood level was 18 m far from H point. It is the highest flood level which is observed in the downstream from 29^{th} August to 13 September 2003. So, I can describe that the highest flood height of this period was reported on 30^{th} September at 12.00 hr as 23.5 levels in Dhonua Nadee.

CONCLUSION

Maximum flood inundation extent is extracted out on 4th September 2003. The highest flood inundated area is 245.95 Km^2, out of which 48% 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 of this study area in 2003 flood. Whole flood area has been classified as three group as mentioned above and out of them shallow flood extended is higher to compare others. However the interpretation results and flood simulation results are most probably super impose with the help of simulation results file and interpretation file.

Acknowledgement *I take this opportunity to pay my deep heartiest gratitude and acknowledgement to my project supervisor Dr V. Hari Prasad, Head, Water resources Division, for the valuable, constructive and critical guidance trough out for the project.*

REFERENCES

Butts, M.B.; Payne, J.T.; Kristensen, M. and Madsen, H.(2004), "An evaluation of the impact of model structure and complexity on Hydrological modeling uncertainty for stream flow prediction", *Journal of Hydrology*, Vol. 298, 242-266.

Flood Cell,(2003), "Discharge data in Maha Nadee Basin Plain", *Flood Cell Report*, Government of Orissa, India.

Fread, G.L. and Jin, M.,(1997), "Dynamic flood routing with Explicit and Implicit Numerical Solution Schemes", *Journal of Hydraulic Engineering*, ASCE, Vol. 123, pp 166-173.

HEC,(2002), Hydrologic Engineering Centre, *HEC-RAS User manual*, Army Corps of Engineers, United States.

HEC, (2001), Hydrologic Engineering Centre, *Hydraulic References*, Army Corps of Engineers, United States.

HEC,(2002), Hydrologic Engineering Centre, *HEC-Geo-RAS User manual*, Army Corps of Engineers, United States.

Hydrometric Office,(2003), "River Network Data", *Annual Report*, Hydrometric Office, Bhubaneswar, India.

MIKE 11, (1999), "Modeling System for River and Channels, Short Introduction" *Guide to getting starts tutorial*, Danish Hydraulic Institute, Denmark.

MIKE 11 GIS, (2000), Flood Modeling and Management tool, Reference and User Manual, Danish Hydraulic Institute, Denmark.

MIKE 11, (2003),"A brief introduction to MIKE 11 and its capabilities", *tutorial hand book*, Danish Hydraulic Institute, Denmark.

Sanders, R. and Tabuchi, S., (2000),"Decision Support System for Flood Risk Analysis in River Thames", *Photogrammetric Engineering and Remote Sensing Journal*, Vol. 66, No. 10, United Kingdom.

Shailesh Kumar Singh, (2004), *Analysis of Uncertainties in Digital Elevation Models of Flood (Hydraulic) Modeling*, MSc Thesis in Geo information Science and Earth Observation with Specialization in Natural Hazard Studies, ITC and IIRS.

Xihua Yang and Bengt Rystedt, (2002), "Predicting Flood Inundation and Risk using GIS and Hydrodynamic Model": A case study at Eskilstuna, *Journal of Hydrology*, Vol. 106, pp 211-232 Sweden.

MIKE 11, (2004),"A Brief Demonstration of Flood Modeling Management", available at http://www.dhisoftware.com/mike11/descripton/whatismike11.htm, (accessed 12 March 2005).