

Geography 270
Geographic Information Science

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Final Project Report

De-Flooding by Re-Directing Runoff

A proposal to curb flooding in Hyderabad

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1.0 Abstract

The aim of this study is to identify sites in Hyderabad (Telangana, India) that are suitable for rain-water absorption given the recent increase in flooding events. In order to assess how rainwater could be re-directed to mitigate or even prevent flooding in Hyderabad, GIS-based analysis was performed. Various parameters such as Precipitation, Soil Moisture, Vegetation Fraction, Well, Water Body, and Channel Locations were analyzed and evaluated in co-relation to each other. This helped create a set of GIS based maps that identified various methods of dealing with the excessive rains in different regions of the city based on their specific environmental characteristics. The study has successfully demonstrated potential solutions that could be revised for application in a real-life scenario.

Keywords: Hyderabad, Flooding, GIS, Precipitation, Soil Moisture, Runoff.

2.0 Description of Project, Study Area, and Data

Hyderabad (7.37°N 78.48°E) is the 650 km² capital of the state of Telangana, India. Hyderabad has a semi-arid tropical wet and dry climate. The monthly mean temperatures range from 21°C - 33°C and usually peak in the months of April and June at about 40°C. Monsoon driven rains in the months ranging from June to September usually bring about 828.5 mm of rainfall yearly.¹



Figure 1 - Geographic Location of Hyderabad²

However, with the increasing impacts of climate change, the receipt of this seasonal rain has been narrowed down to an even shorter window, resulting in rapid and heavy downpour. In October 2017, the city received 46% surplus rainfall.³ On several occasions, this has resulted in severe flooding, bringing the city to a halt. In combination with the poor drainage system, the city's urban sprawl has created a 'concrete jungle', with not enough (permeable) land exposure for the rainwater to be absorbed, leading to flooding.⁴

¹ Hyderabad, Andhra Pradesh Climate & Temperature. (n.d.). Retrieved December 03, 2017, from <http://www.hyderabad.climatemps.com/>

² New state of Telangana . (n.d.). In BBC. Retrieved December 3, 2017, from <http://www.bbc.com/news/world-asia-india-27658817>

³ Heavy rains lash Hyderabad, flood many colonies. (2017, October 8). Deccan Chronicle . Retrieved December 3, 2017, from <http://www.deccanchronicle.com/nation/current-affairs/081017/heavy-rains-lash-hyderabad-flood-many-colonies.html>

⁴ Prasad, K. (2017, July 16). 25 districts in Telangana record excess rainfall. Times Of India. Retrieved December 3, 2017, from <https://timesofindia.indiatimes.com/city/hyderabad/25-districts-in-telangana-record-excess-rainfall/articleshow/59614914.cms>



Collage – Flooding in Hyderabad⁵

Hence, using GIS, I would like to isolate regions with high surface runoff, and identify various methods that could be used to re-direct the rainwater to nearby water bodies in order to prevent flooding. This would also help recharge the underground aquifers (bore-wells), that have been severely depleted from overuse. This study is important as it can help save lives, prevent infrastructural and economic damage, and also help make Hyderabad more environmentally sustainable.

The results of this study are presented in the form of three maps, each focusing on different regions of the city with distinctive environmental characteristics -

- 1) A map identifying Lakes and Channels in regions of High Surface Runoff to re-direct rainwater to.
- 2) A map identifying Wells in regions High Surface Runoff to re-direct excessive rainwater to.
- 3) A map identifying Green Zones in regions of Low Surface Runoff that should be protected in order to prevent flooding.

⁵ Rao, S. (2016, September 22). Hyderabad: Heavy rain triggers traffic jams, roads cave in, localities flooded. Hindustan Times. Retrieved December 3, 2017, from <http://www.hindustantimes.com/telangana/heavy-rains-jam-traffic-flood-localities-cave-roads-in-hyderabad/story-8aLd2Eg354wpS1VnQ81dkN.html>

3.0 Methodology of Analysis

3.1 Data Acquisition and Use

The project mainly relied on satellite data collected by various governments, private organizations, and user generated maps. The following table lists all the data sets that were used for this study.

<i>SN</i>	<i>Layer</i>	<i>Purpose</i>	<i>Format</i>	<i>Map</i>	<i>Source</i>
1	Hyderabad Base Map	A satellite base map of the city	Raster	1, 2, 3	Arc GIS Database
2	Hyderabad Boundary	To gauge the city's size and clip layers to	Vector	1, 2, 3	OpenStreetMap
3	Average Precipitation	Reference	Raster	-	CEDA and NASA TRMM
7	Digital Elevation Model	Reference	Raster	-	NASA ASTER GDEM
5	Relative Soil Moisture	To identify variation in soil moisture	Raster	1, 2, 3	Private Remote Sensing Agency
4	Relative Vegetation Fraction	To identify regions that absorb rainwater well	Raster	3	Indian NRSC OCM2
6	Wells	To identify underground water aquifers	Vector	2	OpenStreetMap
10	Water Bodies	To identify water bodies on the surface	Vector	1	OpenStreetMap
11	Channel Network	To identify water channels	Vector	1	OpenStreetMap

3.2 Procedure Analysis

The following sections explain how each of the individual maps were created.

3.2.1 - Map 1 – Identifying Lakes and Channels in Regions with High Surface Runoff

- 1) First, I added the polygon boundary of Hyderabad along with a high-resolution satellite image into ArcGIS. This serves as a demarcation of the region of interest to perform my analysis within.
- 2) Then, I imported the Relative Soil Moisture raster layer into the working file. This was raw data and hence required classification and clipping:
 - a) I used the Raster Reclassification tool to create categories of Relative Soil Moisture.
 - b) First, I used the exclusion tool to exclude the value -999, which represented water bodies.
 - c) Then, I classified the data into 10 relative categories using natural breaks.
 - d) Once I had a pixel grid over the region, I changed the symbology to a color gradient of red to blue, in decreasing order of soil moisture content.
 - e) In order to smoothen out the pixels, I resampled the display method using cubic convolution as it was continuous data.
 - f) Finally, using the extract by mask tool, I clipped the layer to the boundary of Hyderabad.
- 3) Next, I added the vector Lake polygon layer and Streams line layer and clipped the layers using the boundary demarcation polygon.
- 4) Then I converted the soil moisture raster to a vector file in order to conduct proximity analysis by doing the following -
 - a) Using the raster re-classification tool, I created a new layer of relatively low soil moisture by extracting the values between -999 and 3.
 - b) I then converted the output raster re-classification to a polygon using the raster to polygon tool.
- 5) Next, I created a new layer by adding a 500-meter buffer to these low soil moisture polygons.
- 6) Some of the lake polygons were part of one flat feature, and hence, I edited this layer to make them individual features, by using the explode tool to separate them.
- 7) Next, using the select by location tool, with the input as the lakes and streams, and the source layer as the buffered polygons, I was able to identify lakes and streams of interest.
- 8) Finally, I created a traditional GIS map with all map elements included.

3.2.2 - Map 2 – Identifying Wells in Regions with High Surface Runoff

- 1) First, I added the polygon boundary of Hyderabad along with a high-resolution satellite image into ArcGIS. This serves as a demarcation of the region of interest to perform my analysis within.
- 2) Then, I imported the Relative Soil Moisture raster layer into the working file. This was raw data and hence required classification and clipping. (Refer to step 2 in 3.2.1 for detailed steps)

- 3) Next, I added the vector point layer that displayed the wells over the region of Hyderabad.
- 4) Then I converted the soil moisture raster to a vector file in order to conduct proximity analysis by doing the following – (Refer to step 4 in 3.2.1 for detailed steps)
- 5) Next, I created a new layer by adding a 3-kilometer buffer to these low soil moisture polygons.
- 6) Then, using the select by location tool, with the input as the wells and the source layer as the buffered polygons, I was able to identify wells of interest within the region.
- 7) Finally, I created a traditional GIS map with all map elements included.

3.2.3 - Map 3 – Identifying Green Regions to be Protected in Regions of Low Surface Runoff

- 1) I first added the polygon boundary of Hyderabad along with a high-resolution satellite image into ArcGIS. This serves as a demarcation of the region of interest to perform my analysis within.
- 2) Then, I imported the Relative Soil Moisture raster layer into the working file. This was raw data and hence required classification and clipping. (Refer to step 2 in 3.2.1 for detailed steps)
- 3) Next, I added the vegetative fraction raster layer and extracted a mask the size of Hyderabad.
- 4) I was only interested in regions of high vegetation and hence re-classified the raster by doing the following –
 - a) I used the exclusion tool to exclude the values between -999 and 99, leaving me with a range of values between of 100 – 250.
 - b) Once I had the re-classified pixel grid over the region, I converted it to a vector file using the raster to polygon tool.
- 5) Finally, by adding the preferred symbology to the layer in focus, I created a traditional GIS map with all map elements included.

4.0 Discussion and Results

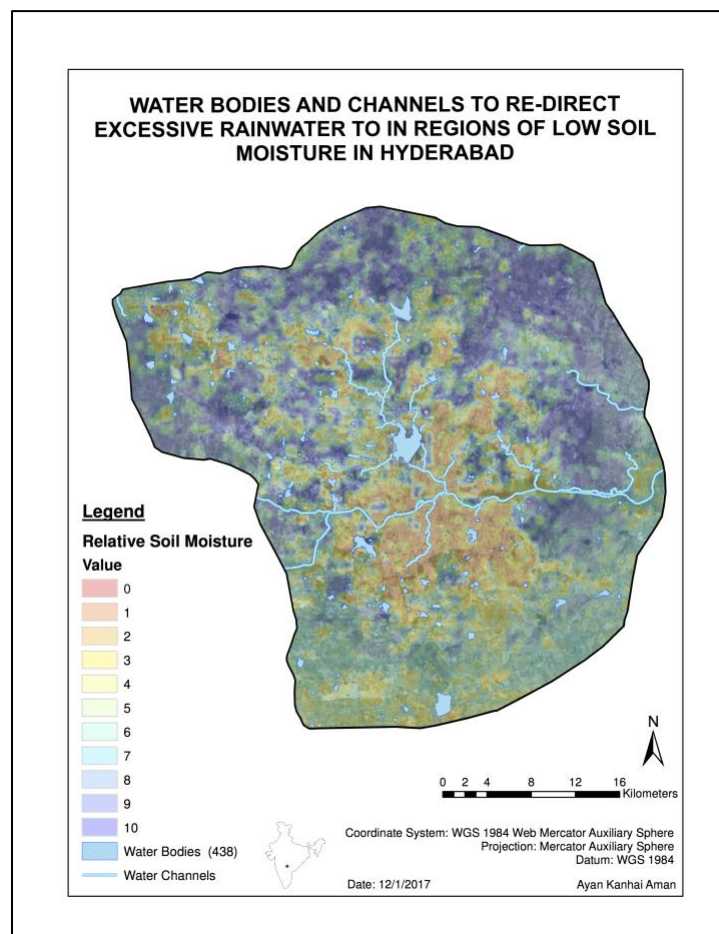
4.1 Underlying Assumptions

Owing to the lack of data, this study was conducted with the underlying assumption that soil moisture content on any given day is a function of surface runoff. Hence, low soil moisture content would imply that the soil is unable to retain water, and hence there is high surface runoff. High surface runoff would therefore imply that the region is flooded given that other conditions for a flooding event are met.⁶ Keeping this in mind, the soil moisture dataset that was used for this analysis, was from a day with excessive flooding across the city.

4.2 Resultant Map Analysis

The following sections discuss the results and implications of each map that was created.

4.2.1 - Map 1 – Identifying Lakes and Channels in Regions with High Surface Runoff



Map 1

This map was created with a focus on the greater region of Hyderabad. Meaning, this map focuses on how flooding can be averted with the whole city as the region of interest. This map analysis proposes

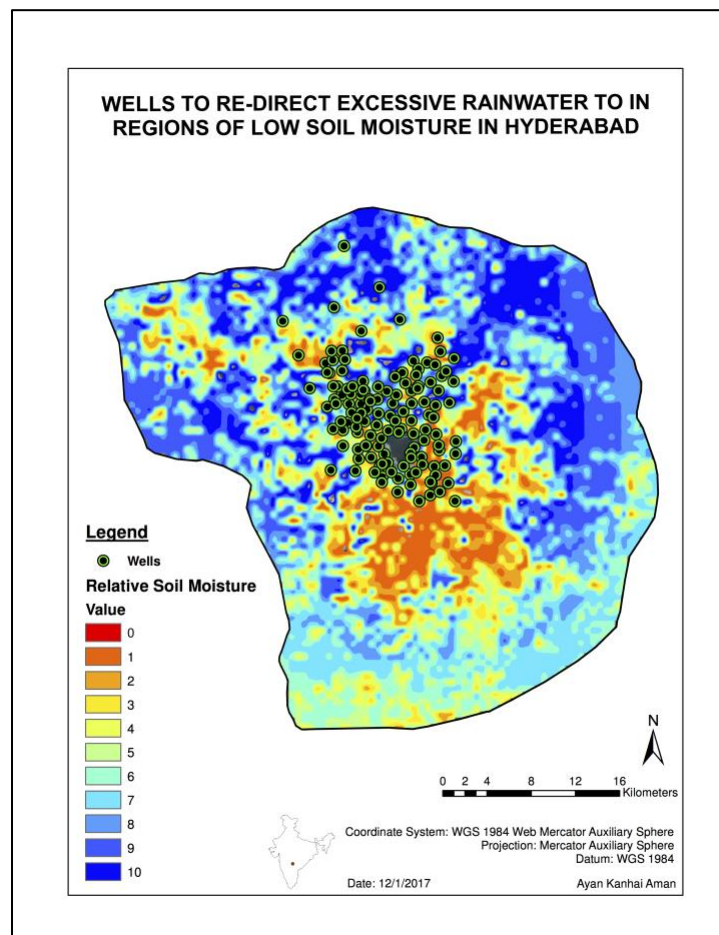
⁶ Meyles, E. (n.d.). Runoff generation in relation to soil moisture patterns in a small Dartmoor catchment, Southwest England (Rep.). Wiley InterScience . doi:10.1002/hyp.1122

the re-direction of excessive rainwater to water bodies and channels within 500 meters of any given locality with a high surface runoff.

Ideally, this proposal would require the building of a new and larger drainage network that would channel large amounts of rainwater directly into the nearby water bodies or channels. However, construction of such a scale would be really expensive, time-consuming, and inconvenient. Hence, a more realistic way of going about this would be by re-structuring and upgrading the current drainage system to channel larger amounts of water and connecting it to the water bodies and channels.

The strength of this proposal is that if executed properly, the system will be able to handle excessive amounts of water at faster rates, reducing the likelihood of a flood greatly. However, this analysis does not consider the holding capacity of the water bodies and channels, which would mean that if the rainfall is severe, there could be an overflow at some point.

4.2.2 - Map 2 – Identifying Wells in Regions with High Surface Runoff



Map 2

This map was created with a focus on the central region of Hyderabad. After the first map analysis, I realized that there are not many water bodies and channels present in the center of the city, making it (4.2.1) a challenging proposal. This region also has the greatest population density, and hence the highest built-up-area, forming a ‘concrete jungle’⁷. This means that the region would have a relatively low soil permeability, implying high surface runoff and hence making it highly prone to flooding.

Therefore, in addition to the first solution (Re-direction to Water bodies and Channels), this proposal identifies wells in the region of high runoff to which the disproportionate rainwater could be redirected to.

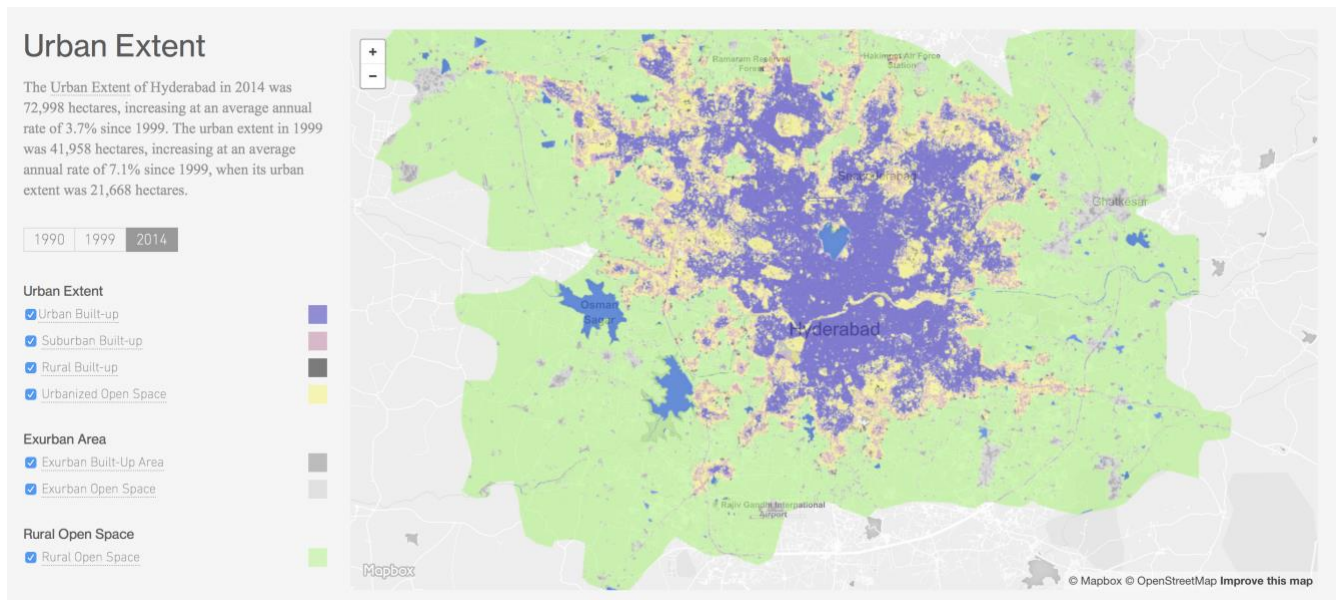


Image 2- Hyderabad's Urban Extent⁷

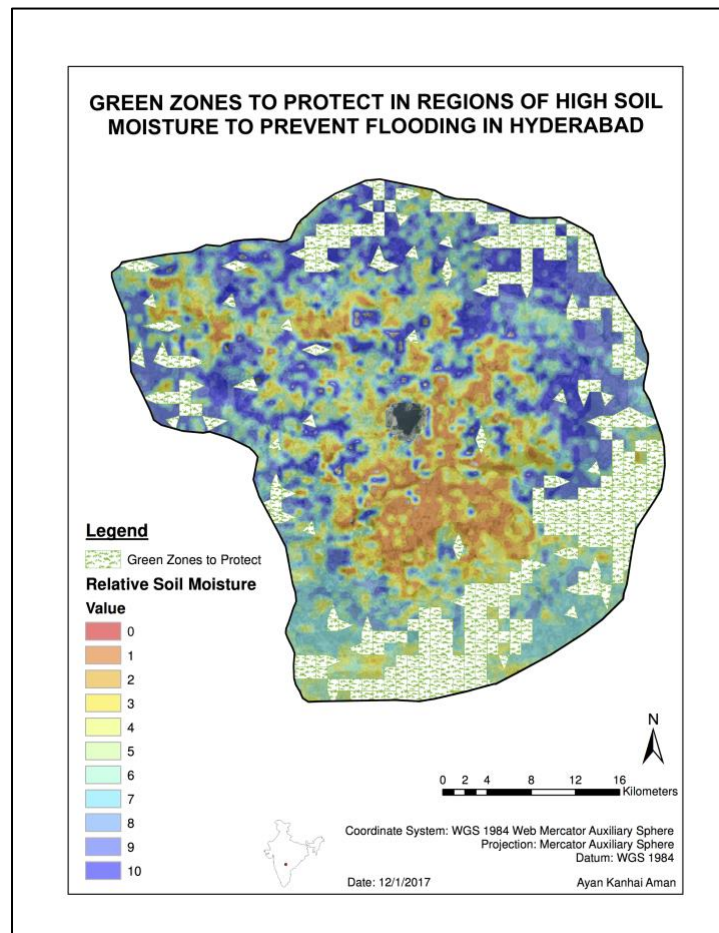
Owing to the high population concentrations, the water table in the region has severely depleted from overuse, leading to chronic water shortages. Therefore, in times of high rainfall, by redirecting the rainwater to pre-existing wells in the region, flooding could be mitigated/prevented while also restoring these aquifers over time.

For the optimal outcome, this proposal would also require the building of a new drainage grid that would directly connect to the inlets of these wells. Alternatively, new wells could also be bored in a systematic manner to directly intercept rainwater. However, these would both again be really expensive, time-consuming, and inconvenient. Hence, a more realistic way of working towards this proposal would again be by re-structuring and upgrading the current drainage system to channel larger amounts of water and connect to all the existing well inlets.

It is important to keep in mind that there is only so much water the drainage system of the interiors could take at once. Hence, it is crucial to realize that this method will reach a saturation point, after which flooding will be possible. However, the flooding would be of a lesser magnitude as compared to how it would have been in a business as usual scenario. Hence, this proposal will only work in addition to the previous (4.2.1). One of the issues with this map analysis is the data gap for wells in the southern region of the city. Meaning, this map does not represent *all* the wells that could have potentially been a part of this proposal.

4.2.3 - Map 3 – Identifying Green Regions to be Protected in Regions of Low Surface Runoff

⁷ Hyderabad Urban Extent. (2014). In Atlas Of Urban Expansion. Retrieved December 3, 2017, from <http://www.atlasofurbanexpansion.org/cities/view/Hyderabad>



Map 3

This map focuses on regions of the city with the highest soil moisture and hence the lowest surface runoff. This analysis was performed by co-relating low-runoff to a high vegetative fraction; The assumption being that the presence of vegetation greatly increases soil permeability and water holding capacity.⁸

Hence, the aim of this map is to show the importance of vegetation in the prevention of flooding. This map proposes that these Green Zones that have been identified, be protected by constituting laws into place in order to maintain their current capacity to absorb rainwater.

The issue with this analysis was that the resolution of the vegetative fraction was low, and hence, smaller sites that could have potentially been a part of it were not identified. However, this map serves as a great example proving the importance of vegetation for the proper functioning and sustainability of an ecosystem.

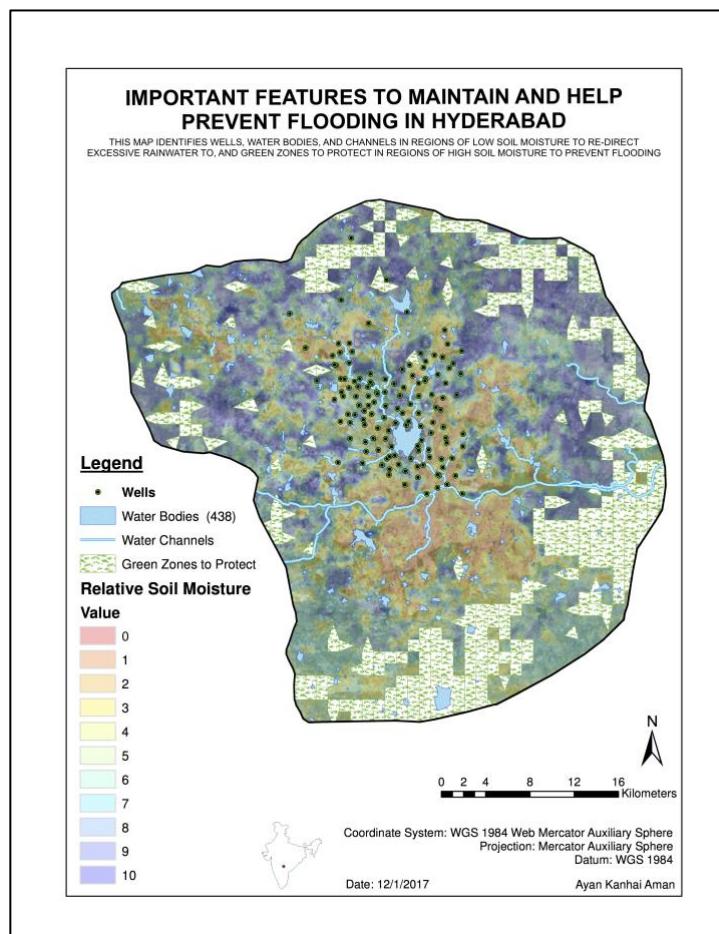
4.3 General Discussion

⁸ Wang, C., Zhao, C., Xu, Z., Wang, Y., & Peng, H. (2013). Effect of vegetation on soil water retention and storage in a semi-arid alpine forest catchment. *Journal of Arid Land*, 5(2), 207-219. doi:10.1007/s40333-013-0151-5

In essence, each of these proposals eventually either call for a newly designed drainage system, or the re-structuring and upgrading of the current network. However, given the rate at which this problem is growing, it is in the best interest of the city and its people to start pushing for the restructuring of the drainage network immediately. To begin with, the government should clean up the current system, as there is severe clogging in a few regions that leads to flooding with minimal amounts of rainfall.

Although I have been able to identify various solutions to deal with this issue, realistically, it seems quite difficult to be actually put into practice due to several barriers such as pre-existing buildings, roads, etc. One of the problems in India has also been the unplanned growth of cities. As the cities grow, new infrastructure is added to the pre-existing ones, creating a complex system that is in-efficient and can collapse anytime⁹. The analysis also helped me understand the importance of vegetation for the maintenance of an ecosystem.

Further, what would be ideal is a new system built solely to intercept rainwater and collect it in holding tanks, providing the city with a surplus of fresh, potable water. If the city does not have the capacity to store such large amounts of rainwater, the water could be connected to a larger network of fresh-water grids across the state, providing several farmers in arid regions with fresh water. Following, is a map that summarizes all my proposals -



Map 4

9 Jaysawal, N. (2014). Urbanization in India: An Impact Assessment. International Journal of Applied Sociology. doi:10.5923/j.ijas.20140402.04

5.0 Error and Uncertainty

A majority of the data was either really difficult to find or needed heavy processing (which I lack experience in). Some of the layers (wells, water bodies, and channels) used in the analysis were user-sourced and hence might have been inaccurate to a certain extent. However, the main analysis was based on datasets that were procured from credible governments and remote-sensing agencies, and were hence quite reliable.

One of the major weaknesses of this analysis is that a Digital Elevation Model was not used to identify the direction of flow. Hence, even though I have been able to identify several features to mitigate flooding, I am not sure whether the water can physically flow in the required direction. However, I was willing to perform this part of the analysis as well but could not find the required dataset of the artificially built drainage network over the city.

The analysis was conducted on the assumption that low soil moisture content during a period of flooding implied high runoff. It would have been great if I was able to perform my analysis against an actual flood map from the given day. However, I was unable to find this data anywhere.

It is also important to keep in mind that the scales of measurement used in this analysis were all relative, in order to make calculations easier and also as the actual measurements were not useful given the depth of this analysis. However, it would be interesting to see how these proposals plays out with actual mathematical and physical analysis.

6.0 Further Research and Recommendations

Overall, I believe that this analysis strongly points to the directions that the city needs to start working in, in order to minimize the impacts of climate change. This study had the potential to be conducted at a greater analytical depth, although the lack of necessary fundamental data was a huge restriction. Additionally, given more time and experience, this analysis could have been much more accurate. Hence, I propose, a further study could be to redo this project in a real-life scenario, with all data and factors at play.

I would also highly recommend considering datasets such as DEM, Soil Type, Land Use, Artificial Drainage Network, Precipitation, Stream Order, and Flood Maps. Further research should also be conducted to better understand the runoff mechanisms with respect to soil moisture retention and land usage in the region of interest.

7.0 Appendices

7.1 Bibliography

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9. Jaysawal, N. (2014). Urbanization in India: An Impact Assessment. *International Journal of Applied Sociology*. doi:10.5923/j.ijas.20140402.04

7.2 Flowchart (Read From Bottom)

