Citizen consumer and civic Action Group (CAG)

Mapping floods to assess risks and vulnerabilities in the Chennai Metropolitan Area

A GIS analysis of the floods in Chennai in December 2015

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Background

Tamil Nadu experiences severe water shortages, and water stagnation and flooding every year. The recent policy focus in the state has been on groundwater recharge through rainwater harvesting, but in practice, the public water utility has been acquiring 'water fields' - agricultural lands in the peripheries of Chennai where the level and quality of groundwater is amenable for supply to the city's burgeoning water demands. Simultaneously, poor planning practices and enforcement of building rules has resulted in the majority of the city's lakes and ponds built over, obstructing the natural hydrology and destroying the ecology of the respective neighbourhoods. Unfortunately, successive governments have allowed for weaker plans and poor enforcement of the rules; they have even pushed for amendments that regularise violations and exemptions that will benefit the more affluent, often at the cost of the environment. For example, the Tamil Nadu government is currently in the process of framing exemptions for multi-storey buildings, reducing the parking requirements within property premises, and reducing the permissible distance between buildings and aquifers, among others. This degradation of the urban ecology has amplified the magnitude of risks that Chennai faces, particularly weakening the resilience of the city's residents.

The city has a poorly planned and severely inadequate storm water drain network, which is in a high state of disrepair despite the large amounts of funds allocated to the construction. A significant feature of the government's spending on all public infrastructures is that the focus is on construction but negligible attention is paid to maintenance. The built channels for water do not adequately meet the infrastructure needs of the city. The Buckingham Canal, the city's main waterway, was built to convey water from the inland to the sea but has been encroached. The commuter MRTS train line is almost wholly built over the Canal. The government has also frequently allocated land and built low income housing in large marshlands and natural catchment areas in the city, amplifying the vulnerabilities of the urban poor. All of this has resulted in Chennai experiencing water stagnation every monsoon and severe floods every 7-10 years.

In 2013-2015 we worked with the Corporation of Chennai (CoC), the city government, on building their capacity to collect and use (spatial) data for planning and monitoring. Despite several contracts and commissions to private businesses and universities, the city government lacks data and maps that it can use to plan and monitor public services, including storm water drains. In October 2014, we worked with city engineers to map water stagnation points in the city and documented possible causes and solutions to create a micro plan. The relevant department relied on an incomplete map that was neither geo-referenced nor to scale. During our engagement we saw that city engineers relied on their latent knowledge to address problems that were of a routine nature, but because of the informal nature of the knowledge and actions, the interventions remain ad hoc and in reaction to water overflows or stagnation. For example, they were aware that the drain network was illegally connected to the sewerage network at several places and this was being carried to the city's waterways and water bodies untreated, but were helpless in institutionalising this knowledge and leveraging it for planning and monitoring. At that time, CoC had requested our support in creating a geo-referenced map of the sub-surface storm water drain network but we did not have the capacity to undertake this task.

The flood map can help us make a compelling case for local actions to combat climate change. Often, city officials have wrongly attributed the devastation from unexpected flooding to the results of climate change alone when in fact it is also a result of poor planning and infrastructure. It has diluted the strategies that cities need to adopt to address climate change and improve resilience.

Objectives

The objective of our short research project was to make recommendations for the identification of water bodies and designation of flood risk zones within the Chennai Metropolitan Area. In order to do this, we needed to determine the actual extent of the inundation caused due to the floods in November and December 2015. Next we examined the possible influence of some factors in determining whether a given part of the metropolitan area will flood or not to identify the most relevant causal factors behind flood inundation in different parts of the city.

While the potential determining factors are many, only a few of them such as height above Mean Sea Level, proximity to water bodies (existing and reclaimed), proximity to water channels and size of upstream catchment area were considered. Other factors such as soil type, prevailing soil moisture levels, slope of land, effect of operations of upstream manmade water structures were not considered for the current timeline and resources. These limitations in scope could be addressed by developing a watershed model for the Chennai watersheds which factor in these variables.

The geographical scope of this exercise is limited to the Chennai Metropolitan Area. The temporal scope is limited to the floods of the first week of December, since based on available rainfall data and news reporting the flood inundation was at its peak during this period.

Approach

We primarily relied on three sources of information. We identified the flood inundated areas from the satellite image we obtained from the National Remote Sensing Centre, ISRO for the 4th of December through a Web Map Service (WMS). This image captures the extent of flooding in the region with reasonable accuracy. For the map of water bodies we used the 1955 US Army map. To estimate the elevation of the Chennai Metropolitan Area we used a Digital Elevation Model (DEM) from NASA.[1] Using these maps and information, we created the following four maps

1. A coastal flood risk estimation map
2. A water channels map
3. A water bodies map
4. A flood inundation map (for the 4th of December 2015)

1. **Coastal Flood Risk Estimation map**

   This map attempts to predict or estimate zones in proximity to the coast within the Chennai metropolitan area that are at risk of flooding due to the heavy rains. The line of reasoning follows that coastal areas below sea level or within a few metres of sea

[1] SRTM 1arc second (https://lta.cr.usgs.gov/SRTM1Arc), NASA

level are more prone to flooding both because of ingress of sea water as well as the longer time taken for drainage of storm water.

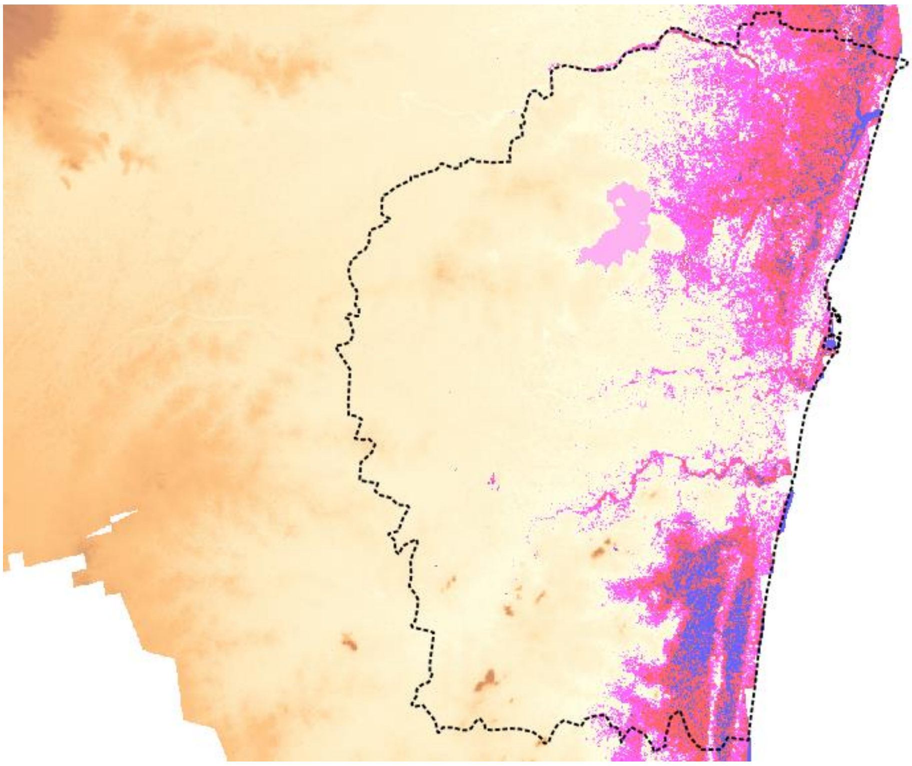

Figure 1: Digital Elevation Model of Chennai Metropolitan Area

We edited the DEM data to indicate the areas of high and low vulnerability with different colours in QGIS. The blue colours in the map indicate areas below Mean Sea Level (0 m) red indicates 0-4 m, pink 4-8 m and shades of brown indicate elevations greater than 8 m.

2. **Water Bodies map**

Digitising both the currently existing as well as the former water bodies in the Chennai Metropolitan Area is important to start the work on restoring the former water bodies and also restoring the ecology of these existing and former water bodies. Further, it helps understand the effect that water bodies and their reclamation may have on flood inundation. The US Army Topographic Maps (1955) showing water bodies for the Chennai area are the best available reference showing old water bodies in the region.[2] We first edited these maps in GIMP/Photoshop, a photo editing software, to filter out pixels from the map that showed water bodies. This was possible by converting into a binary format, with blue showing water bodies and white showing everything else. We then converted the jpg to a geo-referenced tiff file, which in turn, we converted to a polygon vector showing water bodies.

[2] http://www.lib.utexas.edu/maps/ams/india/

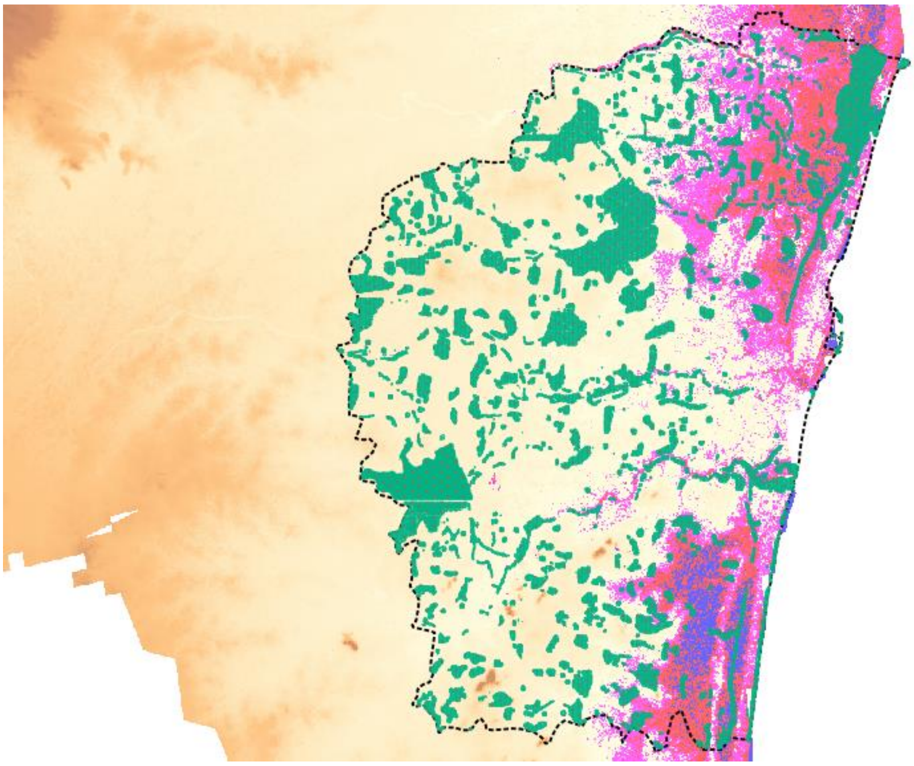

Figure 3 Water Bodies in the Chennai Metropolitan Area

Since this map was pre-satellite era we cannot be completely certain of the precise location of these old water bodies. However, the fact that the water bodies shown on the map clearly align with several currently existing water bodies lends credibility to it.

3. **Water Channels map**

In addition to the water bodies, we also identified water channels, i.e. the path water would take when it rains. The term 'water channel' does not necessarily indicate that water flows via these channels perennially but restoring these channels is important to ensure that the water bodies are fed with adequate water when it is available (e.g. monsoons).

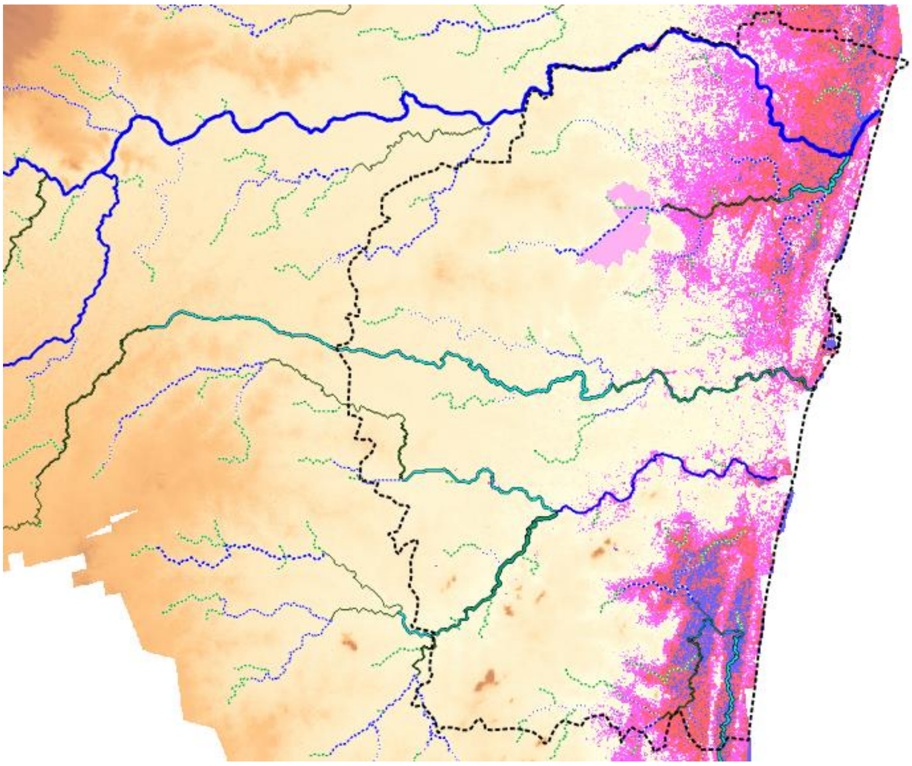

Figure 2 Water channels in the Chennai Metropolitan Area

As a first step we applied a 'sink fill' algorithm to the DEM to smoothen out any gaps. Next we made flow direction and flow accumulation rasters using tools from the SAGA toolbox in QGIS.[3] The flow accumulation raster assigns different values to each pixel on the raster. If the pixel has a large number of pixels upstream bringing water towards it, then it will have a correspondingly high number on the flow accumulation raster, i.e. larger water channels. After we prepared the flow accumulation raster we filtered out pixels with higher values using raster calculator. We then used the QGIS Polygonise tool to convert the raster files to vector, to obtain a water courses map with different line patterns indicating the size of the watersheds of each water channel.

4. Flood Inundation map

To complete the analysis we used a map of actual flood inundation for the city. Bhuvan, the web-platform of the National Remote Sensing Centre, published three maps of flood inundation of the Chennai Metropolitan Area for the dates of December 3, 4, 5 and 7 as Web Map Services that they gave us access to. We found the map for the December 4 most suitable for this analysis because it had the highest resolution. We viewed the map using QGIS, took geo-referenced snapshots and saved these as png files. We then converted the png files to polygon vector format using the QGIS Polygonize tool to obtain a vector file that shows us the boundaries of the flood inundated areas.

[3] http://gracilis.carleton.ca/CUOSGwiki/index.php/Exploring_the_Hydrological_Tools_in_QGIS

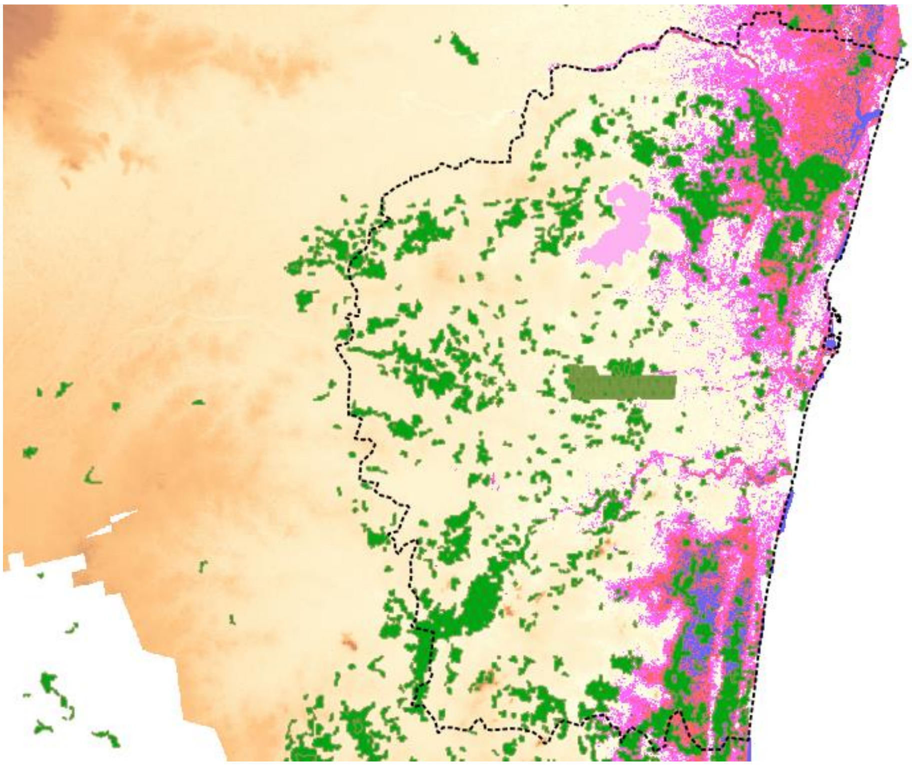

Figure 4: Flood Inundation in the Chennai Metropolitan Area

5. **Workshop on cartography and GIS**

To build capacity of students, citizens, activists and other civil society organisation members, we conducted a 2-day training workshop on cartography and GIS. The workshop covered the following topics:

- Introduction to data and maps, tools and techniques
- Hands on learning through outdoor data collection
- Data transfer from phone and paper to computer
- Geo-referencing and Digitisation of the data
- Visualisation using tools taught and data collected
- Discussion on insights, challenges of techniques learnt
- Applications to governance

After the training, people were encouraged to use the skills acquired to map ecologically vulnerable areas to strengthen their work on environmental protections and environmental justice.

Glossary

A **Web Map Service** (**WMS**) is a standard protocol for serving (over the Internet) georeferenced map images which a map server generates using data from a GIS database.	WMS
A **geographic information system** or **geographical information system** (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.	GIS
To **georeference** means to associate something with locations in physical space. The term is commonly used in the geographic information systems field to describe the process of associating a physical map or raster image of a map with spatial locations. Georeferencing may be applied to any kind of object or structure that can be related to a geographical location, such as points of interest, roads, places, bridges, or buildings.	Geo-reference
Raster images come in the form of individual pixels, and each spatial location or resolution element has a pixel associated where the pixel value indicates the attribute, such as color, elevation, or an ID number. Raster images are normally acquired by optical scanner, digital CCD camera and other raster imaging devices. Its spatial resolution is determined by the resolution of the acquisition device and the quality of the original data source. Because a raster image has to have pixels for all spatial locations, it is strictly limited by how big a spatial area it can represent. When increasing the spatial resolution by 2 times, the total size of a two-dimensional raster image will increase by 4 times because the number of pixels is doubled in both X and Y dimensions. The same is true when a larger area is to be covered when using same spatial resolution.	Raster data
Vector data comes in the form of points and lines that are geometrically and mathematically associated. Points are stored using the coordinates, for example, a two-dimensional point is stored as (x, y). Lines are stored as a series of point pairs, where each pair represents a straight line segment, for example, (x1, y1) and (x2, y2) indicating a line from (x1, y1) to (x2, y2). In general, vector data structure produces smaller file size than raster image because a raster image needs space for all pixels while only point coordinates are stored in vector representation. This is particularly true in the case when the graphics or images have large homogenous regions and the boundaries and shapes are the primary interest. Besides the size issue, vector data is easier than raster data to handle on a computer because it has fewer data items and it is more flexible to be adjusted for different scale, for example, a projection system in mapping application. This makes vector data structure the apparent choice for most mapping, GIS and CAD software packages. Also, topology among graphical objects or items are much easier to be represented using vector form, since a commonly shared edge can be easily defined according to its left and right side polygons. On the other hand, this is almost impossible or very difficult to do with pixels.	Vector data