

A STUDY ON URBAN CHENNAI FLOODING MITIGATION STRATEGIES USING GEOSPATIAL TECHNOLOGIES

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering in
Civil Engineering

by

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DEPARTMENT OF CIVIL ENGINEERING

SCHOOL OF BUILDING AND ENVIRONMENT

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Vaseekaran.R (39200042), Mohammed Riyaz.A (39200023)**, who carried out the project entitled "**A study on urban chennai flooding mitigation strategies using geospatial technologies**" under my supervision from October 2022 to April 2023.

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We, **VASEEKARAN.R** (39200040), **MOHAMMED RIYAZ.A** (39200023) hereby declare that the Project Report on “**A STUDY ON URBAN FLOODING MITIGATION STRATIGIES USING GEO SPATIAL TECHNOLOGIES**” done by us under the guidance of **Dr.S.PACKIALAKSHMI** and **Dr.K.NAGAMANI** at Sathyabama Institute of Science and technology is submitted in partial fulfilment of the requirements of the award of Bachelor of Engineering degree in **Civil Engineering**.

1.

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DATE: 13.04.2023

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ABSTRACT

Chennai, the capital city of Tamil Nadu, is prone to floods during the monsoon season due to various factors such as encroachment of water bodies, improper drainage systems, and urbanization. The purpose of this report is to present the findings of a study on urban Chennai flooding and suggest mitigation strategies using geospatial technology. This study formulates a new method for flood mapping, while remote sensing technology and flood modelling methods are irrelevant due to unavailability of data. Bad weather and temporal resolution (Revisit time) affect the availability of satellite imagery in peak flood hour and for flood modelling, discharge data are required. Mapping the flood is very important for future references and planning. In Chennai, a major flood occurred was on 2015, which is almost 100 years back and we cannot predict the future events also so that a flood map is essential for the future references. By taking Chennai as study area we have designed a methodology for calculating the flood inundated area using GIS. Flood depth was surveyed using a participatory GIS approach and this paper demonstrates the capability of GIS technology to accurately map the flood inundated area. By this method, To minimize the environmental impacts of Flood hazards.

Keywords: Chennai Flood, GIS , Flood Successibility Map, Thematic layers, Rainfall Data, DEM, Slope Aspect.

TABLE OF CONTENT

CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	iv
	LIST OF FIGURES	vii
ix		
1	INTRODUCTION	1
	1.1 GENERAL	1
	1.2 AIM	5
	1.3 OBJECTIVES	5
	1.4 SCOPE	5
2	REVIEW FOR LITERATURE	6
3	METHODOLOGY	1
	3.1 FLOODING IN CHENNAI	13
	3.2 MITIGATION STRATEGIES	14
	3.3 WARNING SYSTEMS	17
	3.4 INTEGRATED GEOSPATIAL TECHNOLOGIES	18

4	RESULTS AND ANALYSIS	21
	4.1 FLOOD SUSCEPTIBILITY MAPS	21
	4.2 SLOPE	23
	4.3 DIGITAL ELEVATION MODEL	26
	4.4 INUNDATED AREA	28
5	CONCLUSION	32
	REFERENCES	33

LIST OF FIGURES

FIG NO	TITLE	PAGE NO
3.1	WARNING SYSTEMS	15
3.2	INTEGRATED GEOSPATIAL TECHNOLOGIES	18
4.1	FLOOD SUSCEPTIBILITY MAPS	22
4.2	SLOPE	24
4.3	DIGITAL ELEVATION MODEL	26
4.4	INUNDATED AREA	28

CHAPTER 1

1.INTRODUCTION

1.1 GENERAL

All over the world, floods are the most common disaster; their frequency, magnitude and the cost of damage are very high. Flooding is a temporary condition where sudden water is accumulated from inland or tidal or from rapid runoff due to rain, causing complete inundation (Jeb and Aggarwal, 2008). The Disasters resulting due to various weather conditions affected many countries which caused the loss of many Lives; several properties were damaged above all overall economic activities were disrupted. Weather-related disasters that happened from the year 1995 to 2015, 47% among them were due to flooding in which 2.3 billion people were suffered were from Asia. The most flood-affected country in the World is Bangladesh and then comes the position of India and one-fifth of the global death rate is happening due to flood. Twenty-three states in the nation are liable to floods and hectares of about 40 million lands, around one-eighth of the nation's topographical region, is inclined to floods. India counts almost one-fifth of worldwide death rate because of floods. Around four Lakh square km or about one-eighth of India's topographical territory is flooding inclined.

Recent floods in Chennai show that the city has learnt nothing from the 2015 deluge. November was a devastating month for flooding in Chennai. With 1,000 mm of rainfall in just four weeks, these were the worst rains since the devastating floods of 2015 when it poured for 22 out of 30 days in December setting a record of 1,049 mm. Then, as now, the flooding in Chennai was described as a man-made disaster, despite occurring during a storm called Cyclone Novara. On both occasions, death, disruption and destruction was the result. India has faced more than 300 weather events in the last two decades, resulting in over 79,000 deaths.

From 1 June 2018 to 19 Aug 2018 Chennai experienced an intensely high rainfall,

which resulted in severe flooding in 13 districts of Chennai. Only one district was out of this tragic flood. As per IMD data, from June 1st, 2018 to Aug 19th, 2018 Chennai received rainfall of about 2346.6mm was only expected rainfall of 1649.5 mm. The resulted rainfall was 42% above the expected value. Above than normal rainfall experienced in Chennai during June, July and August, June faced 15% more, July 18% more and from August 1st to August 19th it was 164% more problem faced by officials was the unavailability of flood prone area maps for reference. Because of that they faced difficulties in evacuation and selecting camp locations, two relief camp locations selected were flooded during the peak flood hours and people were stranded there. This makes the necessity of a Flood map for future reference. When considering the previous major flood in Chennai was on 2015, which is around 100 years back, shows the importance to map the current flood events for the future generation. Otherwise, the same disaster will be repeated. There are several GIS and Remote sensing flood mapping techniques, GIS gives enabling technology by providing a feasible solution. GIS also have suitable tools and methods assisting each stage of flood management. GIS helps in the various processes such as locating, planning, mitigation actions, aiding in response, helps in recovery management. By remote sensing, data for GIS analysis are acquired, there are several research on Remote sensing for flood mapping, most of the works were on optical remote sensing, using several optical satellites like Landsat Thematic Mapper (TM) data in North America [9] and Landsat Multispectral Scanner (MSS) remote sensing of e t Joy et al., International Journal on Emerging Technologies 10(1): 197-205(2019) 198 West Africa , Many studies using Landsat MSS band 7 , TM bands 4 and 7 . NDWI was used in water delineation , Flood monitoring was done using NOAA AVHRR sensor . Found a method using IRS-D and DEM to evaluate safe areas for Tapi Basin, Surat District. In that condition, they believe that Radar Sensors work better than Optical Sensors because it can penetrate the clouds and can work during the night and dark conditions. The Radar sensors available during the flood events are ALOS 2 PALSAR, Dated August 17, 15:30Hrs, Radarsat-2, Dated August 18, 19:00Hrs, Terra SAR-X, Dated August 18: 04Hrs , Sentinel 1A, Dated 21 August. They used Sentinel 1A for studying flood, 2018 for entire Kerala state. But specifically for this study

area, Chennai, peak flood hours was on 16th August and after that, it receded immediately, so satellite remote sensing was not a good option here. So field survey is sometimes the only choice, availability of sensors and temporal resolution may reduce the options to field survey only, Werner had proposed a method for calculating the flood inundated area. The flood depth raster was created using the IDW interpolation technique from flood depth points and was subtracted from DEM. To remove low lying areas, which were not connected to the river, he used a cost distance algorithm. He concluded that to find better interpolation techniques, IDW tends to show some variations. Then had done works on using ancillary information from digital elevation for removing the difficulties of unavailability of satellite data during the peak flood event. 'Least accumulative cost – distance' matrix is derived from digital topography. The least accumulative cost distance matrix was integrated with the flood inundated area extracted from SAR imagery processing. This method can solve the problem of the unavailability of satellites during the peak flood event. Flood depth data collections from the field using traditional survey methods are costly and time consuming due to skilled manpower requirement and sophisticated equipment. So another approach was followed, and it was able to generate data with the help of the local community and to integrate that information in GIS and it is called PGIS, Participatory GIS. To calculate the flood inundated area. When data of flood discharge is not available flood modelling techniques using software like HEC-RAS, MIKE II, LISFLOOD etc. are irrelevant. A good example of using PGIS due to unavailability of data showed in research carried in New Orleans in the USA, where difficulties were faced while surveying neighborhood needs. PGIS is a technology which was upheld as the perfect platform for adding the power of information from local communities of the nation and can be used in natural resource management. PGIS can be simplified to collectively include many groups for mapping purpose. Mobile applications can be used in PGIS to make the mapping simple and efficient. ODK (Open Data Kit) is the perfect open source mobile platform for PGIS because of the facilities of making a questionnaire and storing the data in the server. Every mobile phone is connected to the server and final surveyed results can be downloaded from a single platform. Volunteers are trained on ODK to collect application

and were divided into groups; each group contains local members or panchayat officials, which increased the data quality due to local knowledge.

Recent floods in Chennai show that the city has learnt nothing from the 2015 deluge. November was a devastating month for flooding in Chennai. With 1,000 mm of rainfall in just four weeks, these were the worst rains since the devastating floods of 2015 when it poured for 22 out of 30 days in December setting a record of 1,049 mm, the flooding in Chennai was described as a man-made disaster, despite occurring during a storm called Cyclone Novara, death, disruption and destruction was the result. India has more than 300 weather events in the last two decades, resulting in over 79,000 deaths.

1.2 AIM

The aim of the study on urban Chennai flooding for mitigation strategies using geospatial technology is to assess the causes and impacts of flooding in urban areas of Chennai, identify vulnerable areas, and develop effective flood mitigation strategies using geospatial technology.

1.3 OBJECTIVES

- To Study the prevailing urban flooding issues and their potential impacts through intensive literature survey.
- To analyse the various real time site specific flooding scenarios to derive the cause -effect relations for Urban Chennai Flooding by collecting primary and secondary data sources.
- To identify the potential flood prone zones by conducting geospatial analysis for various thematic layers
- To develop the Flood susceptibility maps to avoid or minimize the environmental impacts of flood hazard.

1.4 SCOPE OF STUDY

The scope of the study on urban Chennai flooding for mitigation strategies using geospatial technology includes the assessment of the current flood situation in urban Chennai, analysis of historical flood data, and identification of vulnerable areas based on geospatial analysis. The study also involves evaluating the impact of land use changes on flooding, analyzing the efficiency of existing flood mitigation measures, and identifying potential strategies for flood mitigation using geospatial technology. The study aims to provide valuable insights and recommendations to stakeholders for effective flood mitigation strategies using geospatial technologies.

CHAPTER 2

REVIEW OF LITERATURE

Zwenzner, H (2008) formulated the flood risk management using a GIS method through multi- criteria analysis. Flood risk assessment using the GIS based multi-criteria methodology is a relatively new approach, and only a few studies have implemented it. A pilot study for the River Mule in Saxony, Germany , was developed using the multi-attribute utility theory (MAUT) and a disjunctive approach was used to assign weights for four different criteria. Given the increase in flood events in recent years, accurate flood risk assessments an important component of flood mitigation in urban areas. This research aims to develop updated and accurate flood risk maps in the Don River Watershed within the Great Toronto Area (GTA).

Nelson SA (2015) used the geographical information systems (GIS) and multi-criteria analysis along with the application of Analytical Hierarchy Process methods to define and quantify the optimal selection of weights for the criteria that contribute to flood risk. The flood hazard maps were generated for four scenarios, each with different criteria (S1,S2, S3, and S4). The base case scenario (S1) is the most accurate, since it takes into account the floodplain map developed by the Toronto and Region Conservation Authority. It also considers distance to streams (DS), height above nearest drainage (HAND), slope (S), and the Curve Number (CN). S2 only considers DS, HAND, and CN, whereas S3 considers effective precipitation (EP), DS, HAND, and S. Lastly, S4 considers total precipitation (TP), DS, HAND, S, and CN. In addition to the flood hazard, the social and economic vulnerability was included to determine the total flood vulnerability in the watershed under three scenarios; the first one giving a higher importance to the social vulnerability, the second one giving equal importance to both social and economic vulnerability, and the third one giving more importance to the economic vulnerability.

Peduzzi (2009) The results for each of the four flood scenarios show that the flood risk generated. The inclusion of social and economic vulnerability highlights the impacts or mapping flood susceptibility under the GIS-based multi-criteria analysis. Therefore, in this study, the total precipitation and effective precipitation (defined below) was also included in order to analyze the influence of these criteria. The floodplain map, provided by the TRCA, was also included in this research. This floodplain map was generated using extensive hydrologic and hydraulic models. The current study includes new criteria, and it also evaluates different flood scenarios by varying the criteria used to improve flood maps compared to previous studies, and the floodplain map generated by the TRCA. The social exposure is based on the number of vulnerable groups in the area. The vulnerable groups were determined by age, family structure, language proficiency, income, education level, land tenure, and population density. These criteria for determining social vulnerability were selected based on a previous study, which reviewed 142 articles related to social vulnerability to flooding disasters. The study found that the category with the highest frequency of appearance was demographic characteristics (58%), followed by socioeconomic status (55%), health (45%), coping capacity (39%), risk perception (36%), neighborhood characteristics (30%), and land tenure (30%).

Athira B et.al (2010) Natural Flood Management (NFM) or Working with Natural Processes (WWNP), as it is also known, to reduce flood and coastal erosion risk involves implementing measures that help to protect, restore and emulate the natural functions of catchments, floodplains, rivers and the coast. WWNP takes many different forms and can be applied in urban and rural areas, and on rivers, estuaries and coasts. Different terminology such as soft engineering, green infrastructure, sustainable drainage and runoff attenuation may also be used to describe the techniques used. NFM aims to reduce the maximum water volume of a flood (the peak flood flow) and/or delay the arrival of the flood peak downstream increasing the time available to prepare for floods. There are 4 key, underlying mechanisms by which this can be achieved. Inc:

Ahmed S (2011) proposed De- synchronising peak flows from tributaries: Slowing down one tributary compared to another can significantly reduce flood peaks downstream. Natural flood management is not the complete solution to flooding but is one of many tools needed to manage flood events. Used in conjunction with other flood management solutions, like hard engineering and community resilience measures, natural flood management can have a beneficial impact on reducing flood risk downstream. Natural Flood Risk Management is a key part of a catchment-based approach, reducing the impact of floods and droughts as well as improving water quality and biodiversity. These benefits will make catchments more resilient to the impacts of climate change if we get the 'design' right. It may take a decade or more before we start to see the true benefits NFM. Recently, floods in Assam and other north-eastern states have caused devastation of life and property, which is an annual problem in the region. However, floods are not restricted to North-eastern India, rather it affects many other areas in the country.

Abdul-Ameer (2012) NFM measures work by affecting one or more of these key mechanisms. The primary aim should be to restore the natural functioning of river catchments as much as possible, but where natural recovery is not possible, measures can be used to emulate natural processes to manage flood risk.. Apart from natural factors like incessant and heavy rainfall during the monsoon, there are man-made factors that contribute to floods in India. India is highly vulnerable, as most of its geographical area is prone to annual flooding. The high losses and damages due to floods show the poor adaptation and mitigation status of India and inadequacy in disaster management and preparedness. As floods cause major damage to life and property every year, it is time the central and the state governments prepare a long-term plan that goes beyond piecemeal measures like building embankments and dredging to control floods. Also, there is a need for an integrated basin management plan that brings all the river-basin sharing countries as well Indian states on board.

Jean joy et al (2018) formulated a new method for flood mapping, while remote sensing technology and flood modelling methods are irrelevant due to unavailability of data. By taking Meloor Panchayat, Kerala as study area we have designed a methodology for calculating the flood inundated area using GIS and PGIS technologies. This research paved the way to found the flood inundated area and the preparation of the map. Due to the low 30 M resolution, small barriers like roads and manmade structures won't count and this will cause scenarios of low flood height, SRTM DEM could cause disparities while flood mapping with this technique.

David Fernandez (2013) has formulated creating temporary storage which will fill up during a flood event and empty slowly (e.g. reconnecting functioning floodplains and creating storage ponds) 6. Increasing catchment and channel roughness: this 'slows the flow' by increasing the resistance to surface and in-channel water flow (e.g. planting trees and hedgerows, restoring meandering rivers and installing leaky dams) 7. Increasing losses: this increases the amount of water that drains (infiltrates) into the ground or is lost back into the atmosphere via evapotranspiration (e.g. changing agricultural practices to improve soils structure and reduce soil compaction and installing sustainable urban drainage systems (SUDS)

Sole-(2008) has discovered- risk maps using geographical information systems (GIS) and multi-criteria analysis along with the application of Analytical Hierarchy Process methods to define and quantify the optimal selection of weights for the criteria that contribute to flood risk.

Daniela Rincón (2017) is proposed this study to apply and test the proposed method. It is located in the Don River watershed in Ontario, Canada. Flood risk assessment using the GIS-based multi-criteria methodology is a relatively new approach, and only a few studies have implemented it. The results of the study show that for flood hazard mapping, only the criteria of distance to streams, slope, height above the nearest drainage, and CN are enough to obtain reliable maps. However, if

the precipitation data is included, it is better to use the effective precipitation rather than using the total precipitation.

Berkat and Fitriana (2019) proposed the study to determine the level of prone area to flood disaster in Semarang by integrating the Geographic Information System (GIS) and remote sensing data including soil type, slope, rainfall data from the imaging satellite Himawari 8, land cover using Landsat 8 OLI, and observation data of catastrophic events in the last five years. The results obtained showed the prone area in Semarang was 44.25% and 8.18% in conditions of very prone, and 47.54% were in the condition of not prone to quite prone. The analysis of flood-prone zones in Semarang uses five parameters, namely rainfall, land cover, soil type, slopes, and flood. Near real time food inundation mapping using social media data as an information source.

Dhivya Karmegam et al (2016) discovered the data regarding water extent and inundation will not be available as the traditional data collection methods fail during disasters. Change in climate, urbanization and other human activities across the globe disturbs the hydrological cycle and cause various water related issues like water pollution, floods, droughts, etc., Greater Chennai Corporation (GCC), which is located at the state of Tamil Nadu in India. GCC is divided in to fifteen zones, which is further subdivided into 200 wards. Chennai city receives almost 60% of the annual rainfall during north east monsoon period (from October to December). Due to flat topography, some localities in Chennai deal with the problem of poor drainage during monsoons.

Anil K. Gupta and Sreeja S. Nair-2015 from the technical report of a national level study accomplished in India covering 8 important cities – Bangalore, Bhopal, Chennai, Kolkata. Chennai, a coastal mega-city 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.

J. Punithavathi et al-2016 presented the flood zone mapping was carried out in GIS. I have taken into Thanjavur district and Tamil Nadu. There are two types of monsoon is available in this area. Mainly for North East monsoon and South West monsoon area. North East monsoon is mostly affected in this area mainly for the month of November and December. An assessment is required to evaluate the flood prone areas. The toposheets on 1:50000 scale used along with auxiliary data to access and map the flood zones in Thanjavur district. Undoubtedly, there will be needed a huge fund to fulfill the suggestions, yet to check the suffering and wastage of money every year, there will be no way out except to adhere to these measures.

C. M. Noor Mansoor and L. Mahesh Bilwa (2015) presented the study, an attempt has been made to delineate flood hazard prone areas in the Bennihalla basin, Gadag and Dharwad district of Karnataka, using Geoinformatics technology. It is concluded that the Geoinformatics technology is very resourceful and useful tool for the flood hazard zonation mapping. This study was carried out with the aim of creating a flood hazard zonation map along the Bennihalla river basin, where it passes through the Gadag and Dharwad districts of Karnataka. The primary purpose of producing these kinds of maps is for public dissemination of flood maps which will serve to increase public awareness.

Lavanya-2016 presented Chennai Urban Flood are witnessing devastating floods more often due to heavy rainfall, cyclones, etc.. Though Tamil Nadu is not under flood risk prone zone as mapped by meteorological department (New Delhi), within the local body there are few low-lying areas which are susceptible to inundation which also depends mainly on the developments near major drainage systems, encroachment of water bodies, inability of major canals to carry heavy rains, overflowing reservoirs. Chennai, one of the fast growing metros is likely affected by the lack of drainage mainly due to uncontrolled developments of concrete spaces, encroachment of major drainage channels, shrinking of marshlands,. The paper discusses causative factors responsible for flood risks in Chennai, the immediate need for proper flood risk reduction and management strategies.

CHAPTER 3

METHODOLOGY

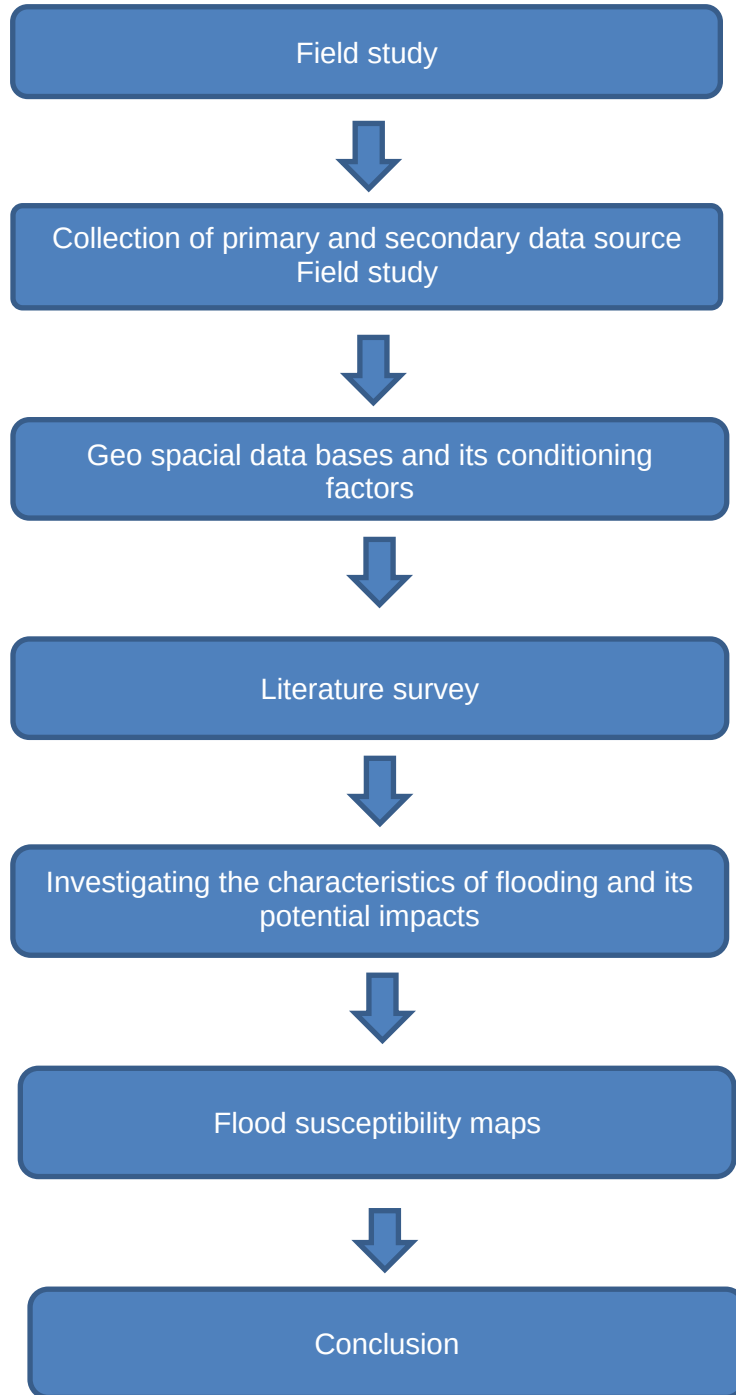


Fig 3.1 Methodology

3.1 FLOODING IN CHENNAI

Chennai Flooding 2015 Chennai is highly sensitized to flooding and is a rapidly developing city in the Indian LECZ³⁶. Every five to ten years large fluvial floods occur in Chennai and because of the low frequency, flood management plans or mitigation measures are less prioritized. However, even the slightest rainfall leads to substantial flooding of roads and streets across the city. This is despite Tamil Nadu being the first state in the country to implement mandatory rainwater harvesting techniques at every individual plots across the state³⁷. Inadequate drains, deficient capacity of drains, blockages, encroachments of flood plains are the most common reasons for flooding in Chennai. The primary way of dealing urban floods in Chennai is through improving Storm Water Drain System (SWDS) and reviving the ery system³⁶. CMA receives an average annual rainfall of 1100 mm (700 mm rainfall during northeast monsoon and 400 mm rainfall during southwest monsoon)³⁵. In November 2015, the south-eastern coast of India was hit by a deep tropical depression through the Bay of Bengal causing heavy rain and floods. Chennai witnessed the heaviest rainfall in the last 100 years causing massive flooding across the city and resulting in disruption of normal life. The first spell of intense rain was between 8-9 November C. Faiz Ahmed and Natraj Kranthi Vol 11 (6) | February 2018 Indian Journal of Science and Technology 3 2015; minor floods across the city were observed. This was followed by the second spell of intense rainfall between 15-17 November 2015. The third spell of intense rainfall was between 1-5 December 2015, causing major floods across the city. The rains and subsequent overflow of Chembarapakkam, Pondi and Puzhal lakes, River Coocum, River Adyar and Buckingham Canal, within the city caused severe flooding and a significant damage to the inhabitants, existing built fabric and infrastructure of the city. Following this, the Government of India declared Chennai, a National Disaster zone. Road and rail access was cut off in several parts of the city. The runways at Chennai airport were flooded and remained closed for three days, severely hampering the day-to-day activities. The rescue and relief operations were stranded leaving the affected people unattended. Decadal rainfall data reveal the consistent recurrence of major floods in Chennai. The

city had witnessed major floods in 1943, 1976, 1985, 1996, 2005³⁵ and the recent one in 2015.

2.3 Overlapping Competencies Chennai is a highly sensitized city in Indian LECZ to flooding due to the Tsunami and massive flooding in 2004 and 2005 respectively. The state government agencies retain the management of urban affairs (including the flood management). Apart from the local government, a number of other agencies or departments are also involved in planning and management of urban services. Chennai's flood management is split across six government departments viz. 1. Public Works Department (PWD), 2. Water Resource Department, 3. Corporation of Chennai - Storm Water Drainage Department (SWDD), 4. Corporation of Chennai (Zonal Office), 5. Chennai Metropolitan Development Authority (CMDA) and 6. Chennai Metropolitan Sewerage and Water Supply Board (CMWSSB) – Sewerage Department and Water Supply Department³⁶. Effective planning and management of floods are practically challenged by overlapping competencies and clash of authorities

3.2 Mitigation Strategies:

Improving Drainage Systems: The existing drainage systems should be improved by clearing the clogged drains and channels, constructing new drains, and providing proper maintenance. Improving drainage systems is a crucial step in mitigating the effects of flooding in urban areas. This can be achieved by clearing clogged drains and channels, constructing new drains, providing proper maintenance, constructing retention ponds, implementing green infrastructure, and advanced technologies.

These strategies can reduce the risk of floods and ensure the safety of people and their property. Improving drainage systems is a complex process that requires the cooperation of various stakeholders such as government agencies, private organizations, and citizens. The implementation of these strategies can go a long way in mitigating the effects of floods and ensuring the safety of people and their property in urban areas.

Encroachment Removal: The encroachments on water bodies should be removed to allow for free flow of water during floods. Encroachment removal is a challenging process that requires the cooperation of various stakeholders such as government agencies, private organizations, and citizens. The implementation of these strategies can go a long way in mitigating the effects of floods and ensuring the safety of people and their property in urban areas. **Green Infrastructure:** Green infrastructure such as rain gardens, bioswales, and green roofs should be implemented to reduce the amount of stormwater runoff.

Green infrastructure can provide numerous benefits, including reduced flood risk, improved air and water quality, enhanced biodiversity, and improved aesthetic values. The implementation of green infrastructure requires the cooperation of various stakeholders such as government agencies, private organizations, and citizens. The use of green infrastructure can go a long way in mitigating the effects of urbanization and improving the quality of life in urban areas.

Land Use Planning: Proper land use planning should be done to ensure that new constructions are not located in flood-prone areas. Land use planning is the process of allocating land to various uses based on their suitability, feasibility, and compatibility with the environment and community needs. Land use planning involves a systematic approach to assessing the current land use patterns, identifying potential land use changes, and developing policies and regulations to guide future land use decisions.

Flood Warning System: A flood warning system should be implemented to alert the residents of flood-prone areas in advance. A flood warning system is a mechanism that provides information about impending floods to communities, government agencies, and other stakeholders in a timely and effective manner. The system is designed to monitor various factors that can contribute to flooding, such as rainfall intensity, river and stream levels, and coastal tides, and issue warnings when conditions are likely to result in flooding. **The Case of Depleted Water Bodies** Since 1970, more than one-fifth area of

Categories	Identified flood prone areas in CMA
Low Flood Prone	Alwarpet, Teynampet, Gopalapuram, Nandanam, CIT Colony, Mylapore, Mandaveli, Ashok Nagar, Santhome, Villivakkam, Besant Nagar, Little Mount, Guindy, Thiruvanmiyur, Pallavaram, Madambakkam, Kannadasan Nagar, Nandambakkam, Madhavaram, Alandur, Nemilichery, Perungudi, Thuraipakkam,
Medium flood prone	Anna Nagar,Chetpet, Perumbakkam, Ambattur, Vepery, Moolakadai, Valasaravakkam, Red Hills, Vanagaram, T Nagar,Taramani, Tambaram
High flood prone	Nungambakkam, Royapettah, Triplicane, Kottur Gardens, Thousand Lights, Pudupet, Egmore, Chepauk, Perambur, Sowcarpet, Saidapet,Vallalar Nagar, Kilpauk, George Town, Park Town, Kotturpuram, Royapuram, Vyasarpadi, Basin Bridge, Washermanpet, Mannady, Flower Bazaar, Tondiarpet, Pulianthope, Purusawalkam, Ennore, Periamet, Chintadripet, Doveton, , Choolai, Otteri, Kellys, Tiruvottiyur, Zam Bazaar, Jafferkhanpet, Adayar, Velachery, Pallikaranai

the water bodies within the CMA limits has been reduced. NDWI results derived out of Landsat-8 OLI (October 14, 2015) detected a reduction in the area of the water bodies i.e. from 267 sq.km to 56 sq.km³⁵ as shown in Figure 3. As pointed out by ³⁶, these ‘naturally low lying areas’ instead of acting as flood sink, pose a greater risk due to urban development. Comprehensive flood management could be worked out by re-inventing the depleted urban water bodies⁴⁷.

4.3 Mapping of the Flood Prone Areas

Mapping of the flood prone areas is a primary step involved in reducing the risk of the region. For this purpose, a modified version⁴⁸ was adopted for demarcating the flood prone areas. A historical record of DEM data i.e. watershed areas extracted from CartoDEM-3 R1 were superimposed with dot density inundation map to identify the flood prone areas. This has enabled to identify the critical spread of the affected areas for undertaking vulnerability analysis, flood plain prediction, etc. Further, this can act as a base for all post flood relief measures and also in turn can have a better control over

the post flood works. The basic inundation map was combined with land use, built-fabric and infrastructure data to form a complete image of the flood plain. Based on the intensity of inundation and extent of watershed area, flood prone areas were categorized into:

1. Low Flood Prone (LFP),
2. Medium Flood Prone (MFP)

Mitigation Strategies Mitigation strategies are classified into:

1. Structural measures
2. Non-structural measures.

Structural Measures that constructing short-term protective structures create false sense of security and have failed historically, long-term urban planning interventions must be explored. No construction must be permitted in the HFP areas. Also, buildings in LFP and MFP areas must be constructed with stilts or on raised platforms. In addition to clearing the encroachment along the river edges, de-silting of River Coocum and River Adyar must be carried out. Lakes like Chembarapakkam, Poondi and Puzhal lakes must be improved in terms of capacity and structural safety. Non-Structural Measures In the demarcated HFP areas, built-up density should be reduced curtailing further developments. Relocation of residents of HFP areas to alternate safer sites must be considered. Necessary steps to revive the already depleted water tanks and water bodies across the CMA must be carried out. Construction of community facilities in the LFP areas must be encouraged. These facilities can be used as make-shift places during floods. Reforestation of banks of the River Coocum and River Adyar must be carried out to reduce the flood damage and increase the retention capacity. In line with the National Disaster Management Plan 2016, a comprehensive spatially integrated flood inundation and risk management plan .

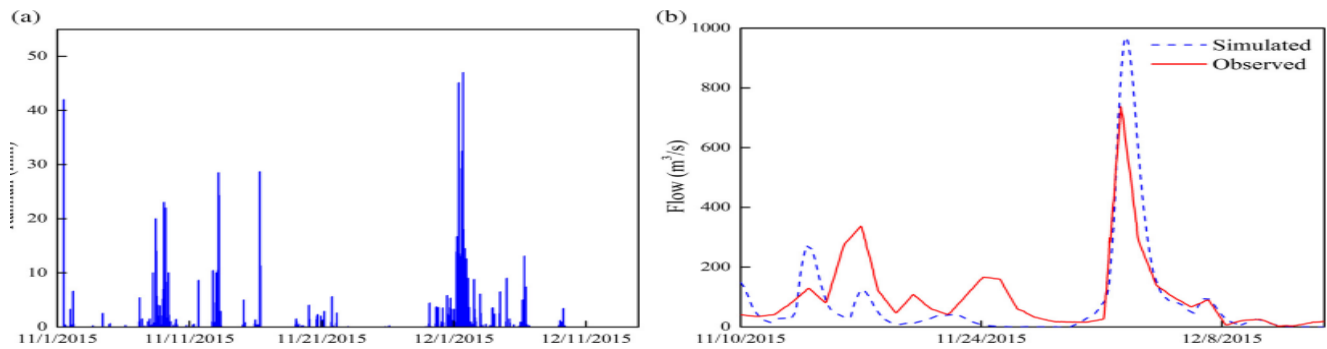


Fig 3.2 velachery lake overflow for the year 2015 and 2019.

Governance The Disaster Management Act (DMA) 2005, gives the legal authority to the state to frame policies and prepare Disaster Management and Mitigation Plan (DMMP) with the help of national disaster management authority. But the mandated role for the state level authorities is relatively limited. DMA also emphasizes the creation and updating DMMP to assess disaster risk and to prepare for mitigate, respond to and recover from disaster. DMMP in Tamil Nadu is not comprehensive enough, as only mere listing of flood prone areas and contact information during disaster is usually carried out.

3.3 INTEGRATED GEOSPATIAL TECHNOLOGIES

Spatial Data Infrastructure Geospatial data infrastructure technologies must be integrated with disaster management plan to facilitate informed analysis and decision making. This can enable sharing and delivery of geospatial data, in advance for effective pre and post flood measures.

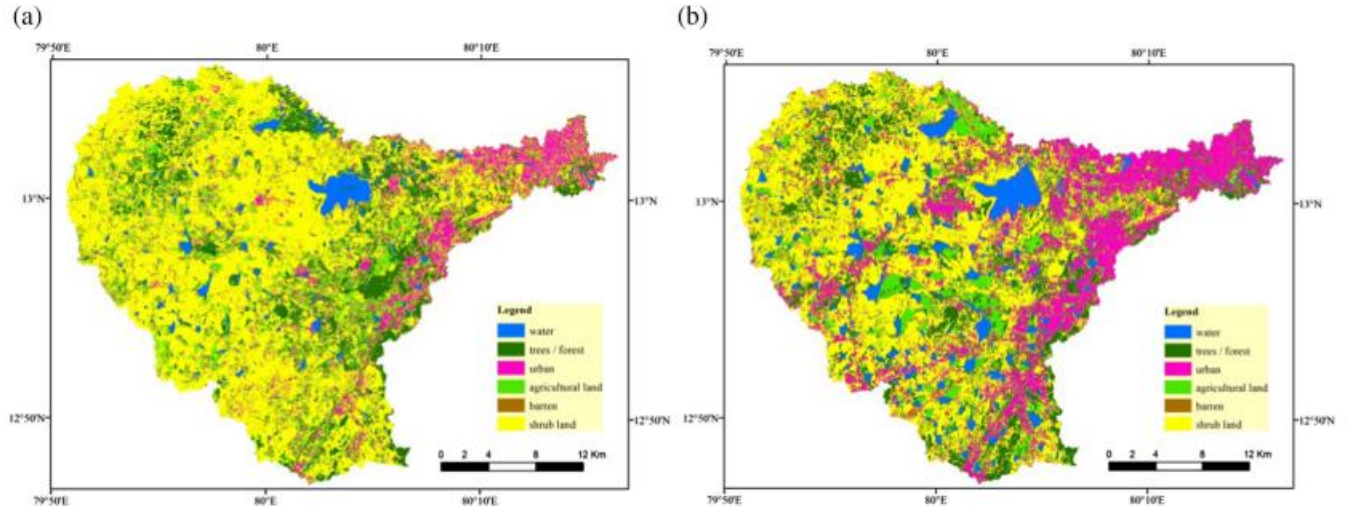


Fig 3.3 Chennai Inundated Area for the Year 2015 and 2019

Logah et al., (2017) and Moya Quiroga et al., (2016) Flood inundation mapping Flood inundation extent and depths corresponding to the baseline and the future flood scenarios are simulated using the widely and freely available two-dimensional (2D) hydraulic model, HEC-RAS (USACE, 2016). The hydraulic domain (Fig. 3.2) is discretized into computational cells of size $\sim 30 \text{ m} \times 30 \text{ m}$. Since the SRTM data for the river mouth area is not available, the freely available General Bathymetric Chart of the Oceans (GEBCO) data is used to fill up the no-data pixels.

The pixels that correspond to buildings (OSM data) are raised to about 5 m from the existing terrain data in an effort to make the flood hazard zoning. The SRTM data can be used with confidence for modeling high magnitude infrequent floods if the purpose of the study is not aligned towards detailed analysis like the design of hydraulic structures (Yan et al., 2014). The HEC-RAS can solve either 2D diffusive wave equations or full 2D Saint Venant equations. For the 2015 Chennai flood event, the computing time for full 2D solution is $4.5 \times$ (CPU time) greater than that of diffusive wave solution. However, the difference in inundation extents simulated by the two solution schemes is found to be only 4%.

Therefore, in order to reduce the computation cost, the 2D diffusive wave equation option is resorted to. The runoff hydrographs obtained from the HEC-HMS are used as upstream boundary conditions for the HEC-RAS model. The locations and the data pertaining to the upstream boundary conditions for the baseline scenario are indicated in Figs. 1 and 7, respectively. The tidal data (Narasimhan et al., 2016) is given as the downstream boundary condition at the river mouth. Suriya and Mudgal (2012) used Manning's n values of $0.025 \text{ m}^{-1/3} \text{ s}$ for 1976 and $0.03 \text{ m}^{-1/3} \text{ s}$ for 1985 floods. However, the 2015 Chennai flood was a result of both fluvial and pluvial flooding.

The urban areas were flooded not only due to overflowing rivers but also due to lack of efficient drainage of the stormwater. It is thus difficult to separate fluvial and pluvial flooding extents and calibrate Manning's n value. Hence, in this study, all the scenarios are run for the Manning's n values of 0.025 , 0.03 , 0.035 and $0.04 \text{ m}^{-1/3} \text{ s}$ to take care of the uncertainty associated with the friction coefficient in the simulated results.

The simulations are run with a stable and convergent time step of 6 s . In order to validate the baseline simulation, the flood-marks surveyed soon after the 2015 Chennai flood are used. The computed water depths are used to prepare flood inundation maps and a threshold water depth of 0.1 m is used to differentiate between dry and wet areas. From Fig. 9, it can be seen that the range of Manning's n values chosen for the study provides almost similar accuracy with respect to the R^2 values.

However, the simulations show different inundation patterns for different values of n . The possible reason for getting similar R^2 values may be due to the fact that all the surveyed points are located close to the Adyar River. Moreover, in the absence of an observed inundation extent map, a single n value can introduce more uncertainty in the results. Hence, all the results are reported in the form of a range for different values of n and scenarios.

4.RESULTS AND DISCUSSION

4.1 GREATER CHENNAI CORPORATION

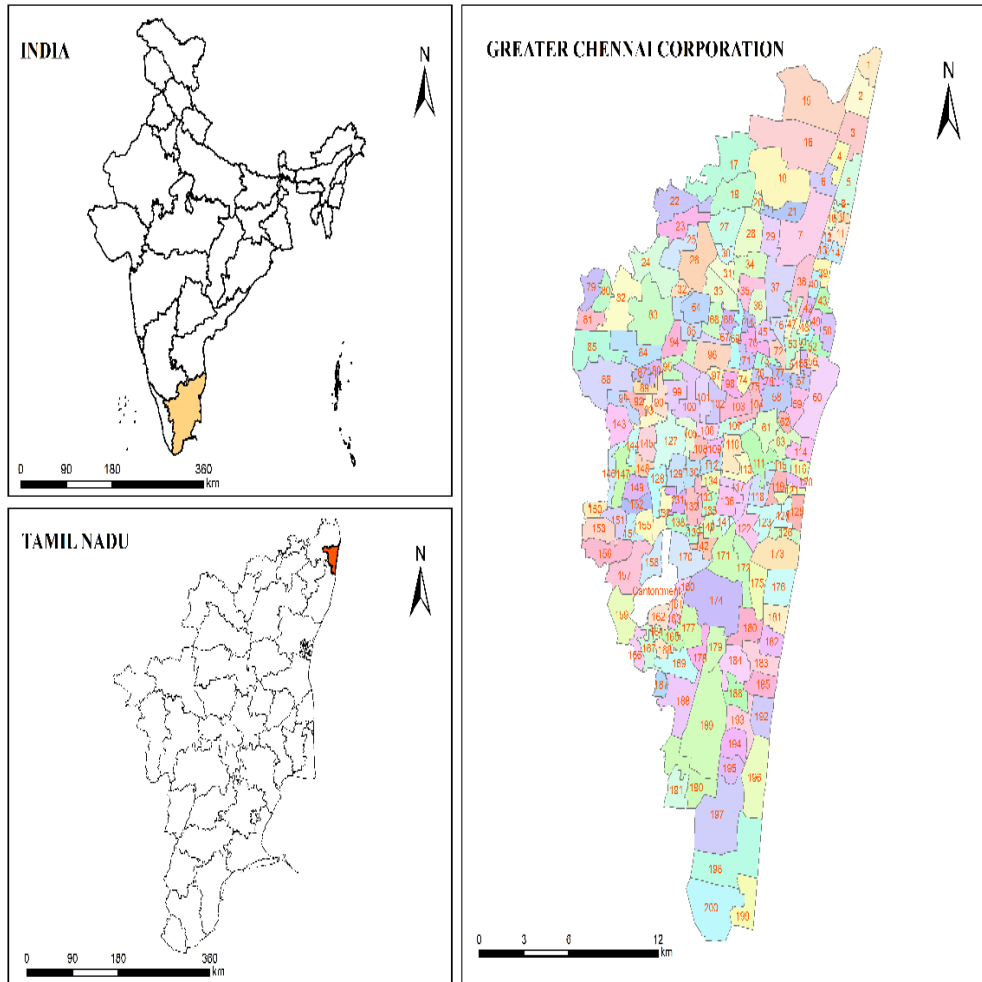


Fig4.1 Greater Chennai corporation

The Greater Chennai Corporation (GCC) is the civic body responsible for the administration of the city of Chennai in the state of Tamil Nadu, India.

The GCC is responsible for providing basic amenities such as water supply, sewage, and waste management, as well as urban planning, road maintenance, and public health services. The GCC is headed by a Commissioner who is appointed by the Tamil Nadu state government. The Commissioner is responsible for the overall functioning of the corporation and is assisted by various departments and officials. The Greater Chennai Corporation,[1] formerly known as the Corporation of Madras (1688–1996) and Corporation of Chennai (1996–2016), is the civic body that governs the metropolitan city of Chennai in the Indian state of Tamil Nadu. Inaugurated on 29 September 1688, under a royal charter issued by King James II of England on 30 December 1687 as the Corporation of Madras, it is the oldest municipal body of the Commonwealth of Nations outside Great Britain. It is among the oldest municipalities in Asia after Daman Municipality, which was established in 1588.[3] It is the largest municipal corporation in Tamil Nadu with an area of 426 km². It is headed by a mayor, who presides over 200 councillors, each of whom represents one of the 200 wards of the city.[4] It is the second oldest civic corporation in the world after the City of London.[5] The city limits, which had been expanded several times over the years, is currently coterminous with the Chennai district.

Overall, the Greater Chennai Corporation plays a crucial role in the development and management of the city of Chennai, and is committed to providing efficient and effective services to its citizens.

4.2 SLOPE MAP

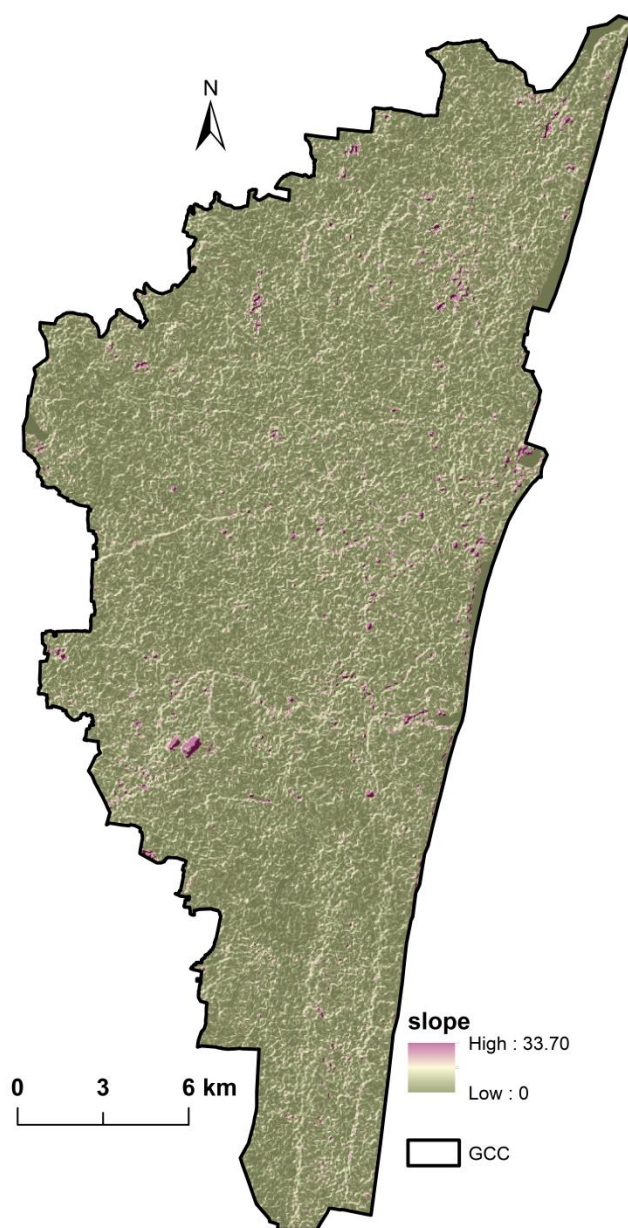


Fig 3.3.2 Slope Map

The map of Chennai's slope can be found in various sources online. It is a map of the city and its surrounding areas showing the elevation of each area. The map includes contour lines that show the steepness of the terrain in each location. The map also shows other features such as roads, rivers, parks, and points of interest.

Slope aspect maps are topographic maps that show the orientation and steepness of slopes in a particular area. The aspect refers to the direction in which a slope faces, which can affect factors such as solar radiation and snow accumulation. These maps are commonly used in various fields, such as geography, ecology, and land management. Slope aspect maps are typically created using geographic information systems (GIS) software, which can analyze digital elevation models (DEMs) to calculate the slope and aspect of each location in the area of interest.

The resulting map is color-coded to show the different slope and aspect classes, which can help users to identify areas with different characteristics, such as north-facing slopes that are shaded and cooler, or south-facing slopes that receive more sunlight and are warmer.

Slope aspect maps can be used for a variety of purposes, such as identifying potential avalanche hazards, predicting vegetation patterns, and planning land use activities. They are also helpful in understanding the distribution of wildlife species, as different species may have specific habitat requirements based on slope and aspect conditions.

GIS software can be used to create a slope map of an area, including Chennai. Here are the general steps to create a slope map using GIS:

Acquire digital elevation data: You can obtain digital elevation data from various sources such as USGS, ASTER GDEM, or SRTM. These data can be downloaded in raster format (such as GeoTIFF) and imported into a GIS software.

Preprocess the data: Before creating a slope map, you may need to preprocess the data by removing any noise or artifacts, filling in missing values, and projecting the data into a suitable coordinate system.

Calculate slope: In GIS software, you can calculate the slope of each cell in the digital elevation data using a terrain analysis tool such as slope, aspect, or hillshade. Slope is typically measured in degrees or percent.

Symbolize and visualize the slope map: Once you have calculated the slope values, you can symbolize the map using a color ramp or gradient to represent different slope classes, such as flat, gentle, moderate, or steep. You can also add other layers such as roads, rivers, or buildings to provide context.

Analyze and interpret the results: Finally, you can analyze and interpret the slope map to understand the topography, terrain features, and potential hazards of the area. For example, steep slopes may be prone to landslides or erosion, while gentle slopes may be suitable for agriculture or construction.

4.3 DIGITAL ELEVATION MODEL

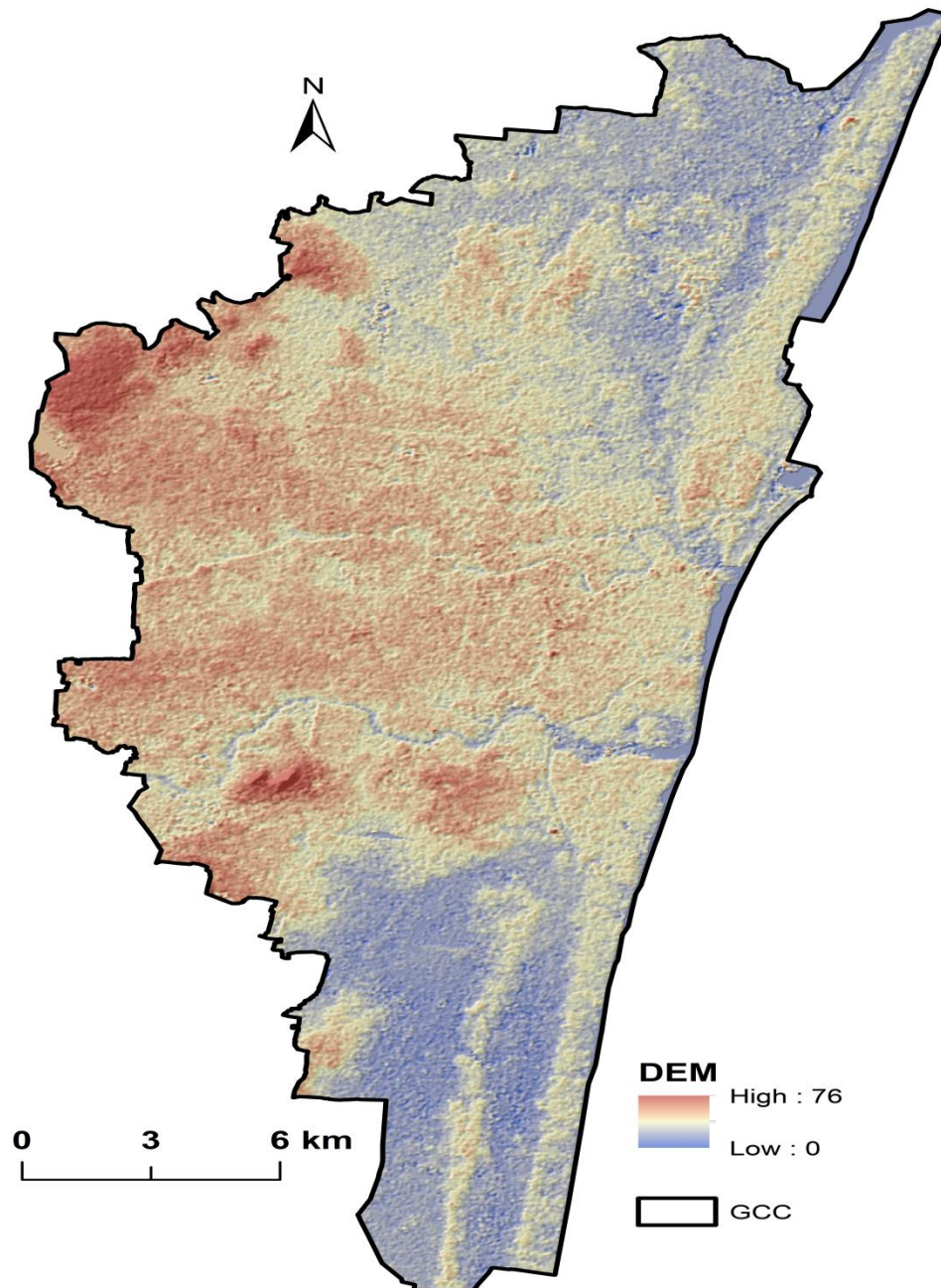


Fig 4.3 Digital Elevation Model

A Digital Elevation Model (DEM) is a digital representation of the elevation of the Earth's surface or terrain, typically represented in a raster format where each cell or pixel represents a unique elevation value. DEMs can be created from a variety of sources, including remote sensing technologies such as LiDAR (Light Detection and Ranging), photogrammetry, or radar.

DEM data can be used in various fields such as geography, geology, hydrology, environmental science, and engineering. Some common applications of DEMs include, Terrain analysis and visualization. DEM can be used to generate 3D terrain models and to analyze various terrain features such as slope, aspect, curvature, and flow direction. Land use planning and management: DEMs can be used to identify suitable sites for various land uses such as agriculture, forestry, mining, or urban development.

Hydrological modeling and flood mapping: DEMs can be used to model surface water flow, calculate drainage basins, and generate flood inundation maps. Environmental monitoring and assessment: DEMs can be used to track changes in terrain features such as erosion, land subsidence, or glacial retreat.

Navigation and transportation: DEMs can be used to generate accurate elevation profiles, plan routes, and design transportation infrastructure such as roads, railroads, or airports.

Overall, DEMs provide a valuable source of information for understanding and managing the Earth's surface and resources. In hydrology, DEMs are used to model surface water flow, calculate drainage basins, and generate flood inundation maps. This information is critical for understanding the distribution of surface water and managing water resources.

4.4 INUNDATED FLOOD LEVELING

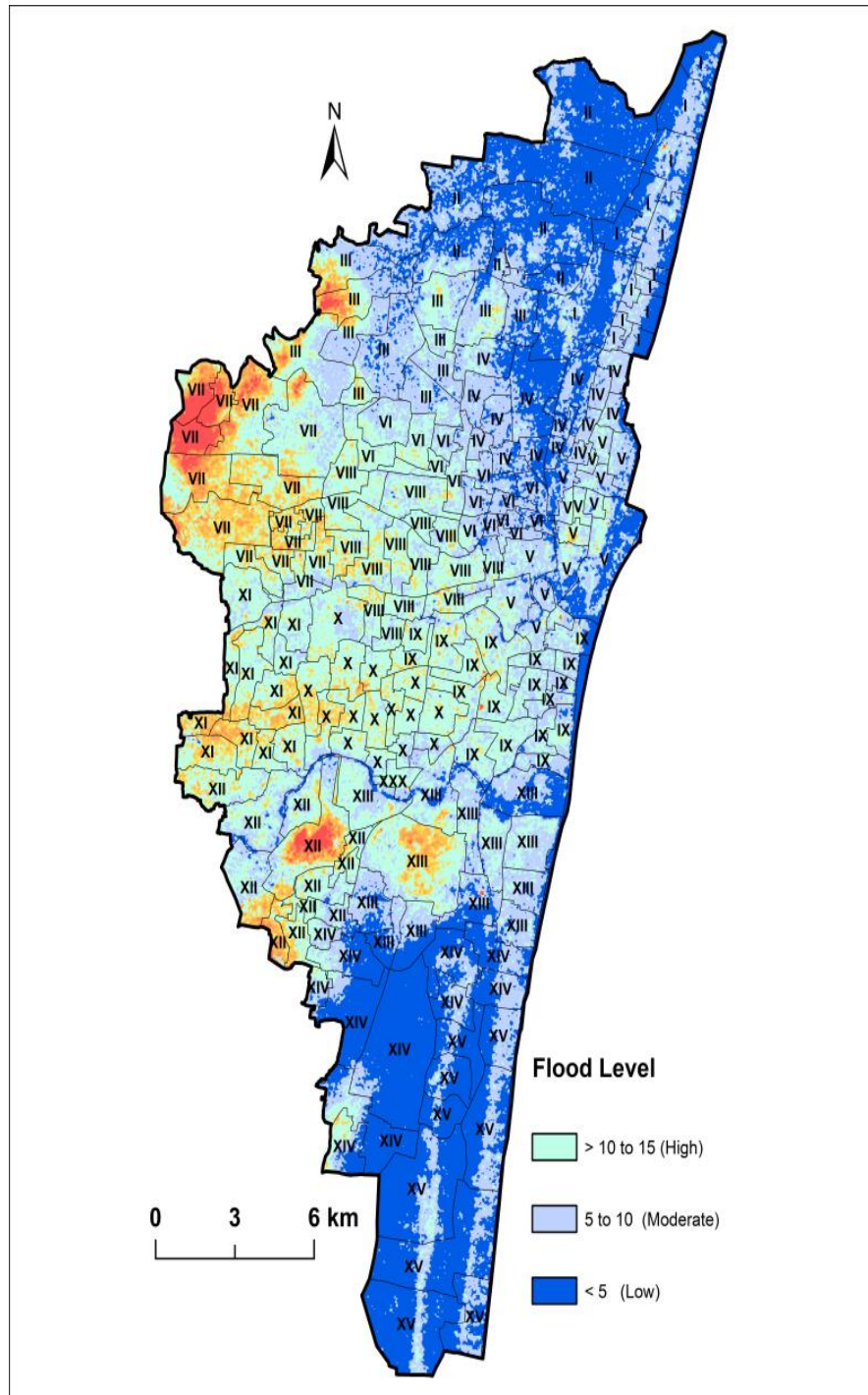


Fig 4.4.4 Inundanted flood leveling map

Chennai has experienced several devastating floods in the recent past, with the most severe one occurring in December 2015. During that time, the flood levels in Chennai reached up to 18 feet in some areas, causing massive destruction of property and loss of life. The flood levels in Chennai are usually measured by the amount of rainfall the city receives, which is measured in millimeters (mm) or inches.

However, it's worth noting that flood levels can also be affected by factors such as drainage systems, topography, and urbanization. If you're looking for specific information about the flood levels in Chennai during a particular period, it would be helpful to specify the time frame you're interested in. Chennai has experienced several instances of inundation in the recent past, with the most severe one occurring in December 2015, when the city received record-breaking rainfall.

During this period, many areas in the city were inundated, and the floodwaters disrupted normal life for several days. The Chennai Corporation and other government agencies have taken measures to mitigate the risk of inundation in the city, including improving drainage systems and clearing of encroachments in waterways. However, it's important for residents to also take necessary precautions during periods of heavy rainfall and follow instructions from authorities to stay safe.

A new, crowd sourced flood map of Chennai shows that among over 250 localities in Chennai, which saw intensive flooding during the November rains this year, many neighbourhoods were unusually flooded. This includes neighbourhoods such as T Nagar, Alwarpet, Egmore which have remained unaffected by monsoons in the previous years, barring the 2015 Chennai floods.

Sl.No.	Zone Number	Name of the Zone	Wards Details
1	I	THIRUVOTRIYUR	1 TO 14
2	II	MANALI	15 TO 21
3	III	MADHAVARAM	22 TO 33
4	IV	TONDIARPET	34 TO 48
5	V	ROYAPURAM	49 TO 63
6	VI	THIRU-VI-KA NAGAR	64 TO 78
7	VII	AMBATTUR	79 TO 93
8	VIII	ANNA NAGAR	94 TO 108
9	IX	TEYNAMPET	109 TO 126
10	X	KODAMBAKKAM	127 TO 142
11	XI	VALASARAVAKKAM	143 TO 155
12	XII	ALANDUR	156 TO 167
13	XIII	ADYAR	170 TO 182
14	XIV	PERUNGUDI	168, 169, 183 TO 191
15	XV	SOZHANGANALLUR	192 TO 200

Fig 3.3.5 Inundated area of greater Chennai based on divisions

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The state authorities tried to control the situation by bringing out motor pumps to clear waterlogged areas and sending its relief teams to flood-affected neighbourhoods. But as sea levels rise and heat waves intensify, experts say the city will need to do a lot more to mitigate the impact of extreme weather conditions in the future and to avoid a repeat of the deadly floods in 2015."The fact that water entered people's homes at the very beginning of the monsoon season shows just how unprepared Chennai is this time," says SA Haris Sultan, a member of anti-corruption watchdog Arappor Iyakkam based in the city.

To prepare for the monsoon season this year, the local government carried out an ambitious project to build storm water drains - which would collect excess rains from the streets and drain them into the sea. But within three days of heavy rains in the first week of November, the city was entirely flooded, bringing life to a standstill. Climate scientist Dr Roxy Mathew Koll says the city faltered in dealing with the situation because of the increasingly erratic nature of monsoons.

CHAPTER 5

CONCLUSION

The study on urban Chennai flooding using geospatial technology identified the major reasons for flooding and suggested mitigation strategies. The strategies proposed can be implemented by the Greater Chennai Corporation (GCC) to mitigate the effects of flooding and ensure the safety of the citizens. The use of geospatial technology proved to be effective in identifying flood-prone areas and can be used for similar studies in other cities prone to flooding. Some possible conclusions based on the use of these technologies are: Accurate mapping such as GIS, remote sensing, and LiDAR can help in accurate mapping of flood-prone areas, vulnerable infrastructure, and critical facilities. This can help in identifying high-risk areas and formulating appropriate mitigation measures. Geospatial technologies can be used to develop an early warning system for floods. Real-time data from sensors, satellite imagery, and weather forecasts can be integrated to predict flood events and issue timely alerts to the public and authorities. Geospatial technologies can aid in effective drainage management by mapping the existing drainage system, identifying blockages, and suggesting measures to improve the system's efficiency. This can help in reducing flood damage by ensuring timely and effective drainage. Geospatial technologies can help in developing flood models that can simulate various flood scenarios and help in developing strategies to mitigate the impact of floods. Overall, the use of geospatial technologies can be instrumental in mitigating the impact of floods in urban Chennai. However, it is essential to have a comprehensive approach that involves stakeholder engagement, capacity building, and a robust governance framework to ensure the effective implementation of these technologies.

REFERENCES:

- [1] Abdul-Ameer Al-Kanon, Ibtihal Adnan Suhel “flood hazards mitigation and strategies”, International Journal Of Scientific & Technology Research, volume 8, issue -October 2019
- [2] Ahmed S Elamary ,”Flood mapping using synthetic gap peature radar sensor” Thin Wall Structures, IEEE Transctions on Geo science and remote sensing NFM measures work by affecting one or more of these key mechanisms - October 2017
- [3] Albano, R.; Mancusi, L.; Abbate, A. “Improving Flood Risk Analysis for effectively supporting the implementation of flood risk management plans:”, Engineering Structures, pp 308-314, May 2017.
- [4] Anil K. Gupta and Sreeja S. Nair from the technical report of a national level study accomplished in India covering 8 important cities – Bangalore, Bhopal, Chennai, Kolkata, Materials Today Proceedings, pp 1159-1162, March 2015
- [5] David Fernandez-Lacabe¹, Claudio Lopez, Miguel Angel Serna “A study on urban flooding machine learning techniques”, Thin Walled Structures, pp 709-713, September- 2022.
- [6] Dhivya Karmegam et al Improving Flood Risk Analysis for effectively supporting the implementation of flood risk management plans titlted “Data regarding water extent”, Chennai, Journal of Constructional Research, pp 509-518, March 2016.
- [7] Jean joy et al “Flood inundated area detection using geospacial technologies” mapping while remote sensing technology and flood modelling methods are irrelevant due to unavailability of data, Hyderabad -2018

- [8] Malczewski, J.; Rinner, C. "Spatial prediction of flood susceptibility using random forest" to GIS-MCDA. In Multicriteria Decision Analysis in Geographic Information Science; Springer Science + Business Media: New York, NY, USA.
- [9] Nelson, S.A. "Flooding Hazards, Prediction & Human Intervention", Tulane University: New Orleans, LA, USA, 2015.
- [10] Peduzzi, P.; Dao, H.; Herold, C.; Mouton, F. Assessing global exposure and vulnerability towards natural hazards: The Disaster Risk Index. Nat. Hazards Earth Syst. Sci. 2009.
- [11] Punithavathi - An Flood prediction of flood susceptibility for assessment and presented the flood zone mapping was carried out in GIS Thanjavur district, Tamil Nadu (2016).
- [12] Saaty, T.L. How to Make a Decision: The Analytic Hierarchy Process. Eur. J. Oper. Res. 1990.
- [13] Samela, C.; Albano, R.; Sole, A.; Manfreda, S. An open source GIS software tool for cost effective delineation of flood prone areas. Comput. Environ. Urban Syst. 2018.
- [14] Sole, A.; Giosa, L.; Albano, R.; Cantisani, A. The laser scan data as a key element in the hydraulic flood modelling in urban areas. Int. Arch. Photogramm. Remote sensing.
- [15] Zwenzner, H.; Voigt, S. Improved estimation of flood parameters by combining space based SAR data with very high resolution digital elevation data. Hydrol. Earth Syst. Sci. Discuss. 2008.