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Full Length Research Paper

Spatial strategies for flood vulnerability analysis and long term scenario with geographic information system (GIS) in Sirajganj, Bangladesh

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Flood is a natural hazard resulting from extreme meteorological events which cause an unexpected threat to human lives and properties. Flood stems from the probability that a major hazard event will occur in a well-defined area and it will impacts negatively, in particular on the people and their welfare. Flood protection planning is a very important step which helps not only to rescue the people affected by flood but also to mitigate the effects of these calamitous events and to take necessary preventive measures. Geographic Information System (GIS) is a useful tool to carry out methods of environmental management. With Remote Sensing (RS) techniques, GIS helps in (i) bringing forth hidden patterns in a dataset (ii) performing queries (iii) storing, editing and retrieving (converting) data in maps, (iv) preparing exceedingly 'expressive' maps to facilitate survey, spatial modeling, analysis and decision-making. This paper aims to take stock of the GIS capabilities which are particularly relevant to Flood projection for determining a suitable location to build a dam on the basis of 50 years projected data and determining flood vulnerability in Sirajganj area, in Bangladesh, by using a vulnerability analysis.

Key words: Sirajganj, remote sensing, geographic information system (GIS), vulnerability analysis.

INTRODUCTION

Bangladesh is known as the 'land of rivers' and major rivers that flow through Bangladesh are Ganges, Brahmaputra and Meghna with a complex network of 230 rivers including 57 international trans-boundary (cross boundary) rivers. Ganges (Padma), Brahmaputra (Jamuna) and Meghna are largest fluvial systems in the world. Topography of the country is mainly flat except some northeastern and southeastern parts, which are hilly. The land elevation changes from 3 to 90 m above MSL (BUET'88 CLUB, 2010). More than 50% of the floodplains in Bangladesh are within the 5 m above MSL. The geographical location and the meteorological and the topographical characteristics make the country vulnerable to floods. For instance, in 2010, floods affected 49 districts of Bangladesh and tens of millions of people. The area more affected by this natural hazard was Sirajganj. The Flood protection dams on different locations were damaged and as a result a huge area including the district headquarters were inundated under water. In September, 2010 the flood level exceeded that in 1988 in Sirajganj (Bangladesh Water Development Board - BWDB, 2010). In 2010, after the initial flooding occurred from the last week of July to the first week of August, a second round of flooding affected Sirajganj in the first week of September. After the first flooding caused great damage, some of the farmers planted some crops, but the second flooding affected most of the cultivation too (Alauddin, 2010). It has been learnt from different sources (UP, GOB ad the ministration and different NGOs) and field observation by field survey staff

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that all 9 Upazilas in the sirajganj district have been inundated under flash flood (occur within minutes or a few hours after heavy rainfall, tropical storm, failure of dams). River erosion has become more marked in some parts of the district. Road communication seriously disrupted and suspended in different route that is, Sirajgonj-Bogra, Sirajgonj-Kazipur and Kazipur-Dhunat road (Alauddin, 2010). The embankment of Sirajganj, so-called "Town Protection" is at high risk and the embankment (Ring) built by Water Development Board near khokshabari unions has damaged. As a result, the huge area of Sirajgonj Sadar and Kazipur Upazila was submerged in 2010 (Bangladesh Bureau of Statistics - BBS, 2011). So, it is necessary to do something to protect the people affected by floods. This research focuses on the problem (i) to find out the suitable location for building a dam based on 50 years projected data and (ii) to determine the flooding area by using the vulnerability analysis.

STUDY AREA AND METHODOLOGY

The district of Sirajganj consists of 9 Upazillas. Besides Brahmaputra river (Jamuna), there are other rivers in this district, so-called Baral, Ichamati, Karatoa and Phuljuri. On the floodplains of these rivers, the major hazards hanging over the district are represented by floods and riverbank erosions. Ullah para Upazilla is the largest Upazilla in Sirajganj but it is the fourth more populated Upazilla in terms of people living in per kilometer square. With regard to population drinking water from tubewell, this Upazilla has the lowest percentage. Tarash Upazilla has the lowest density of population among others (Bangladesh Bureau of Statistics - BBS, 2011). Sirajganj is one of the places whose elevation is very low comparing it to the other places in Bangladesh. This is the main reason when choosing this area as a flood study area. Figure 1 shows the elevation map in Bangladesh and the marked black line shows the lower elevation line; in addition, Figure 2 is a magnifying picture of Sirajganj. In ArcMap, all maps are resulting from overlaps of boundaries of Sirajganj which were produced by geo-referencing and a Digital Elevation Model and some maps are added by flood level data (Figure 3).

Six rivers, so-called Ichamati-NW, Bangali, Durgadah, Barnai, Breach and Jamuna, flow on Sirajganj area. Bangladesh Water Development Board (BWDB) collects data on 126 points in those rivers.

Zoning and flood vulnerability

Preparedness of the flood vulnerability map required data storage, such as spot height and Sirajganj area boundary and those shape files have been uploaded as mxd layers in ArcMap software (Bera et al., 2012). A Digital Elevation Model (DEM) of Sirajganj area has been created by interpolating spot height values-with spatial resolution of 10 m in average. DEM is reclassified into four categories such as High Susceptibility to Flood Zone, Medium Susceptibility to Flood Zone, Low Susceptibility to Flood Zone and No Susceptibility to Flood Zone, resulting in Susceptibility to Flood Map of Sirajganj and Flood Vulnerability Map has been generated by on the basis of Digital Elevation Model of Sirajganj (Lower elevation is Highly Susceptible to Flood Zone).

Generally, TIN (Triangular Irregular Network) surface is one procedure of ArcMap software adopted to understand the detail of

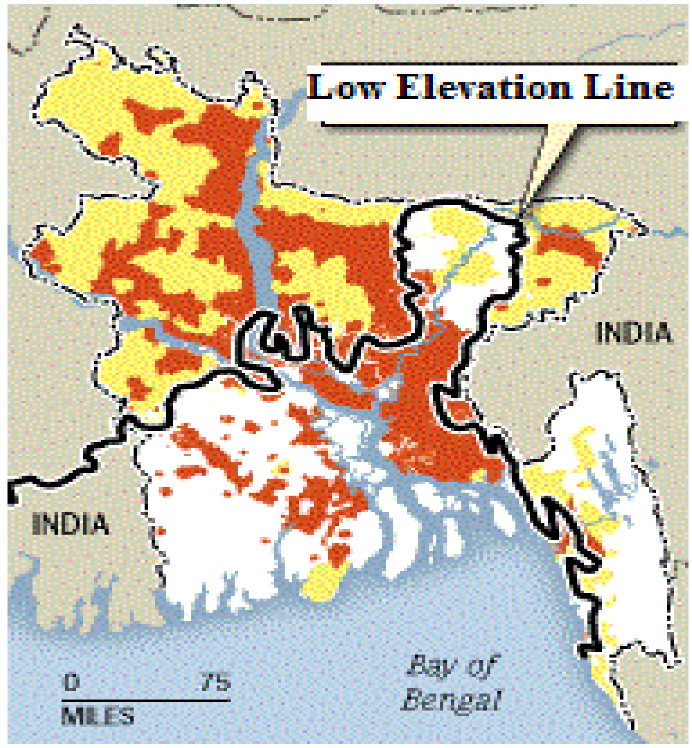

Figure 1. Elevation Map of Bangladesh.

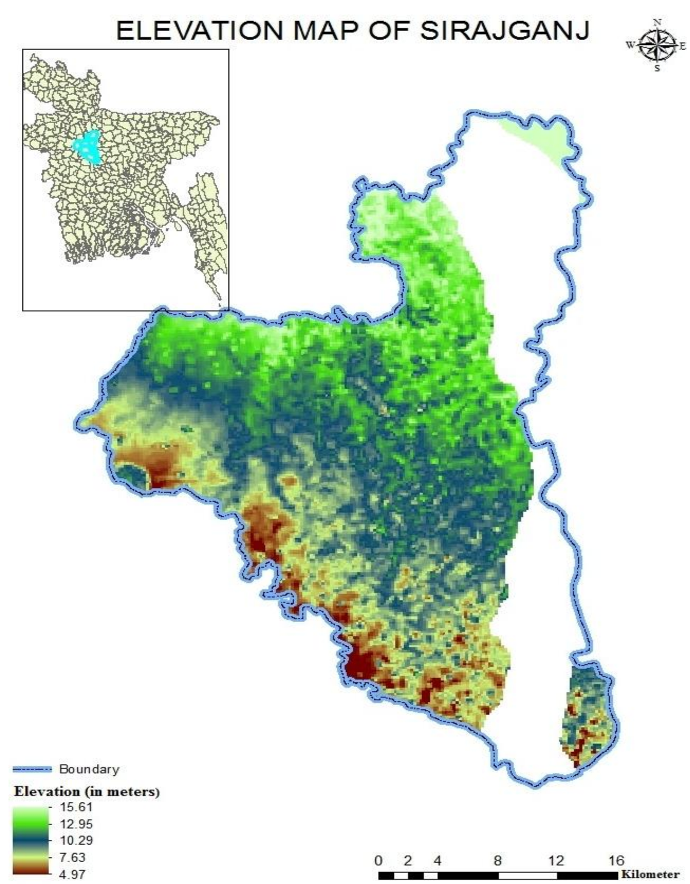

Figure 2. Elevation Map of Sirajganj.

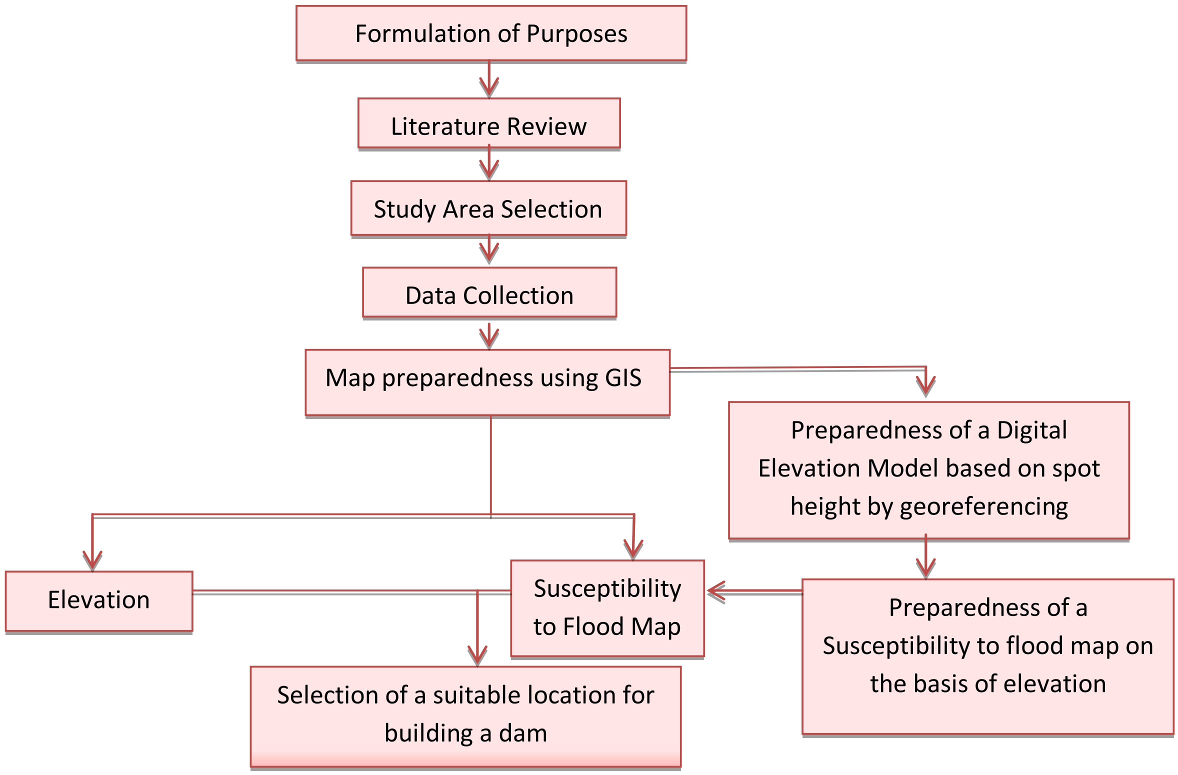

Figure 3. Processing workflow.

elevation in an area (Okoduwa, 1999). Figure 5 shows the TIN surface of Sirajganj area. DEM is reclassified, by using 3D Analyst extension from elevation and then it is converted to shape file. The purpose of the zonal analysis is to classify the whole area according to flood vulnerability.

DEM has been reclassified in order to create susceptibility to flood map (Figure 5) on the basis of four categories; which are:

4.97 to 7.63 m = High Susceptibility to Flood Zone
7.63 to10.29 m = Medium Susceptibility to Flood Zone
10.29 to12.95 m = Low Susceptibility to Flood Zone
12.95 to 15.61 m = No Susceptibility to Flood Zone

Then, the area under each susceptibility to flood zone is obtained by using a geometrical analysis. The pie chart of Figure 4 shows the percentages of total area with respect to each susceptibility to flood zone and illustrates that, most of the Sirajganj area is under medium and low susceptibility to flood zone. In 2004, the demolishing of a dam was started by flood and in 2007 it was totally destroyed; so, now, it is necessary to plan and build a new dam in a suitable location for flood risk management and protection human lives and properties in the study area.

RESULTS

Major flood level scenario in Sirajganj

Frequency analysis (Barroca, 2006) (Figure 6) based on major flood data in Sirajganj is the first part of analysis and shows how highest frequency of flood level is decreasing day after day. The flood level (Figure 7) which is dangerous for Sirajganj is 13.75 m (Alauddin, 2010); this value, corresponding to major height of flood in Sirajganj, is a value extracted from BWDB.

Figure 7 scenario shows the areas affected by floods in different years. It is based on the flood decreasing level and it shows that the area mostly affected corresponding to north-eastern part of Sirajganj. Once mapped the major flood level data in different years, the mean center was found out by using spatial statistics tool and this data was classified with respect to their flood mean level in those respective years, as shown in Figure 8. This map shows that flood level data maintain a decreasing trend from 1988 to 2010. In addition, this map shows that, the region more affected by floods is surrounded by Breach 3X and Breach 7X river, where, in all above mentioned years, the mean level of flood is also high.

Projected flood level scenario in Sirajganj

In order to project any kind of flood data, Gumbel's method is the most popular and appropriate method.

There are two kinds of approach in Gumbel's methods:

(i) Graphical
(ii) Analytical

In the first approach, the data based on visual projection are picked from log-log graph in which time factor, in

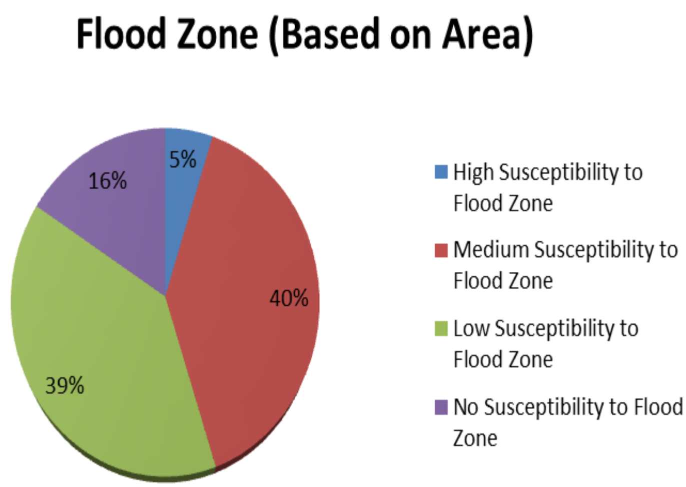

Figure 4. Susceptibility to Flood Zone.

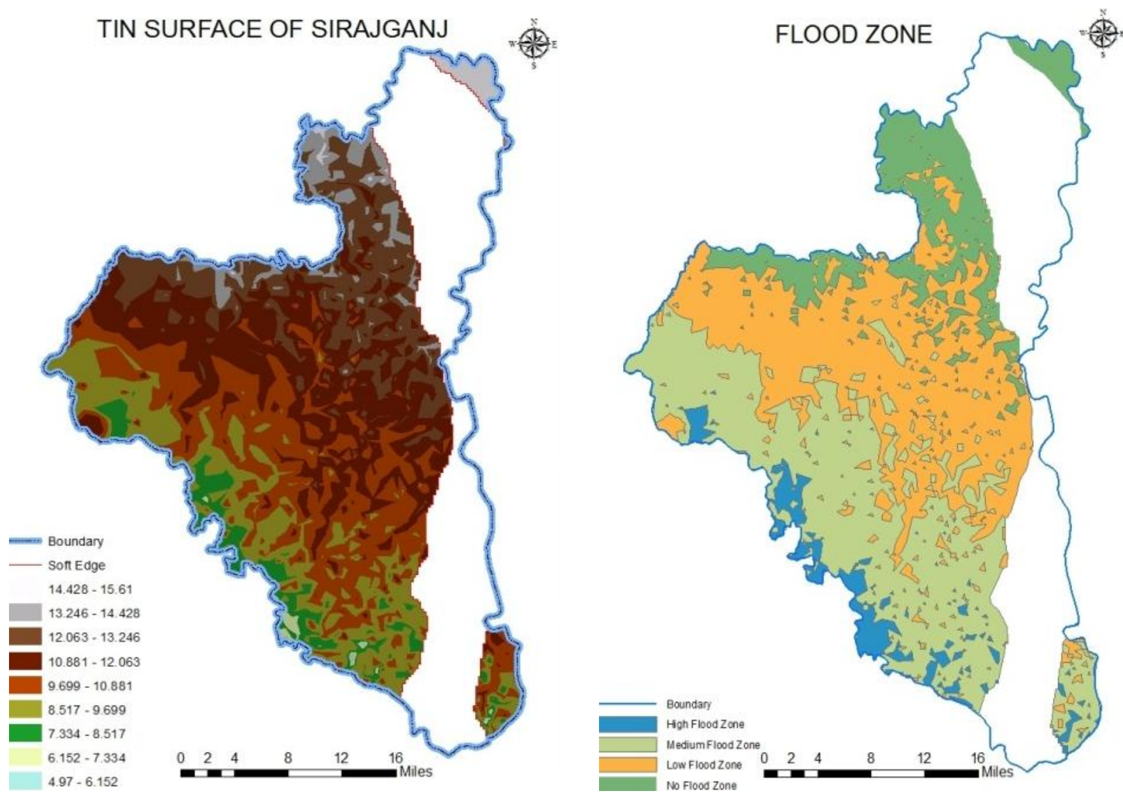

Figure 5. Tin surface map and Zonal variation in Sirajganj.

years, is represented in X axis and flood level, in meters, is represented in Y axis. In the second approach, the values can be found out, by using the equation:

$$X = X + K \times \sigma$$

Where:
X= any variable;
$\overline{X}$ = Average of flood data;
σ = Standard deviation of flood data;
K = Frequency factor.

Figure 9 shows a simple comparison between Graphical and Analytical approaches based on Mean, Maximum and Minimum levels of flood in 50, 75 and 100 projected years later. All flood levels maintain an increasing trend

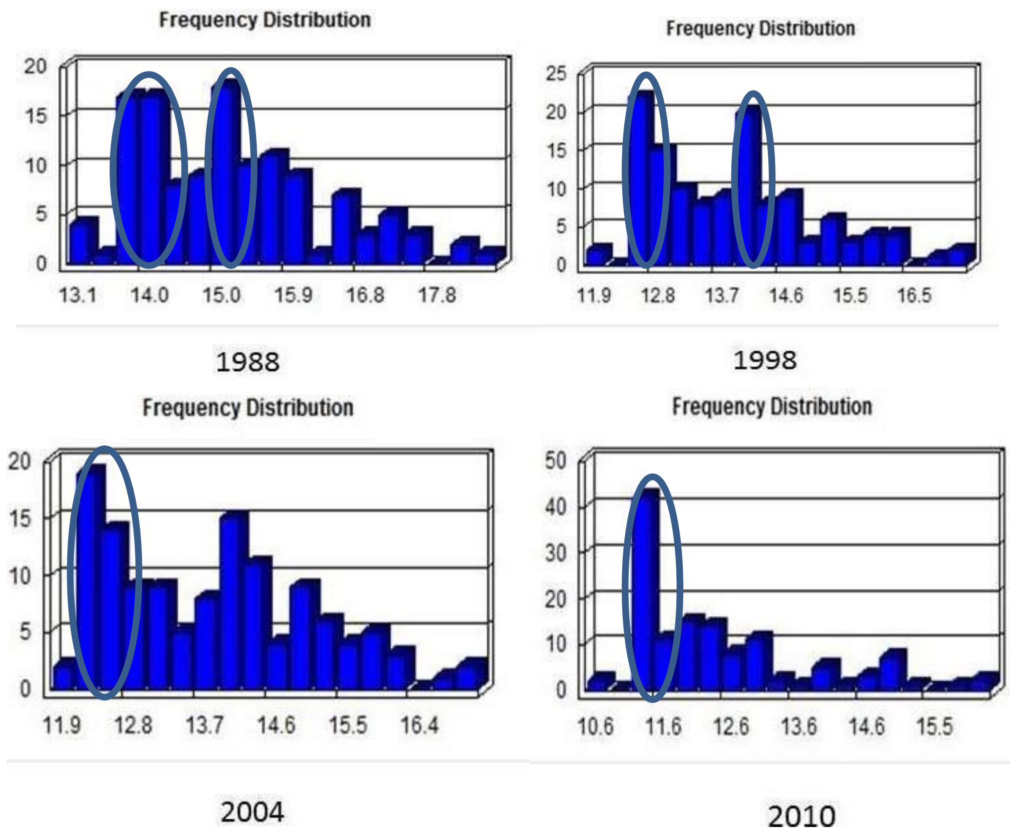

Figure 6. Frequency analysis of major flood.

with respect to time, but these are found less in Graphical approach than in Analytical approach. Figure 10 shows a percentage increment comparison between these two approaches of projection in major rivers in Sirajganj area. Both these graphs maintain an increasing trend in projected years. The percentage will be almost one-fifth percent higher in most of the rivers in analytical approach than graphical approach. So, higher values will be got for designing from analytical approach than from graphical approach. From this point of view, analytical procedure for flood projection is more appropriate and sophisticated than Graphical procedure.

Figure 11 shows the projected flood level and the mean center in major river points which categorized by upper and lower mean levels based on the flood mean level in those respective projected years. After projecting this data and analyzing the flood level data on 126 points, it can be said that, the north-eastern part is the area with the highest flood level and mostly affected by floods on the basis of flood level after 50 year projection and the best location for building a dam.

At this stage of analysis, based on the previous flood level data and projected data after 50 years, it can be said that the north eastern part of Sirajganj is the area more affected by floods. In addition, from the mean center analysis, it may thus be inferred that Breach 3X and Breach 7X, Ichamati, Jamuna are the rivers with highest flood level which based on the mean data in nine major rivers flowing through the Sirajganj area. So, a decision that, the water level in these four rivers is higher than in others can be reached. The north-eastern part of Jamuna River is the suitable location for building a dam in order to protect human lives and properties by flood events.

CONCLUSIONS AND RECOMMENDATIONS

Flood is a natural hazard in the world. Every year, flood affects lowering zones in Bangladesh (Alauddin, 2010). This study established an effective low cost solution to find out a suitable location for building a dam. Thus, Sirajganj in Bangladesh can be saved by building a dam in those lowering zones where the flood level is high. Some proposed recommendations are:

1. Structural measures are very expensive and time-consuming policies. So new solutions may increasingly acknowledge the indigenous, traditional and innovative strategies to cope with floods, like flood tolerant houses and crops.
2. GIS is useful technique to manage flood vulnerability analysis and, in addition, to compile long-term database on flood proneness and relief management.

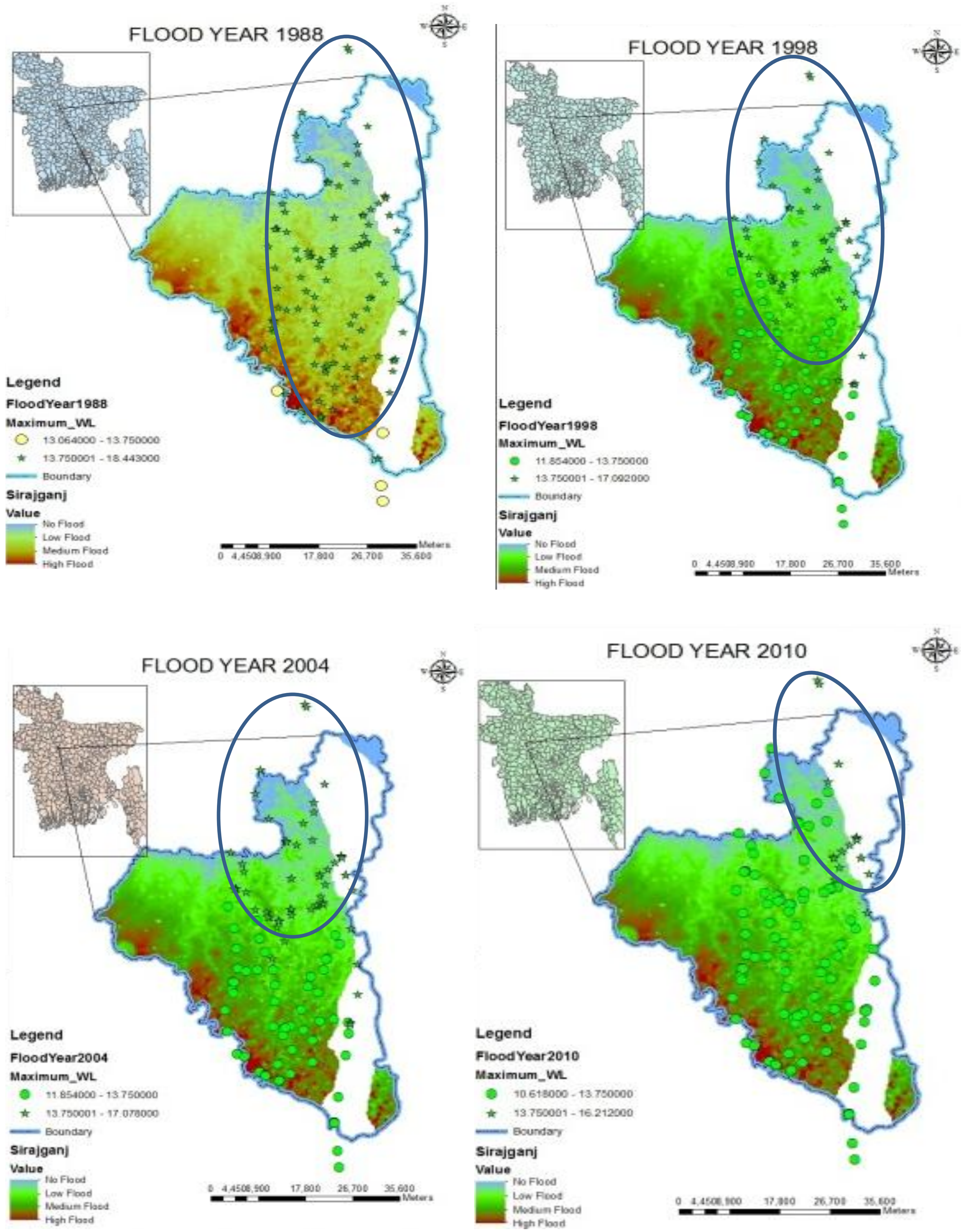

Figure 7. Major flood level data expressed by 13.75 m.

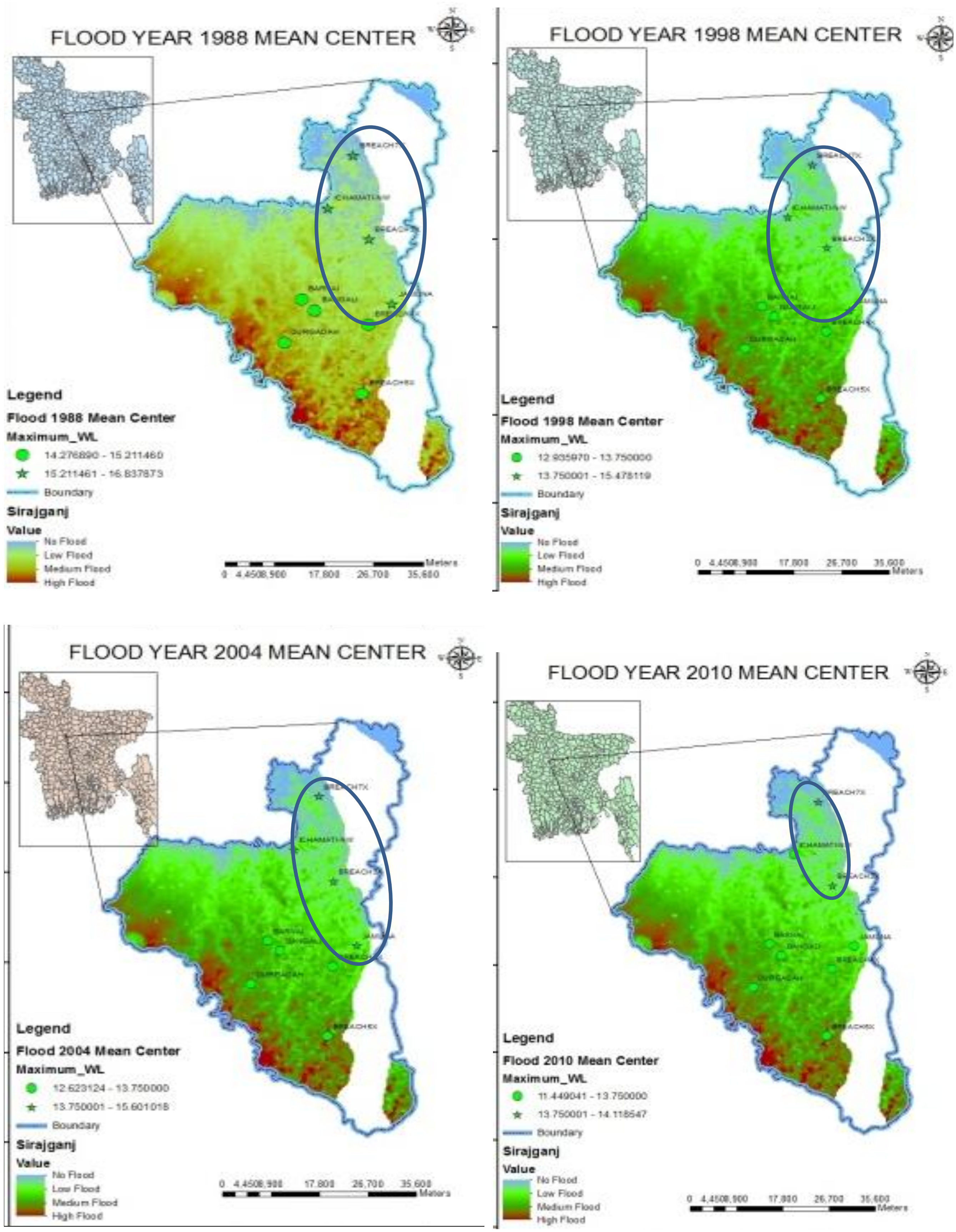

Figure 8. Flood mean level 1988, 1998, 2004 and 2010 in major river points in Sirajganj.

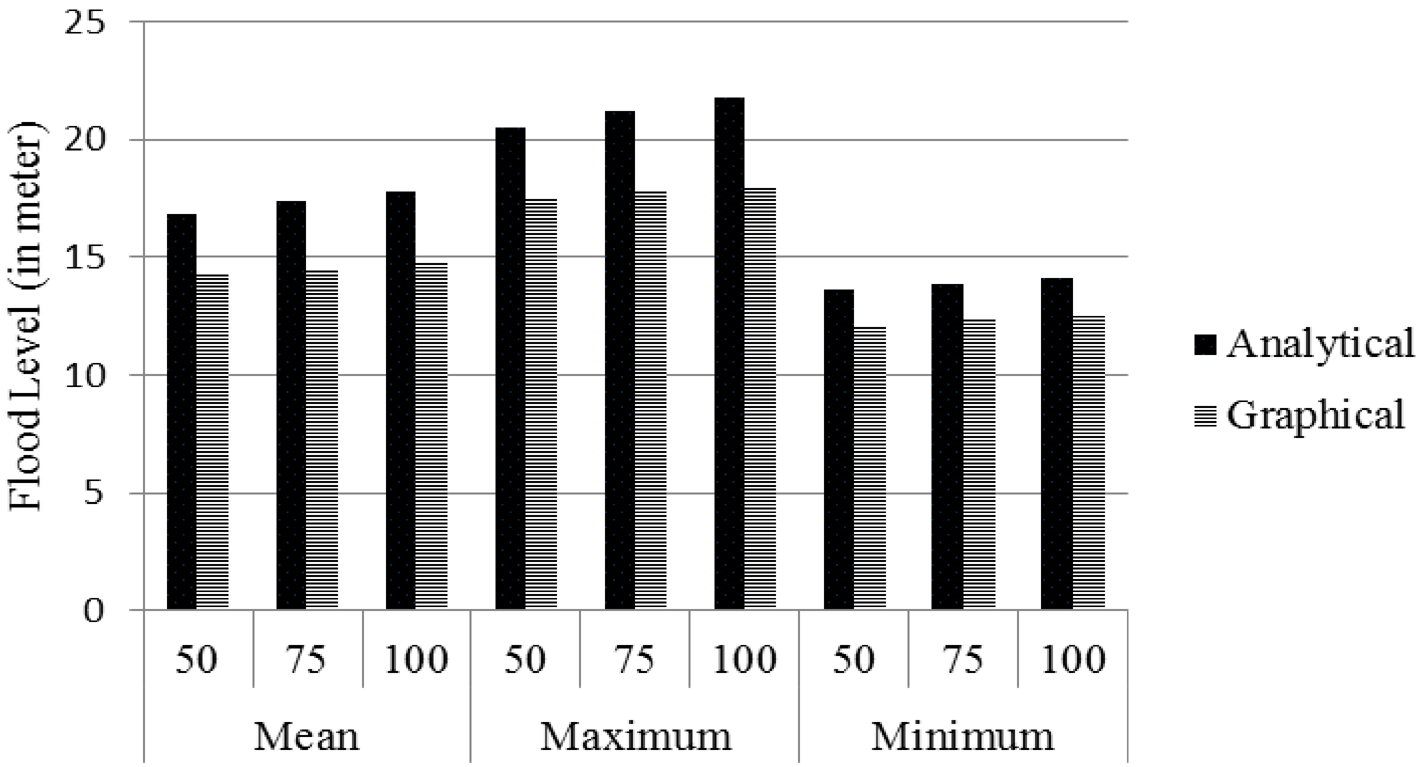

Figure 9. Comparison between maximum, mean and minimum projected flood level data for 50, 75 and 100 years.

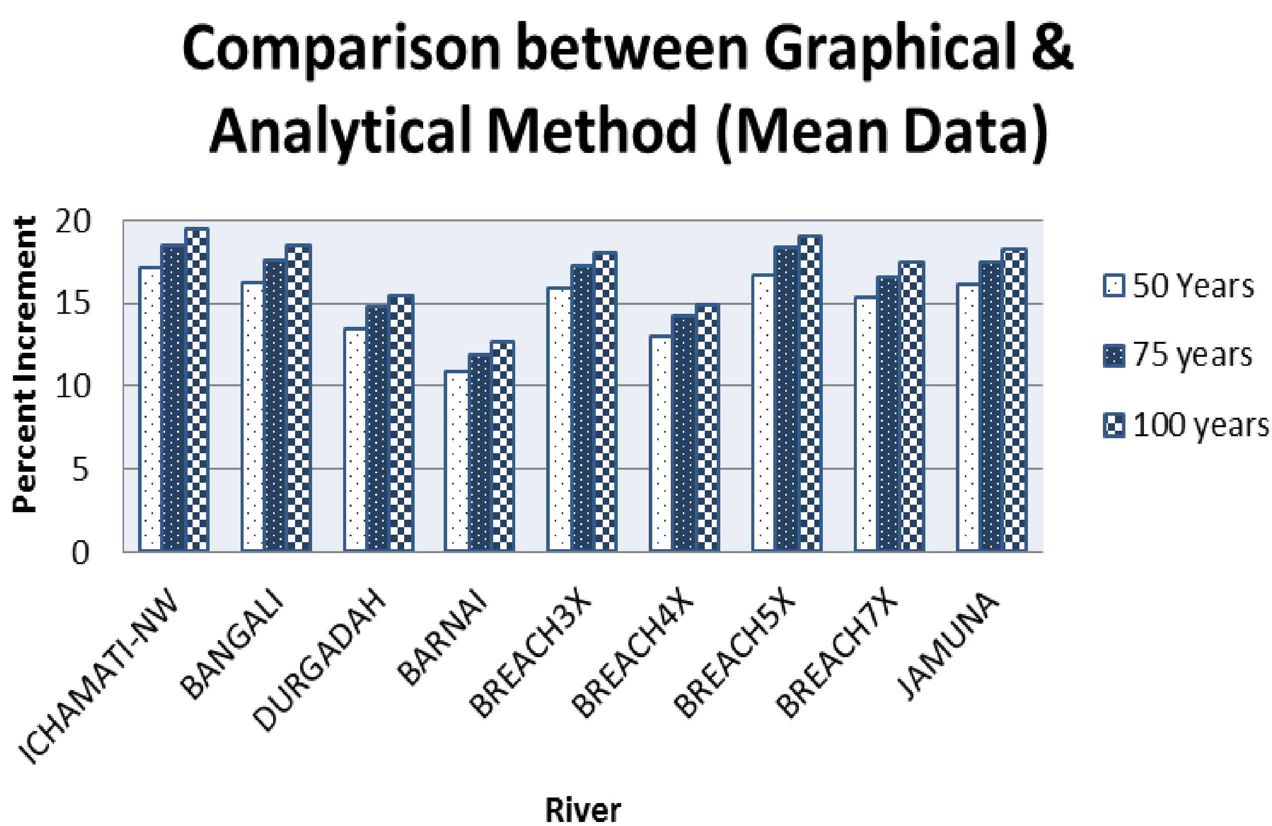

Figure 10. Percentage Increment of flood mean level data in nine river points.

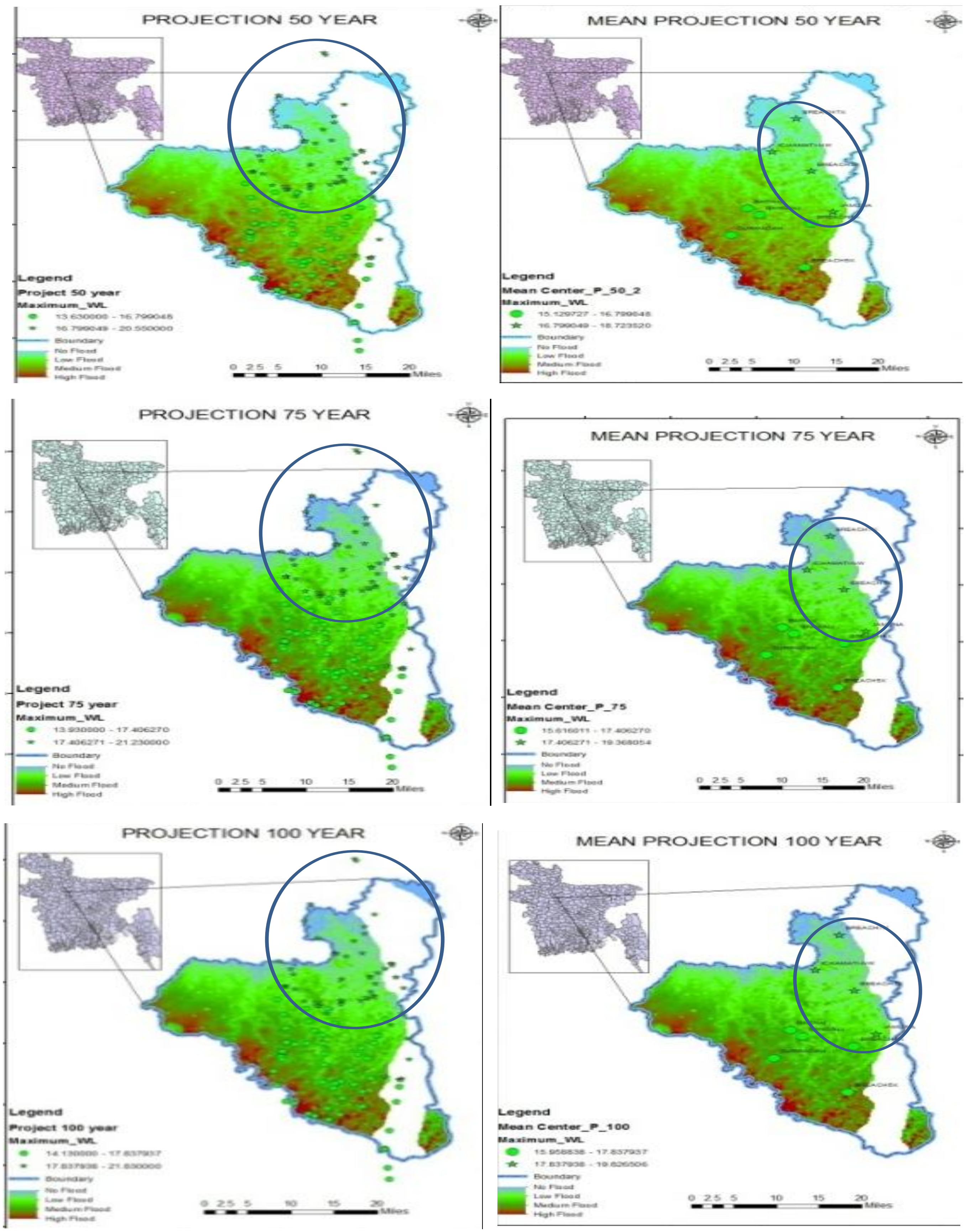

Figure 11. Flood level and mean center in 50, 75 and 100 year projection.

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