Flood Mapping Analysis of Chennai City using Geomatics

Sandhya Kiran¹, N. Vijay Kumar²
¹² Assistant Professor, Department of Civil Engineering, St. Martin's Engineering College, Hyderabad, India.

Abstract - India witnessed increased flooding incidences during recent past especially in urban areas reportedly since Mumbai (2005) as a mega disaster. Other South Asian cities like Dhaka, Islamabad, Rawalpindi, besides many other cities in India, are also reportedly been affected by frequent floods. Flood risk in urban areas are attributed to hazards accelerated by growth in terms of population, housing, pavedup areas, waste disposal, vehicles, water use, etc. All contributing to high intensity – high load of runoff. Reduced carrying capacity of drainage channels is also a key concern. Haphazard growth of low income habitations and unorganized trade added to challenge. Spatial dimensions of all these flood factors are often characterized by land use and changes. Chennai, a coastal megacity is fourth largest metropolis in India, has a history of over 350 years of growth. Meteorologically there is no major upward or downward trend of rainfall during 200 years, and a decrease in last 20 years with a contrast record of increasing floods have been experienced. Analysis of land use changes and generation of thematic maps over the temporal and spatial scale has been undertaken for Chennai city in order to understand the patterns on green cover, buildup area and consequences on hydrological settings and flood inundation map. The paper discusses flood analysis and land use change detection analysis using GIS in urban context with example of the Chennai city and draws attention of land use planners and disaster management experts to integrate their efforts for better and sustainable results.

Keywords – Floods, land use, disaster management thematic maps, GIS

I. INTRODUCTION

A flood is an overflow of water on land which is usually dry. Sometimes a river receives too much extra water, either from heavy rain or other natural disasters. When this happens, the water overflows from its normal path in the river bed and onto dry land. This is called a flood. The origin of the word flood is from old English which means to flow during the mid of 5th century. The first flood recorded was in the year 1034 known as yellow river flood according to the flood records total floods received 338 and India has alone experienced the flood disaster in ten states in just a span of one year.

By virtue of geoclimatic conditions about 60 percent of the landmass of India is prone to flood and it is the most common of all environmental hazards. Flood regularly claims over 20,000 lives per year and adversely affects around 75 million people worldwide (Smith, 1996). The reason lies in the widespread geographical and geomorphological distribution of the tracks of rivers and floodplains and low-lying coasts, together with their longstanding attractions for human settlement. Death and destruction due to flooding continue to be all too common phenomena throughout the world today, affecting millions of people annually, especially in the low lying and coastal regions. Floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters.
The last century have shown that there were several catastrophic flooding in Chennai in 1943, 1978, 1985, 2002 and 205 caused by heavy rain associated with cyclonic activity. These disruptive events were found to be attributable to failure in maintaining major rivers and drainage systems. Flooding of lesser magnitude occurs regularly in low-lying areas of Chennai and its suburbs because of inoperativeness of the local drainage infrastructure and rapid urban development.

Due to increasing frequency of the disasters and their severe impact on individuals, communities, society, economy and environment in the last few years, the subject of planning for disaster management has received greater attention.

Advancements in the remote sensing technology and the Geographic Information Systems (GIS) help in real time monitoring, early warning and quick damage assessment of flood disasters. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices.

The present study is to identify the flooded areas in Chennai city, to develop the thematic maps of flood affected areas, to analyze land use/land cover changes using GIS and to give sustainable measures and remedies.

II. STUDY AREA
The Chennai Metropolitan area consists of three districts namely Chennai city and the districts of Kancheepuram and Thiruvallur. The city area covers an area of 4.76 km² (184 sq. mi). The metropolitan area covers 1.177 km² (455 mi²). Chennai, situated on the shores of the Bay of Bengal, is the capital of Tamilnadu and the fourth largest metropolis in India. Its older name Madras was officially changed to Chennai in 1996. The Chennai Metropolis (with a latitude between 12°50'49" and 13°17'24", and a longitude between 79°59'53" and 80°20'12") is located on the Coramandal coast in South India and the land is a flat coastal plain. The Chennai Metropolitan Area comprises of the area covered by the Chennai City Corporation (Chennai District), an area of 176 sq.km comprising of 155 wards (villages/Local Bodies) in 10 corporation zones as shown in Plate 4.1, 16 Municipalities, 20 Town Panchayat and 314 villages forming part of 10 Panchayat Unions in Thiruvallur and Kancheepuram Districts. It extends over 1189 Sq. Km and has a population of 7.04 million. Study area is as shown in the Fig. 1.

**Fig. 1:** Study Area

III. REVIEW LITERATURE
Development is an essential element for a community to seek for a better life but when the urban development spreads to river flood plains, it will reduce the storage for floodwater and also the area
essential for diverting the floodwater [1]. Floods have brought numerous damage to the community causing loss of human life, economic loss and other damages. [2]. In Malaysia, the costs of damage for an annual flood, a 10-year flood and a 40 year flood are estimated as USD 0.98 million, USD 5.87 million and USD 14.34 million [4]. The impact of urbanization is not only on the hydrologic response of urban watersheds but also on the precipitation of urban regions. Urban heat islands are the factors that alter the precipitation causing floods [3].

Khaled A [5] conducted a study on the Impacts of urban growth on flood hazards in Makkah City, Saudi Arabia using GIS. The NRCS, formerly known as the soil conservation service (SCS), might be considered as the most widely utilized flood modelling methodology. The software used are AutoCAD and ArcGIS (v. 10). Remote sensing images and topographic sheets from SOI were used. The current research aims to investigate and quantify the relationship between urban sprawl and flood hazards in Makkah city. The NRCS curve number approach has been used in this study, utilizing available topographic, geological, and land use datasets, to estimate flood hazards in Makkah city in 1990 and 2010. The results showed that the residential regions of Makkah city have been increased by 197%, while the total flood volumes have been enlarged by 248%. These Two factors might be considered possible reasons leading to the rise in significant flood hazard.

Ismail Muhammad [6] conducted a study on Application of Remote Sensing (RS) and Geographic Information Systems (GIS) in flood vulnerability mapping: Case study of River Kaduna. Flood vulnerability mapping is fundamental in flood risk management because it identifies areas vulnerable to flood disaster. In Nigeria, flood maps for many areas are lacking 31 and the available ones are obsolete. Recent flood disasters along River Kaduna in Nigeria has claimed many lives and properties, and threatened the ecological biodiversity. This study applies remote sensing and GIS techniques to produce flood map of the Middle Course of River Kaduna. A flow accumulation model was created, using the DEM and the DEM was reclassified into high risk, moderate risk and low risk zones using equal interval of separation based on elevation. The study also conducted interviews with a sample of residents of certain areas that are at risk from flooding to identify elementsat risk of flood. The authors have discovered that, a flood map can be used effectively in public enlightenment, disaster response planning and flood risk management.

Anil K. Gupta and Sreeja S. Nair [7] studied on the flood risk of Chennai city due to urban population in 2010.this report was drawn from a national report covering 8 important cities. Analysis of land use changes over the temporal and spatial scale has been undertaken for Chennai city in order to understand the patterns on green cover, buildup area and consequences on hydrological settings. Land useissues like decreased natural areas, loss of water bodies, encroachment of river/streams and other drainage channels, uncontrolled multiplication of buildupareas, have been identified as contributory factor to flood risk in Chennai. The paper discusses flood risk reduction and management strategies in urban context with example of the Chennai city and draws attention of land use planners and disaster management experts to integrate their efforts for better and sustainable results.

IV. METHODOLOGY
The methodology of the study involves the generation of thematic maps showing current landuse and land cover, surface water resources, drainage pattern etc., using remote sensing data. For that, topographical sheets with scale 1:50000 arecollected from Survey of India (SOI) department. Topographical sheets are then Georeferencedusing coordinates given in SOI which is Georeferencedby Arc GIS 10.3.1.The contour map isthen Georeferencedover the downloaded earth image of the study area and a spatial adjustmentis applied for better accuracy. The above methodology is applied to prepare a flood analysis mapfor the severely flood affected area in
Chennai region. For finding out submerge areas either indifferent zones or under different town planning scheme, shape files of the whole districts withzonal boundaries and contour maps are digitized and then used to find out submerged areas integrated with town planning scheme. Elevation maps were extracted from SOI topographical maps which are used to prepare slope maps. Slope maps are obtained from the toposheet by measuring the distances between the contour lines.

Methodology for developing Drainage Pattern and Slope map:
Drainage map was prepared from SOI Toposheet and was subsequently upgraded using the image from NRSC. Slope map and aspect map for the entire catchments area were generated in 1: 50000 scales. Slope map is developed by using the topography sheet and by measuring the distances between the two contour lines by overlaying topographical sheet of three districts on satellite image slope map was developed.

Methodology for Land use/Land Cover map:
Digital data of 23.5 spatial resolutions was used for current land use/ land cover classification. Digital image analysis techniques were employed for obtaining different land use/ land cover categories. The boundary of the study area was extracted from the topographical maps as well as remote sensing data based on the boundary maps.

Digital Elevation Model:
A digital elevation model is a digital model or 3D representation of a terrain's surface commonly for a planet (including Earth), moon, or asteroid, created from terrain elevation data. DEM of Chennai city has been obtained and terrain analysis had been analyzed.

V. RESULTS AND DISCUSSIONS
From the study it has been identified that, in the study area there six flood hazard zones which falls under mandals namely Perambur Purasawalkam, Maduravoyal, Egmore Nungambakkam, Chennai City Corporation, Chennai and Tondiarpet. The number of villages in the six mandals are shown in table 1.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Mandals</th>
<th>No. of Villages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perambur purasawalkam</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Maduravoyal</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Egmore Nungambakkam</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Chennai city corporation</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>Chennai</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>Tondiarpet</td>
<td>21</td>
</tr>
</tbody>
</table>

Flood Map:
Flood map of the study area gives details about the passage areas affected by flood in Chennai region. Cooum River and Adyar river are the two large water bodies in an around Chennai regions shown in the map with the help of legends.

Two major rivers flow through Chennai, the Cooum River (or Koovam) through the center and the Adyar River to the south. A third river, the Kortalaiyar, travels through the northern fringes of the city before draining into the Bay of Bengal, at Ennore. The estuary of this river is heavily polluted with effluents released by the industries in the region. Adyar and Cooum rivers are heavily polluted with effluents and waste from domestic and commercial sources, the Cooum being so heavily...
polluted it is regarded as the city's eyesore. Pollution and urbanization is one of the causes of flood. The flooded region is shown in figure 2.

*Slope Map:*
Slope map gives the data of the variation of slopes and different colors in the map shows the different levels of terrain or slopes. The slope map of the region is shown in figure 3.

*Variation of Slopes in Percentage:*
The slope map in figure 3 is taken in degrees which when converted into percentage gives the variation in percentage.

![Fig. 2: Flood map of the study area](image1)

![Fig. 3: Slope map of the study area](image2)
TABLE 2: VARIATION OF SLOPES

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Variation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nearly level</td>
<td>0-1</td>
</tr>
<tr>
<td>2</td>
<td>Very gently slope</td>
<td>1-3</td>
</tr>
<tr>
<td>3</td>
<td>Gently slope</td>
<td>3-5</td>
</tr>
<tr>
<td>4</td>
<td>Moderate sloping</td>
<td>5-10</td>
</tr>
<tr>
<td>5</td>
<td>Moderately steep to steep</td>
<td>10-30</td>
</tr>
<tr>
<td>6</td>
<td>Strongly sloping</td>
<td>30-35</td>
</tr>
<tr>
<td>7</td>
<td>Very steep sloping</td>
<td>35 and above</td>
</tr>
</tbody>
</table>

Nearly level and very gently slope areas can be used for irrigation and agriculture purposes. As in these three districts more than 50% area is of nearly level to very gently slope.

Moderate steep slope to steep sloping, strongly sloping and very steep slope areas can be used for afforestation.

Variation of Rainfall in Chennai:
Average rainfall in Chennai: Chennai, Tamil Nadu is endowed with on average 1541 mm (60.7 in) of rainfall per year, or 128.4 mm (5.1 in) per month.

On average there are 91 days per year with more than 0.1 mm (0.004 in) of rainfall (precipitation) or 7.6 days with a quantity of rain, sleet, snow etc. per month.

The driest weather is in March when an average of 4 mm (0.2 in) of rainfall (precipitation) occurs. The wettest weather is in November when an average of 409 mm (16.1 in) of rainfall (precipitation) occurs.

The rainfall during the flood has been recorded and plotted which depicts the normal and actual rainfall received in Chennai region.

As per the above graph during the month of November, the city recorded a whopping 1218.6 mm of rain, which is three times its monthly rainfall. The normal rainfall figures for November stand at 407.4 mm.

On December 1, in just a span of 12 hours, Chennai has received a record-breaking 272 mm of rainfall. The city’s normal rainfall for December stands at 191 mm. Not only this, Chennai has also broken over a 100-year-old 24-hour rainfall record.
Previously, on December 10, 1901, Chennai had recorded 261.6 mm rainfall in a span of 24 hours. Chennai has also broken monthly rainfall record of December 1910. With more rain in the offing, 2015 will be a record breaking year for Chennai in terms of rainfall.

Due to vast flooding all the reservoirs in Chennai region have being filled and figure 5 depicts the results.

By observing the differences in the above LULC map of year 2004 & 2015 there was massive reduction in forest land and increase in urbanization. Due to increase in urbanization the water supply demand in that area increases which directly effects the ground and surface water conditions, this leads to the formation of floods in these regions. Figure 6 and 7 depicts the LU/LC maps of study area in 2004 and 2015.

The statistical data obtained from LULC map of year 2004 & 2015 are shown in chart 1 and 2.

![Fig. 5: Reservoir Levels in Study Area before and After Flooding](image1)

![Fig. 6: LU/LC Map of Study area in 2004.](image2)
Fig. 7: LU/LC Map of Study area in 2015.

The above figures shows the LU/LC maps of study area obtained using GIS.

VI. CONCLUSIONS

In this study, the flood problem in Chennai has been analyzed as a part of flood management and exile. The flood hazard maps

Chart 1: Statistical data of Land use and Land cover of the year 2004
generated can help in prediction of flooding stretches of the river for a given rainfall hyetograph and the variations for the study area. The thematic maps i.e. drainage and slope map prepared using GIS environment help in flood management. Furthermore, the LULC comparative studies made for the flood affected areas of three districts analyzes the causes behind the flood Chennai region and the various parameters represented in the graphs show evidently that LULC changes can trigger flood analysis.

By the study of the above slope, LULC, drainage, DEM maps we can conclude a flood map. The flood map shows the flooded regions. The thematic maps produced describe the reason for the cause of flood and it proposes that by increasing the vegetation land and also taking required measures implementing better for controlling the rainfall run off so that the floods could be avoided in the near future.

REFERENCES
5. Khaled A. AlGhamdi1, Ramze A. Elzaharny1, Meraj N. Mirza1,2 and Gomaa M. Dawod. Impacts of urban growth on flood hazards in Makkah City, Saudi Arabia IGeography Department, Umm AlQura University, Makkah, Saudi Arabia. Center of Research Excellence in Hajj and Omrah, Umm AlQura University, Makkah, Saudi Arabia. Survey Research Institute, Egypt, 2334, February 2012.
6. Muhammad Ismaii, Iyortim Opeluwa Saanyol Application of Remote Sensing (RS) and Geographic Information Systems (GIS) in flood vulnerability mapping: Case study of River Kaduna Department of Geography, Ahmadu Bello University, Zaria ISSN 0976 – 4380 2013