

**ASSESSMENT FLOOD VULNERABILITY AND MITIGATION PLANNING  
IN MUNSHIGANJ DISTRICT OF BANGLADESH  
USING REMOTE SENSING AND GIS**

Kulapramote PRATHUMCHAI  
Geoinformatics Center, Asian Institute of Technology, PO Box 4,  
Klong Luang, Pathumthani, Thailand. 12120  
Email: kulapram@ait.ac.th

Lal Samarakoon  
Earth Observation Research Center, Japan Aerospace Exploration Agency,  
Triton Square Office Tower-X 23F, 1-8-10 Harumi, Chuo-ku, Tokyo, JAPAN 104-6023  
Email: lal@ait.ac.th

**KEYWORDS:** Flood, Mitigation, GIS, Remote Sensing

**ABSTRACT:** The geographical position and topographic composition have made Bangladesh vulnerable to natural disasters. Bangladesh is frequently hit by natural disasters, most of them related to water, like flood, drought, riverbank erosion and cyclone associated storm surge etc. Munshiganj district is situated on the mixed floodplains of rivers the Ganges (Padma), the Brahmaputra (Jamuna), and the Meghna. Every year even during normal rainy season floodwater drains through bordering rivers of the area to the Bay of Bengal. Most of the severe floods affect large area and cause maximum damages to the lives and properties in comparison to other areas. On the other hand, the area is densely populated and the number is increasing rapidly raising the number of people at risk.

A study was therefore carried out to create a flood vulnerability map of Munshiganj district using satellite and GIS techniques. Landsat TM data was used to generate a land cover, while JERS-SAR and RADASAT data were combined to map the flooded area in a normal flood event. Combining them with population data a population distribution map was produced according to land use types. Subsequently, this outcome was compared with flooded area mapped using satellite data in creating population that is at risk during a normal flood event. Attempt was made to identify shelters in a flood event based on information such as existing schools/hospitals location, topography and accessibility. Serviceable area of shelters was carried out based on shelters location and land surface conditions. Finally, an evacuation plan as a flood mitigation action for Mushiganj district was proposed based on optimum route to selected centers.

## **1. INTRODUCTION**

Flood is the most devastating natural phenomenon that affects and disrupts the well being of a society, especially that of poor people due to the limitation of their resources. Most of the natural disasters in Asia are related to flood causing maximum damage to lives and properties in comparison to other disasters. Bangladesh is probably the most affected country by such flood hazards.

Bangladesh is known as the 'land of rivers' and major rivers that flow through Bangladesh are the Ganges, the Brahmaputra and the Meghna with a complex network of 230 rivers including 57 international trans-boundary (cross boundary) rivers. The Ganges (Padma), the Brahmaputra (Jamuna) and the Meghna are the large rivers systems in the world covering a total combined catchment area of about 1.6 million sq km and extending over Bhutan, China, India and Nepal of which only 7% falls in Bangladesh (FFWC, 2001). Topography of the country is mostly flat except some part in the northeast and southeast, which are hilly. The land elevation varies from 3 to 90 m above MSL. More than 50% of the floodplain is within the 5m level above MSL. The very location and the topography make the country vulnerable to floods.

People in Bangladesh accept flood as a part of their life that bring both good and evils. A normal flood that occurs every year is not a problem for them as they are habituated to accept it. However, Bangladesh experiences severe floods affecting large number of people in the extreme case. Therefore, it is vital to develop a plan to live with flood and prepare an appropriate land use planning and mitigation measure.

## 2. OBJECTIVE

The main objective of the study was to make the use of remote sensing and GIS for flood hazard mitigation by the way of;

- Preparation of flood map and identify vulnerability of flooding area
- Developing criteria to identify suitable locations for shelters
- Identifying the best route for evacuation
- Proposing a suitable flood mitigation/evacuation plan

## 3. STUDY AREA AND THE DATA

Munshiganj district lies approximately between 23°22' to 23°40' N latitudes and 90°05' to 90°42' E longitudes (Figure1) and has area of about 919 sq km. The population of the study area is according to the population census of 2001 (BBS 2004) is 1,293,972. The main physiographic units of the area include the floodplains of the Padma, the Jamuna, the Meghna and the Old Brahmaputra rivers.

The study area has a tropical and humid monsoon climate characterized by the twice-yearly reversal of air movement in the area. From December to March (winter) airflows from northeast, while from June to September (summer) it flows from the southwest. The southwest monsoon originates over the Indian Ocean and carries warm moist air that produces some of the highest rainfalls in the area. A reversal of the monsoon takes place in about two months. The first reversal occurs in April-May when the change of regional wind direction is from northeast to southwest via northeast and the second reversal occurs in October-November when the change is from southwest to northeast via southwest. Average annual rainfall ranges from 1400 mm in the southwest to 2200 mm in the northeast. About 85% of the rainfall occurs during monsoon i.e. from June to September. Direct rainfall, over bank spills from the major boundary rivers and over bank spills from the international or regional rivers are identified to be the three sources of a flood event. Following are the data used for the study.

- Landsat TM 2002 February
- JERS SAR (L Band) 1996 June
- ADEOS AVNIR 1996 November
- RADARSAT (Scan SAR Wide mode) 2004 July
- SRTM 2000
- Population 2001 taken from the Bangladesh Bureau of Statistics
- Administrative boundaries, roads, water bodies, Agricultural land, Metal roads, School/College and Hospital from LGED

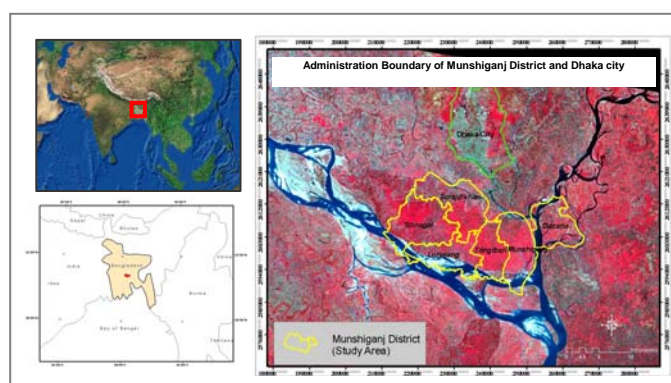


Figure 1 Location map of the study area

#### 4. METHODOLOGY

Figure 2 shows the conceptual flowchart developed for the study. This figure shows the main input information, analysis method and output. There are landuse map, normal flood map and population affected based on land cover as population density. Further it was attempted to develop the methodology to identify the suitable of shelter location, shelter's serviceable area as well as path to evacuate people while flood occurring.

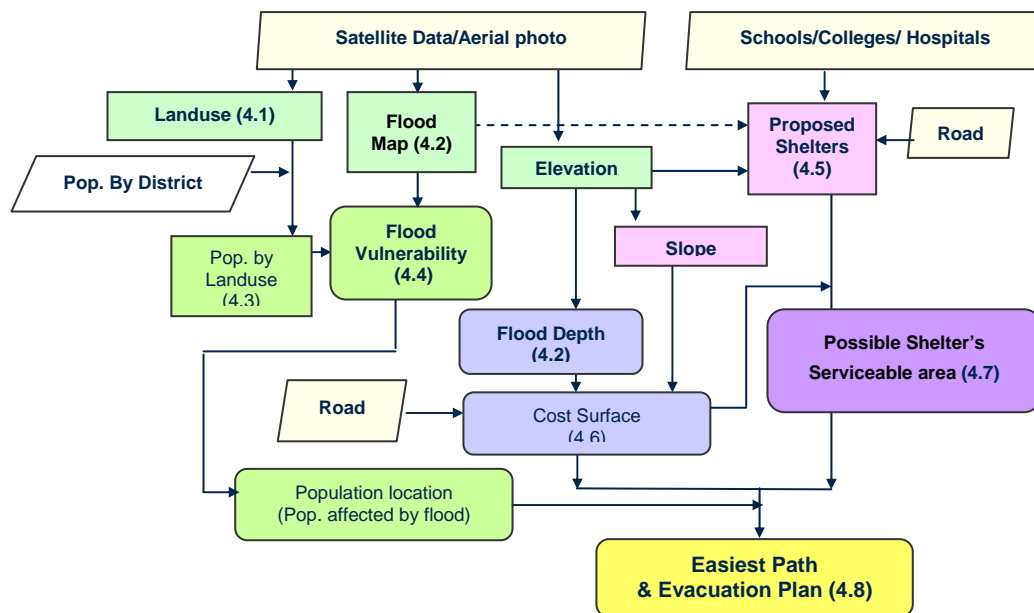


Figure 2 Flowchart depicting major steps of analysis

The significant data and output are listed below and explained in processing function;

##### 4.1 Land use map

Vector data layers of land cover of the study area were generated for preparation of land use map. The data layers have been generated from aerial photographs taken during 1999-2000. The land cover and the land use of the study area were found to be very heterogeneous. Therefore, visual interpretation, the most primitive method in land feature interpretation has been applied using aggregated datasets with on screen digitization technique. ADEOS AVNIR data and Landsat TM data were used for interpretation of the confusing land features of the study area.

##### 4.2 Flooding area and Flood depth map

This was generated combining optical and SAR data. Attempt was made to combine two sensor data as a way of practical usage of satellite data during a rainy season when it is impossible to acquire optical sensor data. ADEOS AVNIR, JERS SAR along with and RADASAT were used for interpretation of the flooded and non-flooded areas. Simple threshold classification technique and visual interpretation were used in interpreting both optical and SAR images. It was not difficult to interpret flooded areas on SAR images. Except for few locations, scattering from flooded areas were comparatively low when compared to other areas. The intermediate mean value created confusion, these areas were covered with summer rice in floodwater and the brighter area was hyacinth on the floodwater. In this cases, optical images and field verification had been used to further clarify in flooded and non-flooded areas where there was ambiguity in interpreting satellite data. Also, the optical images helped in identifying water features that are not affected by rainfall. Further, flood map and SRTM image were calculated for averaging the normal flood boundary. It was identified at the altitude of 7 meters then built flood depth using cut/fill technique to subtract elevation at flood boundary maximum height. Finally, inside flood depth classification was completed.

### 4.3 Population by landuse

Population information received from statistical department was in Union (sub-district) basis. This data merely states the number of people registered in a given Union, but does not reveal real spatial distribution of population. It is unrealistic to say that population density is uniform through out a given sub-district as the inhabited area could be a fraction of the total land area of a district. Sub-district was not an appropriate spatial size to use for most population distribution, but village base data which could be the appropriate spatial unit to represent population distribution was not available. The question of estimating a realistic population distribution was addressed incorporating land use categories with population of sub-districts. In order to establish different population densities with respect to land use classes, a population density ratio of corresponding to 3 major landuse classes in each sub-district was used 16.63:1:0 which referred to Urban: Rural: Agriculture & Water bodies. This ratio was calculated from total population of Munshiganj district where the source from the National Summary books of Population Census of 2001, published in 2003. (Population in urban was 166,960 in 6.69 Sq.km. and rural was 1,122,140 in 74.76 Sq.km.)

### 4.4 Flood vulnerability map

Flood vulnerability map was generated from population affected by flooding area. Flood map was extracted to population distributed by landuse, the vulnerability was estimated by the size of population which was affected by flood in each area. The final product was to generate the vulnerability area to points (centroid) location of population, these points were assumed as village locations as were used for evacuation process.

### 4.5 Proposed flood shelters

The criteria for selecting a shelter at the initial stage was based on four factors as given below;

1. A shelter should be existing schools/colleges/hospitals
2. It/They should not fall in flooded area
3. Should be within 200 m. from an asphalt/metal road
4. Need to be at a level not less than 10 m.

There were 89 schools/colleges/hospitals satisfied above criteria. Querying process was done through the existing schools, colleges and hospitals. Basic concept as shelters should be out of flood area, located in high land, which was identified as 10 meter or higher and last criteria, was emphasized on transporting to evacuate people.

### 4.6 Cost Surface

Cost is the “trouble” or “difficulty” to reach a shelter from a place of living. If a person is required to select a shelter among several nearest of them, it could be first made based on the distance. However, in some cases the linear distance may not be the critical factor as these could be un-passable areas between the shelter and the place of living. This un passable area could be a river, flood area, mountain etc. in which case it could be assumed of a higher degree of difficulty. In the Cost Surface this is evaluated for each cell on defined factors. In the present study four factors that could influence the selection of a shelter was used to create the cost. Those are Flood Depth, Road Surface Density, Road Accessibility and Slope. The percentage of influence by each factor was assumed to be 40:30:20:10, for Flood Depth, Road Surface Density, Road Accessibility and Slope, respectively.

**Flood Depth:** This factor was defined as the most influencing factor (40%) for the cost surface. During a flood, it would not be possible to move through the inundated area; higher the flood depth more the difficulty. This study focus in cases of evacuation on non-flood area or where low flood level therefore the assumption excludes boats etc. The rivers and water bodies were identified as most difficulty to travel as same as flood depth at very high level.

**Road Surface Density:** This was considered as the second most influencing factor (30%). Road density of each cell was calculated based on road type by assigning 20 m. to metal roads and 8 m. to the rest. More roads provide better access implying less cost.

**Road Accessibility:** This factor indicate the distance to roads. Higher the remoteness of the place of having from roads was lesser the accessibility to roads and higher the cost. This factor was attributed with a 20% influence.

**Slope:** Slope is another factor that affects the travel time and that would indicate the topography that cannot be crossed. As the study area was laying in a flood plane, the area had only micro relief.

Finally, cost was created by combining all four factors using weighted overlay technique in GIS software tools in a raster environment. Details of weighting and reclassification of oriented score are shown in Table 1.

Factors	% Influence For cost	Classes	Interpretation	Cost score
• Flood depth	40	- Non Flood - Flood depth <= 1 m. - Flood depth >1-3 m. - Flood depth >3-5 m. - Flood depth >5 m. & Rivers	-No flood -Low flood depth -Moderate flood depth -High flood depth -Very High flood depth	1 2 3 4 5
• Road surface density	30	- Metal road area > 10% - Metal road area <=10% or Soft road area > 10% - Soft road area <=10% - All road area = 0%	-High density -Moderate density -Low density -No road density	1 2 3 4
• Road accessibility	20	- Inside Metal & Soft road buffer - Inside Metal buffer 500 m. - Inside Soft road buffer 100 m. - Outside Metal & Soft road buffer	-Very high accessibility -High accessibility -Moderate accessibility -Low accessibility	1 2 3 4
• Slope	10	- Slope 0 - 5 % - Slope 5- 10 % - Slope > 10 %	-Low steep slope -Moderate steep slope -High steep slope	1 2 3

Table 1. Weighting influence factors and scoring factors for cost surface analysis

#### 4.7 Shelter’s serviceable area

As discussed in Section 4.5, 89 areas of building were found to be shelters. This step was superimposed to determine the size of population that would seek each shelter. The basic concept was to identify the zone of each shelter based on the neighbor shelters and the nearest distance to them. In section 4.5, it was shown that serviceable area of a shelter will not simply depend on geographical distance, rather it should be based on the “difficulty” to arrive at a place which was discussed as cost. The shelter location points (89) and cost surface which generated in section 4.6 were input in Cost allocation tool in ArcGIS to identify the zone of each source cell that could be reached with the least accumulative cost. This analysis is very useful for evacuation planning, suppose people is living in between two shelters with equal distance, if the topography are same then we can say that people can go to either shelter. If the topography (travel surface) are not the same such as way to go to the first shelter have more road, not high steep slope and no flood then it have least cost. Moreover, these would be for mitigation planner or government to support/improve of shelter’s potentials.

#### 4.8 Best evacuation path

Determination of the best way to go (least-cost path) was carried out using Cost distance tool in ArcGIS. The analysis considers destination and origin together with cost surface. Origin places located where people live and in this case it was assumed this location to be the centroid of polygon that are identified as flood affected areas. Destinations were the shelters that were identified in previous section. The tool calculates accumulated cost of traveling from any particular location to each shelter points and generate least cost path.

## 5. RESULT

Figure 3 and 4 show Landuse map and the flooded/non-flooded areas of the study. There are four categories of land use: agriculture, built-up, settlement, and water bodies. During normal flood 61 % of the study area is affected by flood and the affect is very prominent in west part of the study area.

Figure 5 shows the Flood vulnerability map. It was found that almost all unions of this district would be inundated during a flood event. In terms of area and population affected by flood, the Serajdikhan is the most affected Upazila (93.61%) due to its elevation which is comparatively low. Lowest affected area is Lohajang (83.95%).

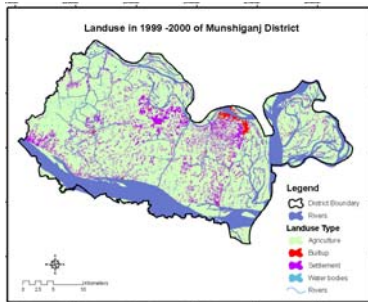


Fig.3 Landuse map in 1999-2000



Fig.4 Food and non-flood area

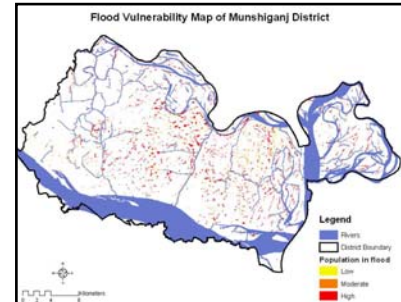


Fig.5 Flood vulnerability map

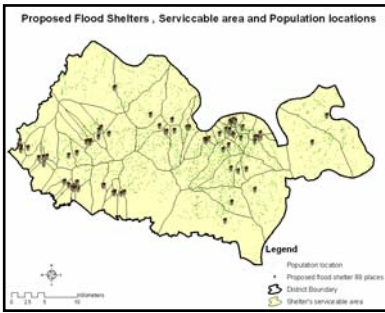


Fig.6 Propose shelters & Serviceable area

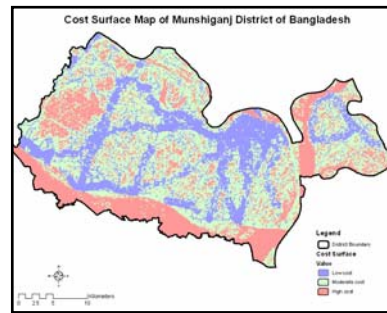


Fig.7 Cost Surface map

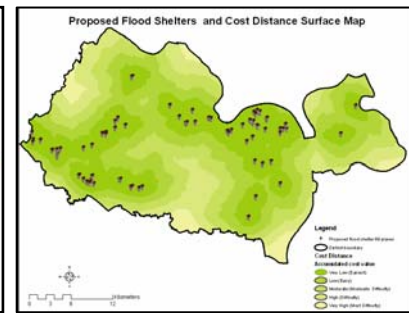


Fig.8 Propose flood shelters & Cost Distance Surface map

Figure 6 shows the generated map with 89 shelters based on population limit and cost surface. The boundaries represent serviceable areas of each identified shelter. Figure 7 shows the Cost Surface classified into three categories; High, Moderate and Low. The low cost areas mostly consist high density of roads and outside flood area. Proposed 89 flood shelters and Cost Distance are shown in Figure 8 The Cost Distance Surface illustrates smooth continues surface of accumulated cost value. The least cost was found near shelters and increasing with the distance.

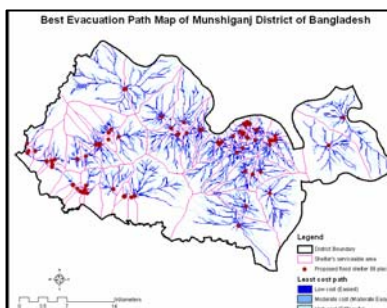


Fig.9 Least cost paths for evacuation



Fig.10 Least cost paths with road networks & flood area

Figure 9 shows the best path for evacuating people in each serviceable area of 89 shelters. When comparing the evacuation path with road networks and flood prone areas, it was found that this analysis is rather precise. The best path provides less difficulty to travel to a shelter. It was found that most of them are at road networks and away from flooded areas. Several paths were observed

as travel paths even they are flooded due to low flood levels and unavailability of roads. Figure 10 is an exaggerated view showing shelters, population location and best path for evacuation.

## **6. CONCLUSION**

RS/GIS techniques were successfully utilized for flood hazard mapping with reasonable accuracy, using SAR were combined with optical images. It could be said that this usage has high potential in practical usage of satellite data in flood area mapping, specifically in tropics. Visual interpretation is rather straightforward and easy to carryout with limited resources.

It may be required to combine what with digital elevation model to rectify the areas where there is a high canopy cover. Also, the method used to estimate the population density gives a reasonable approximation as the population data was re-distributed according to land use classes. The final product, flood risk map is the combination of land-use, flood area and population distribution. This combined information analysis was easily carried out within GIS environment demonstrating the potential of GIS system.

It was found that GIS is a promising tool for examining cost surface, identifying suitable flood shelters as well as generating best evacuation path for mitigation plan. It could be said that for mitigation plan can acquire more information from this analysis such as evacuation zone that face difficulty to evacuate people.

In the present study it was possible to convert cost surface to travel time so that it could be more useful for decision making for evacuation in emergency case. Moreover, the evacuation can be considered for the traveling by boat case. Further, the above analysis could be further improved by incorporating of other relevant factors such as speed and travel time. More important and accurate results could be developed if it were possible to collect information on village location, village population and school capacities.

## **ACKNOWLEDGEMENT**

Authors would like to acknowledge the use of data of “Mini-Project on Bangladesh flood” carried out under the financial support of Japan Aerospace Exploration Agency (JAXA) 2004-2005 as well as the use data prepared by Bangladesh Space Research and Remote Sensing Organization (SPARRSO).

## **REFERENCES**

- Bangladesh Bureau of Statistics (BBS),2003, Bangladesh Population Census 2001, National Report (Provisional), Planning Division, Ministry of Planning-p17,30.
- Brown, A., 1997. How to format references. Unpublished report, NIWA, Christchurch, New Zealand.
- Jim McCoy, 2004. Geoprocessing in ArcGIS. ArcGIS9, ESRI.
- Samarakoon, L.2004, Land use planning for flood mitigation in Dhaka city using remote sensing and GIS. ISTS-2004-n-22, pp. 1-5.
- Shahid, M.A.and Salam, Abdus, 2005, Application of Remote Sensing and GIS data for flood monitoring and mitigation measures in Munshiganj district of Bangladesh, Report of Mini Project supported by JAXA and RASTEC,(un published)