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Impact of decadal change in basin morphometry due to Urbanization – Bengaluru, India

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ABSTRACT

Bangalore is one of the fastest growing cities of Asia, is having population of over ten million, the third-most populous city and fifth-most populous urban agglomeration in India. The city was not as big it is now with advent of growing software industry the overall dimensions of city changed in less than two decades. Since the inception of the city, Bengaluru had a proper set of drainage characteristics through a proper network of tanks, surface water bodies interconnected. But unplanned and unpredicted urbanization has led to forceful change of course of streams, encroachment of tanks etc.… which has affected the natural flow of water. This advent of urbanization, various basin morphometric changes it has been experienced in the city and would be a near concerns in future.

Key words : *Bengaluru, Landuse and Lndcover, Flash Flood, Urbanisation*

Introduction

The urban areas are at risk and needs to be addressed in a conservative manner (Niemczymowicz, 1999). The recent shift of population from rural to urban areas, is termed as urbanization. But this shift has been regulated properly in a scientific way in some cities and in few it has not been regulated. This in recent decades has diverse effects on environment leading to pollution and contamination of natural resources, thus effecting the quality of human health. Along with this Urbanization encroachment to a watershed decreases the pervious surface areas (Paul and Meyer, 2001) which in turn reduces the rate of infiltration with a increase in runoff (Dunne and Leopold, 1978; Gordon *et al*., 1992).

Hegde and Subashchandra, (2012), has discussed the reduction of water availability. The scenario explained says that the change in land use and land cover affected the natural precipitation process with low infiltration and high runoff scenarios which willled to flash floods generally termed, "the urban floods". The heavy downpour lives the water clogged in the city with improper management of runoff. Bangalore is also facing the threat of this large-scale urban floods (Ramachandra *et al*., 2009, 2013). The exclusive concerns for these urban floods include man made intense alterations in the landscape like encroachment, asphalting of roads, poor solid waste management etc…There is a change in ground water infiltration patterns as well (Mehta, 2013). The city experiences Southwest Monsoon which is seasonal having peaks in the month of September, according to Department of Economics and statistics it has been getting an average rainfall of 800mm to 900mm per annum regularly. City is still dependent on very old drainage network of water catchment which has been unscientifically altered due to urban expansion (Suresh, 2001).

Study Area

Greater Bangalore, has an areal extinct of 741 square kilometres. Is the city termed as silliocon valley of India. It is a place where people from all across the country come for and carrer development (Figure 1). Moving on to technical aspects of the study area, geomorphology of the city hasintermingling hills and valleys more like a pediplains. The general geology of the area consists mainly of granite and gneissic with minor intrusions of pegmatite veins and dolorite and ambhibolite dykes. There are tectonic impressions in fractures along the area which is responsiple for hosting the ground water. Rainfall is a dynamic factor in basin morphometry, the rainfall patterns and fluctations, rainfall mean and peaks are imperative. A century rainfall data wasobtained. The normal rainfall of Bangalore urban is about 831 mm (Department of Statistics, Government of Karnataka, 2018). The precipitaion is from two different wind patterens namely southwestern monsoon which contributes 54.18% and northeastern monsoon contributes 26.53% with an additional precipitation frompremonsoon showers of 18.53%. According to the Figure, (2 & 3) there is no major change in rainfall pattern, slight change is in the peak rain fall months. Earlier the rainfall peak was in august, september and october now in past six dcades.

Methodology

The Images were obtained from LANDSAT 8 an

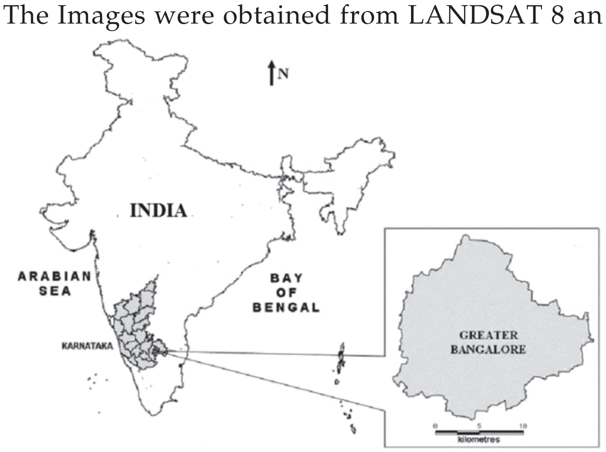

Fig. 1. Study Area

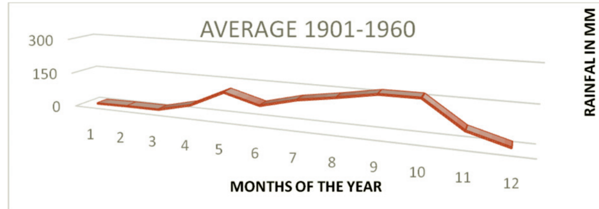

Fig. 2. Rainfall data analysis from 1901-1960

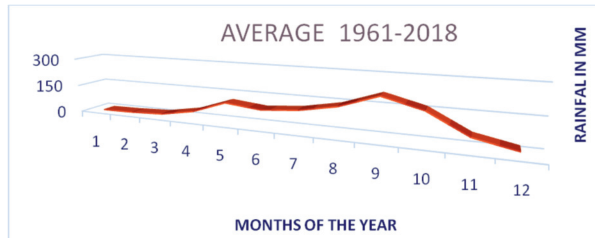

Fig. 3. Rainfall data analysis from 1961-2019

USGS Earth Explorer and then these images were imported to Q-GIS/Arc GIS to create a hill shade view. Digital Elevation Model of Bengaluru was obtained from clipping of the required shape file area from the obtained satellite images. Land-use/ Land cover Map was obtained using Landsat 8 band combinations 5-4-3 (F.C.C.) in ArcGIS to convert it to raster format. Drainage pattern were extracted from the same tool. The drinage intersection with the urban enclaves are drawn. Intersection point between Drainage Pattern & Urbanization helps usto find zones of urban floods for disaster management.

Results and Discussion

The morphometric data, Land use and land cover

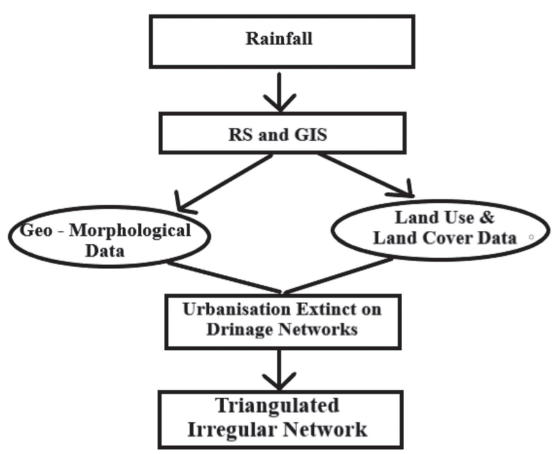

Fig. 4. Methodology Flow

maps, tank reduction map, were obtained from satellite and aerial imagery. Supper imposing potential maps and the result and discussion from them are as follows:

Morphometric Data

Bengaluru city, is situated at an altitude of 839 to 962 meters above sea level. The catchment in centeral Bengaluru has aridge running NNE-SSW which marks the basin boundary of different catchments. Doddabettahalli at an altitute of 962m is the highest elevation in the area. The slope is gentle with smaller valleys all along hence the velocity of streams are not so high. The a undulating terrain at places are responsible for number of tanks all along the area which has been desmanled due to urban activities. There are three major catchment systems, i.e. Vrishabhavathi Valley the one which lies in the south west, Challaghatta Valley towards north east, Hebbal and Koramangala Valley lieing in the south eastern side. The interconections of lakes added as primary function as flood carriers, have provided the city with reasonable ecological and recreational values.

The major river basins are absent in the area, however they form a healthy catchment to rivers like Arkavathi and Kaveri which merge together probably in Mekedatu, which is located 60 km south of Bangalore. Smaller channel of Vrishabhavati is a tributary of Arkavathi which flows for a small stretch in the Bangalore South, now it carries a bulk of the city's sewerage. The stance is the city is left with handful of freshwater lakes. The catchment map sugests that the Kormangla Hebbal valley has the longest flow path and DEM sugests that the slop is not to high in this area which might be a hotspot for urban flooding.

Drainage Network

Bangalore is a host of different watersheds, having varing geomorphic feactures whichmakes the city self suffeciant to harvest its own water. It is havig a quality length of first order and secound order streems and convertion rate to thirt and fourth orders. The below table gives the length of the streems and the number. Bangalore is having a good amount of drinage network for being a self sufficient water management system (Figure 7). The

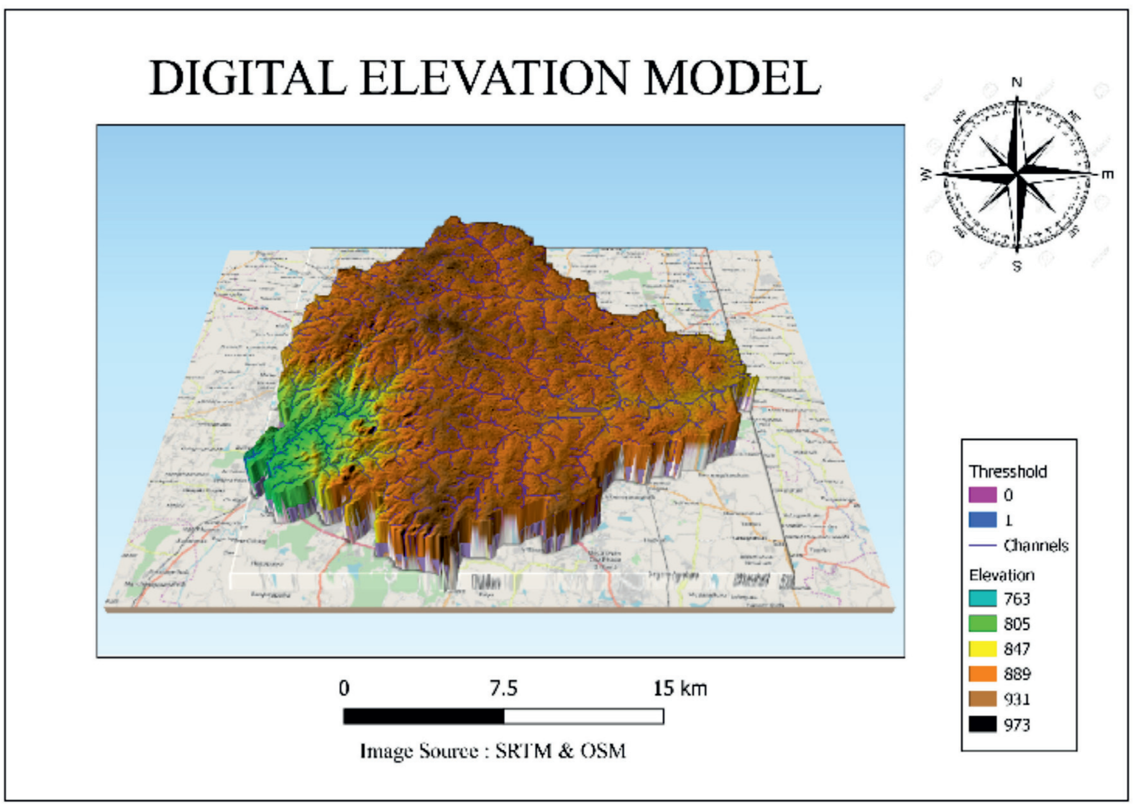

Fig. 5. Bengaluru digital elevation map

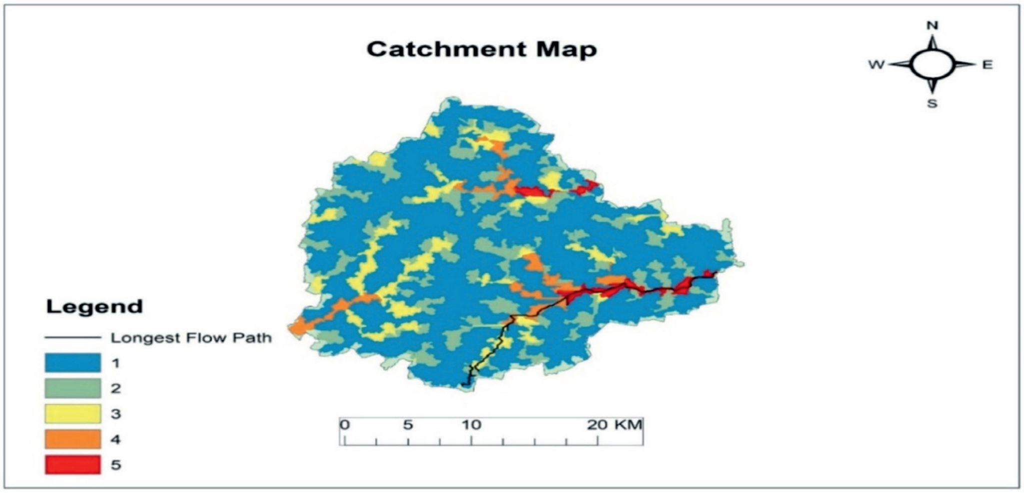

Fig. 6. Bengaluru Catchment map

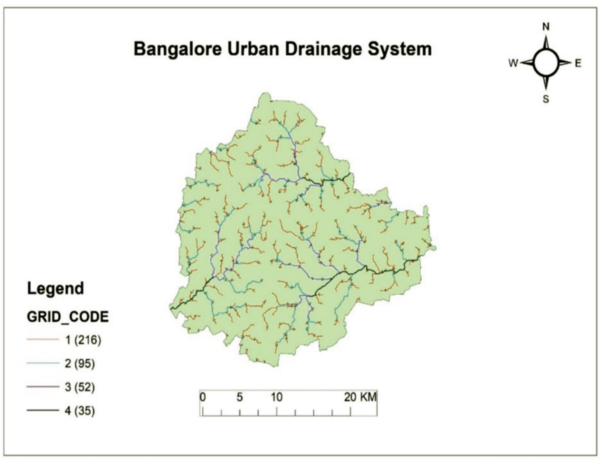

Fig. 7. Bengaluru Catchment map

length of the stream is mentioned in Table 1.

Table 1. Stream length

Stream Order	Length (m)
1	282354
2	137648
3	66225
4	35837

Land Use and Land Cover

There is a dynamic change in Land use and land cover from 2006 to 2019 (Figure 8). The data of 2006 and the present analysis was made from the LANDSAT 8. The comparative analysis show there is a 22% reduction of land cover this also shows the drastic reduction in size of tanks as well. This shows the rapid urbanization has been accelerated from

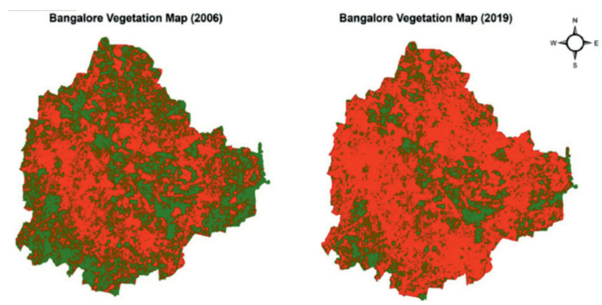

Fig. 8. Changed Land use area in Bangalore

2006 (Table 2).

Reduction of Tanks

A lesser known fact is that Bengaluru also had a number of tanks. According to the city corporation, (BBMP), the city had 198 lakes. The rapid urban growth has further reduced to only 38 water bodies currently (Table 3). The best practices' that was used to harvest water in the city was through tanks but now their number and area reduced (Figure 9). These tanks earlier had the capacity to hold runoff and prevent flooding but now this might result in

Table 2. Change in Land use & Land cover

Bengaluru in 2006		
Vegetation or Green Cover	398 km^2	53.71%
Land used	343 km^2	46.28%
Total Land	741 km^2	
Bengaluru in 2019		
Vegetation or Green Cover	243 km^2	32.77%
Land used	498 km^2	65.99%
Total Land	741 km^2	

Fig. 9. Existing Tanks in the city

flooding due to increased urbanization (Figure 10).

Urban Floods

The delineation of flood prone areas can be done by identification of current urbanized structures on the earlier streams and tanks of general morphometry. This flood mapping involves the complex interaction of stream flow with morphometrical features and revised land use structures, i.e. civil structures. From conventional flood hazard mapping technique based on field investigation to a knowledge-based system, the study focused on the preparation of Triangulated Irregular Network (TIN) (Fig. 8) these are the surfaces of 3D coordinate pointes connected to form a triangular tessellation. These are the volumetrically good junctions of the drainage pattern from available cross section data, contours and spot elevations and then comparing the same with ground report, i.e. the impact of urbanization has made its way into the blocking of streams or not. This also provides basic framework that would help administrators and planners to identify areas of risk and prioritize their mitigation and response efforts. Due to unplanned urbanization drainage network is entirely affected, streams of various orders are disappeared, and vegetation reduced. In the present study we have tried and find out the actual effect on the drainage network reduction in area under vegetation and green cover. Over 50 locations of channel flow have been completely modified to roads, apartment's, layouts etc.… without proper network our water disposal method. There is also a drastic change in land use, land cover, the vegetation or green cover has reduced by 22%. The study was done using satellite image of land sat 8 and the data was field verified. We can conclude that the Bengaluru morphology is severally affected by the

Table 3. Reduction of water bodies

Year	Number of Water bodies	Area in (ha)
Before 1970	207	2342
1973	159	2003
1992	147	1583
2002	107	1083
2007	93	918
2019	38	332

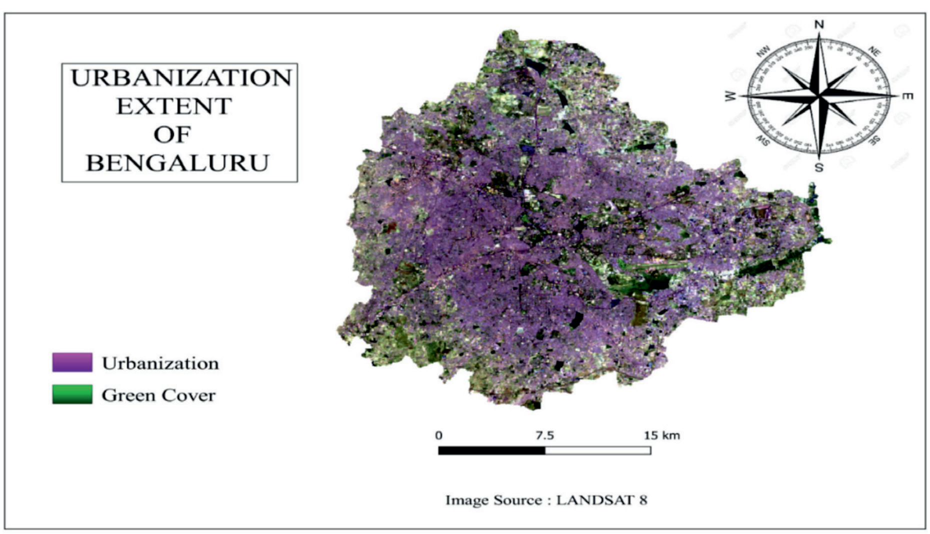

Fig. 10. Urbanization Extinct

Table 4. High volumetric junctions with current structures

OID	Current Structure	E	N
1	Urban Enclave	77° 36' 4.822" E	12° 51' 12.804" N
2	Urban Enclave	77° 34' 44.064" E	12° 51' 5.857" N
3	National Highway	77° 34' 17.642" E	12° 50' 54.929" N
4	Urban Enclave	77° 30' 51.113" E	12° 54' 18.650" N
5	Urban Enclave	77° 28' 47.544" E	12° 54' 31.448" N
6	Apartment	77° 38' 20.297" E	12° 53' 20.440" N
7	Silk board flyover	77° 37' 24.316" E	12° 54' 59.445" N
8	Urban Enclave	77° 37' 13.934" E	12° 55' 13.318" N
9	Urban Enclave	77° 34' 23.622" E	12° 55' 1.243" N
10	Urban Enclave	77° 35' 6.302" E	12° 55' 56.756" N
11	Urban Enclave	77° 36' 56.696" E	12° 55' 42.748" N
12	Urban Enclave	77° 44' 15.344" E	12° 59' 6.042" N
13	Urban Enclave	77° 44' 53.654" E	12° 59' 58.984" N
14	Urban Enclave	77° 31' 51.062" E	12° 56' 45.486" N
15	Urban Enclave	77° 30' 21.482" E	12° 58' 4.664" N
16	Urban Enclave	77° 33' 7.773" E	12° 58' 48.657" N
17	Urban Enclave	77° 33' 36.745" E	12° 58' 50.093" N
18	Urban Enclave	77° 33' 39.734" E	12° 57' 59.291" N
19	Urban Enclave	77° 34' 37.436" E	12° 57' 38.929" N
20	Urban Enclave	77° 38' 19.112" E	12° 57' 10.033" N
21	Urban Enclave	77° 40' 54.350" E	12° 55' 43.261" N
22	Urban Enclave	77° 41' 24.366" E	12° 56' 1.022" N
23	Urban Enclave	77° 42' 7.341" E	12° 57' 21.460" N
24	Urban Enclave	77° 40' 44.918" E	12° 57' 25.754" N
25	Urban Enclave	77° 39' 57.415" E	12° 57' 55.068" N
26	Urban Enclave	77° 38' 42.697" E	12° 59' 4.669" N
27	Main Road (Railway Parallel Road)	77° 39' 5.773" E	12° 59' 29.388" N
28	Urban Enclave	77° 38' 25.820" E	13° 1' 31.125" N
29	Urban Enclave	77° 43' 44.044" E	12° 59' 40.273" N
30	Urban Enclave	77° 42' 47.288" E	13° 0' 5.821" N
31	Urban Enclave	77° 42' 36.583" E	13° 1' 10.466" N
32	Urban Enclave	77° 41' 26.012" E	12° 59' 15.039" N
33	Urban Enclave	77° 40' 58.575" E	13° 0' 14.695" N
34	Urban Enclave	77° 41' 30.320" E	13° 0' 28.994" N
35	THE DEFENCE ENCLAVE	77° 38' 40.894" E	13° 3' 17.468" N
36	Urban Enclave	77° 31' 10.767" E	12° 59' 12.400" N
37	Urban Enclave	77° 29' 51.338" E	12° 59' 22.310" N
38	Water Treatment Plant	77° 29' 36.230" E	13° 2' 31.784" N
39	Urban Enclave	77° 32' 52.842" E	13° 0' 12.181" N
40	Urban Enclave	77° 35' 27.350" E	13° 0' 41.370" N
41	Urban Enclave	77° 34' 51.047" E	13° 0' 25.921" N
42	Urban Enclave	77° 33' 16.855" E	13° 0' 58.477" N
43	Urban Enclave	77° 32' 46.864" E	13° 1' 2.043" N
44	Yeshwanthpur APMC Yard	77° 32' 37.200" E	13° 1' 35.943" N
45	Urban Enclave	77° 31' 23.560" E	13° 1' 12.672" N
46	Urban Enclave	77° 31' 19.640" E	13° 2' 18.174" N
47	Police Station, Peenya, Bangalore,Karnataka	77° 31' 10.765" E	13° 1' 47.370" N
48	Urban Enclave	77° 31' 19.239" E	13° 2' 44.085" N
49	Commercial Complex	77° 32' 41.746" E	13° 4' 9.762" N
50	Apartment	77° 35' 41.846" E	13° 3' 42.154" N
51	Apartment	77° 35' 38.747" E	13° 5' 3.504" N
52	Urban Enclave	77° 36' 34.061" E	13° 7' 9.441" N
53	Urban Enclave	77° 36' 11.282" E	13° 6' 32.240" N
54	Urban Enclave	77° 35' 10.927" E	13° 6' 53.500" N

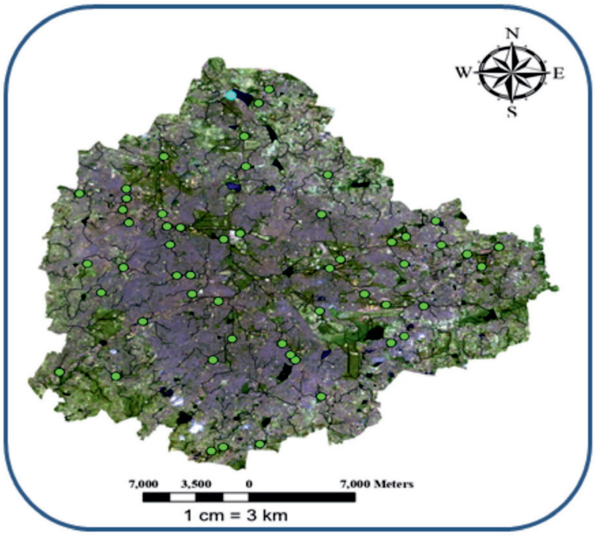

Fig. 10. High volumetric junctions of Bangalore

rapid urbanization in recent decades. Rainfall pattern is not changed majorly only the peek months have changed.

The high risk areas are near K R Puram, Kothnur, Dooravaninagar, Indranagar, Marathahalli a stretch of areas that fits in Kormangala valley which starts from central Bangalore and the rate of accumulation increases as it reaches this area and it requires more spacing and proper channel flow as well. Bengaluru North areas of Hebbal Valley, i.e. Yelahanka, Yeshwanthpur, Jakkur earlier had a great network of organized tank management system where the water used to get accumulated now due to dying of these lakes we are facing same condition but the risk seems to be less compared to the Kormangala Valley. In southern Bengaluru, i.e. Vrishabhavathi Valley has a high steep gradient according to the DEM data hence if there is a free flow of water the risk of urban flooding would be less.

Conclusion

The intense flood zones are marked based on Geomorphology and Catchment, around 50+ high flood risk areas are identified which needs immediate action.Lakes which were created basically for checking floods, recharging, sediment traps, prevent clogging up of natural valleys and reduce erosion are now converted to urban civil structures. There is a serious problem of water drains because of encroached drainage systems by the buildings and apartments, pooling of water on roads makes traffic issues in Bengaluru in rains. Micro catchment mapping and working out with artificial lakes is need of the hour in the city. This is indirectly affecting the levels of water table as well. The collective level of acting to the cause has to happen from the people as well. Hence, measures for rejuvenation of tanks and lakes in the will build up water resources and reduce the flash flood rates and intensity.

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