

# Floods in Delhi: causes and challenges

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## 1. Introduction

India's urban population is the second largest in the world after China, and is higher than the total urban population of all countries put together barring China, USA and Russia. In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001 and 53 in 2011 (Census of India, 1991, 2001 and 2011). The prominent ones are Delhi (16.34 million), Mumbai (18.39 million), Kolkata (14.05) and Chennai (8.65 million). There is a mass migration of people from rural areas to cities and also from smaller to larger cities and then to metropolitan centres like Delhi, Mumbai, Kolkata and Chennai.

The major cause of this urbanization is the search for better employment opportunities in these urban centres in comparison to neighbouring States. As urban population increases, the demand of land for various urban activities also increases. The process of urbanization in India gained momentum with the start of the industrial revolution in the 1970s followed by globalization in the 1990s. Forests were cleared, grasslands ploughed or grazed, wetlands drained and croplands encroached upon due to expanding cities, yet never as fast as in the recent past (Rahman, 2007a). This exponential population growth has wreaked havoc on human life in the city environment. The doubling and tripling of urban population in practically all major cities and towns and the consequent strain on existing systems has manifested in environmental chaos. Every major city of India faces the same proliferating problems of urban expansion, inadequate housing, poor transportation, poor sewerage, erratic electric supply, and insufficient water supplies. An increasing number of trucks, buses, cars, three-wheelers and motorcycles all spewing uncontrolled fumes, all competing for space on city streets already jammed with jaywalking pedestrians, rickshaws and cattle. The phenomena of rapid urban economic growth and urbanization are the main culprits, which besides bringing higher standards of living, has also brought problems related to the growth of dense and unplanned residential areas, environmental pollution, lack of services and amenities, solid waste generation, and growth of slums. Population growth and in-migration of poor people, industrial growth, inefficient and inadequate traffic corridors, and poor environmental infrastructure are the main factors that have deteriorated the overall quality of the city environment.

Many urban cities in India are facing stresses like urban poverty, basic urban services, loss of urban green spaces, disrupted ecosystems, exhausted institutions due to rapid and unplanned development. These stresses can further exacerbate the impact of disasters in the complex urban environment. For example, For instance, Mumbai flood of 2005 is a classic example that shows disaster impact as a result of interaction between shocks (floods) and stresses (urban poverty, unplanned development, and loss of urban green space, among others) (Government of Maharashtra 2005).

Over the last few decades, urban areas are increasingly getting affected by climate-related disasters, which have resulted in increase in economic losses and deaths (Munich Re Group 2009). Typically, in urban areas, impacts of disasters depend upon several factors including intensity and frequency of natural hazards, climate change, and urban stresses, among others. However, it is also widely assumed that resilient cities can effectively address urban stresses and impact of climate change. To build a resilient city, it is essential to assess their resilience level (Prashar et al., 2012).

India is one of the most important countries in the world with regard to the impact of hydrometeorological disasters such as floods, storms, mass movements (wet), extreme temperatures, droughts, and wild fires. Between 1980 and 2010, more than 400 disasters have occurred in India and most of them are hydrometeorological in nature, affecting millions of people through the loss of lives, injuries, and damage to infrastructure. The Centre for research on the Epidemiology of Disasters (EM-DAT, 2010) noted that 54.2 % of the total people were killed from hydrometeorological disasters, 34.8 % from geophysical, and the remaining 10.8 % were reported killed from biological disasters. Impact of hydrometeorological disasters is increasing in urban areas of India, especially due to the floods that occurred recently in several megacities of India. About 12% (about 40 million hectares) of India's geographical area is subject to riverine and flash floods of which about 8 million hectares are susceptible to annual flooding. In 2010, floods occurred in many megacities like Delhi, Guwahati, Ahmedabad, and Mumbai (National Disaster Management Authority, 2010). Similarly, in 2008, Jamshedpur, Mumbai, and Hyderabad were worst affected cities in India. On one hand, these cities are the major economic centres with large international operation, and on the other hand, they encountered higher economic loss due to floods than other disasters (National Disaster Management Authority, 2010). Moreover, these cities create a complex dynamic system as a result of concentration of people, resources, and information (Chatterjee, 2010).

After independence of India, Delhi the capital of India also witnessed a large influx of migrants, within a very short time; the population of Delhi increased more than two fold. To house such a large migrant population, the city has to expand. The rate of expansion is very fast, unplanned, uncontrolled and most of them are illegal (Rahman and Agarwal, 2007). The un-even distribution of rainfall coupled with mindless urbanisation, encroaching upon and filling up natural drainage channels and urban lakes to use the high-value urban land for buildings are causing the increase in flood incidences in the city. The illegal filling of urban water bodies in city like Delhi is a rampant. The number of water bodies in Delhi accounting for about 800 had now remained 600 and rest vanished. Thousands of illegal colonies have emerged in city and planning has been thrown to the winds resulting in narrowing of natural drainage which is posing a serious threat to health of the city and invitation to urban flooding (NIDM, n.d.).

The territory of Delhi has been reportedly experiencing riverine floods mainly from Sahibi Nadi (passing through Najafgarh Drain in Delhi) and Yamuna River. Nonetheless, local drainage system has also been, at times, found to be inadequate to meet the requirement, when there is heavy rain fall or during floods.

This paper deals with causes, effects, and trends of floods in general with focus on Delhi, the capital city of India.

## 2. City Profile: Delhi

Delhi is the capital of India located in the northern part of the country. The capital is also called as National Capital Territory (NCT) of Delhi. The state is spread over an area of about 1,484 km<sup>2</sup> of which about 470 km<sup>2</sup> is urban area. Its maximum length is 51.90 km and greatest width is 48.48 km.

Delhi is among the seven world's largest cities and is increasing in population. The total population of the city increased from 14 million in 2001 census to 16 million in 2011 census making it one of the densely populated areas in the country (Census, 2001, 2011; Singh, 2010). By 2030, Delhi is projected as second world's largest city after Tokyo with swift rise in population to 37 million (United Nations, 2014). It comprises of nine revenue districts – Central Delhi, North Delhi, South Delhi, East Delhi, North East Delhi, South West Delhi, New Delhi, North West Delhi, and West Delhi (Fig. 1 & 2). More than 53% of the population of Delhi in 2011 lived in three districts viz. North-west, South and West districts of Delhi (Prashar, 2013; Economic Survey of India, 2014-2015). 93% of the population of Delhi is urbanized. The population density as per 2011 census is ~~1,124~~ 11,320 persons per sq. km. (Census of India 2011). The city is the largest metropolis in India in terms of area and second largest by population (Prashar, 2013).

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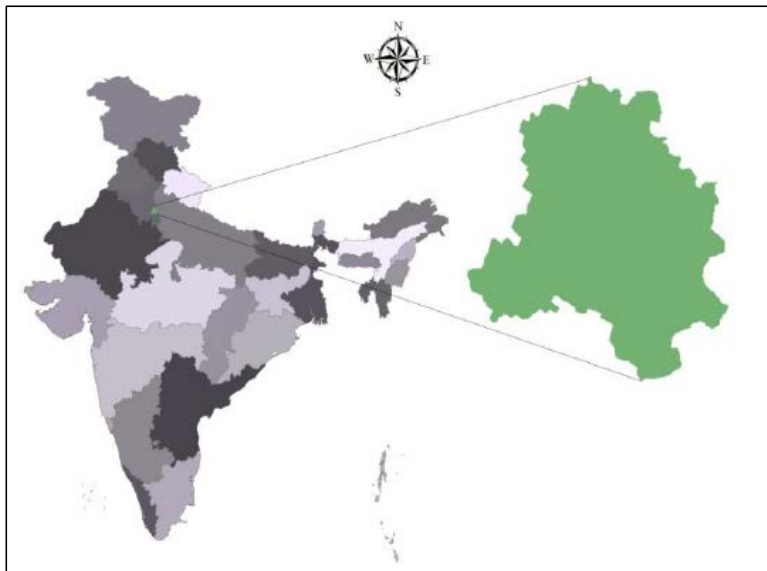


Fig. 1 Location of Delhi within India

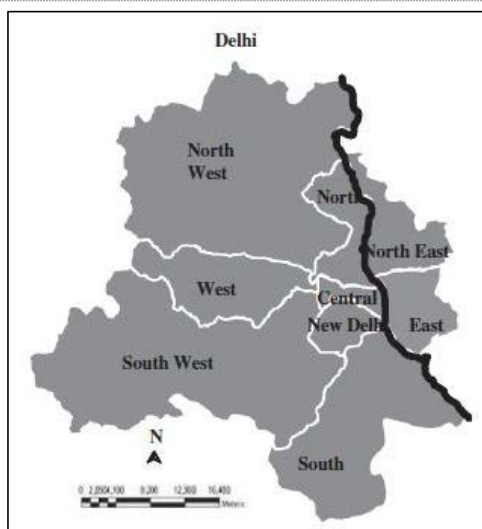


Fig. 2 Districts of Delhi

## 2.1 Physical Features

### Geography

According to the Indian geography the state is located at the center of the Indian subcontinent, in the fertile alluvial plains of Northern India amidst the ranges of Himalaya and the Aravalli. Delhi is located at latitude of 28°34' N and a longitude of 77°07'E having an average elevation of 233 m (ranging from 213 to 305 m) above the mean sea level. Delhi can be divided into three major geographical regions: the Yamuna flood plain, the ridge and the Gangetic Plains (Singh and Mohan, 2008). Delhi is bounded by the Indo-Gangetic alluvial plains in the North and East, by Thar Desert in the West and by Aravalli hill ranges in the South. The terrain of Delhi is flat in general except for a low NNE-SSW trending ridge that is considered an extension of the Aravalli hills of Rajasthan. The ridge may be said to enter Delhi from the SW. The eastern part of the ridge extends up to Okhla in the South and disappears below Yamuna alluvium in the NE on the right bank of the river (DDMA, 2014-15).

### Water Resources

Delhi is situated on the western banks of river Yamuna. The presence of Yamuna makes the soil very fertile. Yamuna provides major proportion of surface water supply in Delhi, which constitutes nearly 86% of the total water supply. Other sources that provide water for city's supply are Himalayan Rivers and sub-surface resources such as Ranney wells or tubewells. The other major sources of water include the Agra Canal, Hindon Canal and the Western Yamuna Canal. In about 90% of the land in Delhi, fresh water is available at depths varying from less than 2 m upto 60 m and the quality of water is also all right i.e. in drinkable condition. Only some 10 % of the area comprises the ridge and some has saline and brackish waters (DDMA, 2014-15).

### *Drainage*

National Capital Region in general, is a part of well integrated drainage system of the Ganga basin. The extremely gentle gradient that spreads almost all over the region restricts the degradational activities of the streams/drains.

The region forming the metropolitan area of Delhi, almost entirely comprises plain land which is characterised by the presence of two main features - a long rocky ridge extending roughly in the south-west - north-east direction and a river, entering from the north-eastern edge of the territory and flowing across its south-eastern edge. The general slope of the land in Delhi is from north to south and the Ridge acts as the local watershed dividing the drainage system of the region into two sectors. While the eastern region drains directly into the Yamuna, the western region does the same through the Najafgarh drain.

On the basis of topographical characteristics, the National Capital Territory of Delhi has been divided into five major drainage basins viz. Najafgarh basin, Alipur basin, Shahadra basin, Kushak-Barrapullah basin and Mehrauli basin. This drainage system is such that all waters collected through the main drains, link drains and small rivulets are directly or indirectly discharged finally into the Yamuna.

### *Groundwater*

Total annually replenishable ground water resources of the state have been assessed as 0.31 BCM, out of which net annual ground water availability has been assessed as 0.29 BCM. Total annual ground water draft for all uses has been estimated to be 0.39 BCM, with overall stage of ground water development at 137% (CGWB, 2013).

### *Topography*

The topography of Delhi is such that the drainage system so created carried the rain water from the Western higher elevations to the East to drain in the Yamuna. Naturally the low-lying Eastern side was a part of the Yamuna flood plain and considered uninhabitable due to frequent floods. Today, this Eastern part which is also known as the Trans Yamuna area houses about 20% of the total population of Delhi (City Development Plan Delhi, n.d.).

## **2.2 Climate**

The climate of the National Capital Territory of Delhi is influenced by its island position with the desert of Rajasthan in the west and the Gangetic plains of Uttar Pradesh. The geography of the region plays pivotal role in shaping up the city's climate. The city is characterized by semi-arid climate with stark contrast in day and night temperatures, high saturation deficit and low to moderate rainfall. Delhi has three distinct seasons – summer, winter, and monsoons with extreme temperatures and concentrated precipitation. The climate of Delhi is extreme in both summer and winter with temperature variation from 44.2 °C to 27.6 °C and 22.2 °C to 3.5 °C respectively. The rains in Delhi start from June and continue till September and receive most of its rain during this period from the North-westerly winds. The region receives an annual average rainfall of 714 mm (27 inches). City receives 75% of this rainfall during the monsoonal months of July, August and September. Maximum rainfall is usually received during August, which is around 245 mm. Relative

humidity is minimum in dry weather months and maximum during monsoon months. The flood season observed by Delhi Government is from July to October. Winters are dry and last from November to mid-March, with December and January being the coldest months with temperatures as low as 7°C (Vijay, 2007; Delhi, 2016).

### 2.3 Geology and Soil

Physiographically, Delhi is divided into; ridge area, older alluvium (west of ridge), newer alluvium (east of ridge) and the recent Yamuna ridge. Delhi is located in the Yamuna basin comprising of new alluvium soils (Fig. 3). Soil comprises of fine to medium sand, silt, gravel, clay and cankers. Alluvium sediments consist of hard formations. The recent to sub-recent formation is of alluvium, post Delhi intrusive geological formation is pegmatic and basic intrusive, and the most previous formation is Delhi system of rocks (Algonkian) which is Alwar quartzites. A mature topography with dispersed isolated hillocks is dominant in the city. Bedrocks comprise of quartzites with intercalated beds of Mica-Schists belonging to Alwar formation of Delhi group of Cambrian age. Quartz Veins and pegmatites boundins are seen along some of the major horizontal fractures. The city is mainly covered with fine-coarse loamy soils with different levels of moisture-retention capacity. Urban land use transformed the soils, converting good or moderate quality soils into non-agricultural uses. Fourteen soil series are observed in Delhi.

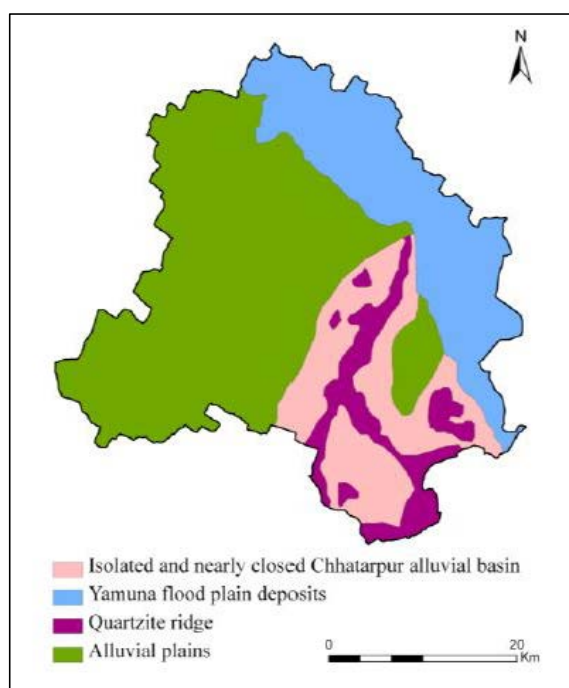


Fig. 3 The geological map of Delhi (Source: Parvez et al., 2011)



## 2.4 Demographic and Economic Profile

The population of Delhi was less than a million during pre-independence times. But after the independence and partition, there was massive immigration into the city with millions of immigrants taking the refuge. These were the times (1941-1951) when the annual average exponential growth rate for population was the highest (6.63%).

This resulted in a sudden jump in the population of the city during the post-independence era. Delhi has been exploding with population since past few decades. The city recorded a population of ~~9.85~~ ~~13.8~~ million in 2001, finally reaching 16.7 million in 2011. Though the decadal population growth for the city has dwindled from 90% in 1951 to 20% in 2011, but the rapid population growth has shot up its population density from 6352 persons per square kilometres in 1991 to 9340 in ~~2001 2011~~ and to ~~11297 11320~~ in 2011. Delhi with a 3.8% annual growth rate over the 1990s is adding half a million additional inhabitants each year. 52.76% of total population in Delhi was urban in 1901, which has increased to 97.5% in 2011 (Mehrotra, 2011).

Delhi's per capita income is around 2.5 times of national average. The rising per capita incomes are increasing energy consumption and over-stretching its infrastructure. At its widest dimensions, Delhi stretches ~~50 51.90~~ Km and occupies an area of ~~1,400 1,483~~ Km<sup>2</sup> (Mehrotra, 2009).

The growing population is straining out the city's resources including land, water, materials and energy and yet these demands cannot be met satisfactorily. This is typically due to dearth of proper and sustainable management strategies. The poorest of the citizens are forced to build and live in slums and squatter settlements (Hoyt et al., 2005). More than the 45% of Delhi's population resides in slums, unauthorized colonies and other unplanned settlements.

## 2.5 Urbanisation of Delhi

Being the economic and political centre of the nation, Delhi exhibits rapid urbanisation and offers a host of employment opportunities that attract people far and across the country resulting in formal and informal settlements. These increasing settlements gradually impose constraints on land, climate and resources such as air, water and soil. The urban expansion of city over the years is firmly established by gradual engulfment of several villages by the city. The number of villages has decreased from 231 in 1981 to 165 in 2001 to 112 in 2011 (Mishra, 2011). The city has shown vast expansion of built-up space within as well as beyond its boundaries (Kant et al., 2009).

The expansion within Delhi has been well represented by rapid development of its west, south-west and eastern sides. There is a 122% increase in highly dense residential area was recorded during last decade in Delhi. There was a reduction (17%) in agricultural land because of urban expansion in the fringe areas (Rahman, 2009; DDA, 2013; MDP, 2013).

The change in land use in the city has greatly affected very fertile lands in terms of productivity. ~~Natural lands including water bodies, flood plain regions, and small lakes have been converted into built-up areas. Agricultural land has also been converted into urban areas.~~ This process has led to the loss of ecosystem services such as water recharge, bioremediation, nutrient cycling, waste management, and climatic regulation (Kumar, 2009).

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Agricultural land is traditionally used as a percolation zone, and now it is continuously being reduced. The net agricultural area sown in 1950–1951 was 97,067 hectares and decreased to 25000 hectares by 2005–2006 (Pareva, 2006). The use of agricultural land has rapidly decreased after 1999. The pressure of urbanization has resulted in the increase in urban land usage (Kumar, 2009).

The last three decades have led to changes in the land-use pattern (Rahman and Netzbund, 2007). In particular, there has been an increase in the built-up area. In 1990–1991, the built-up area was 742 sq. km, 50 % of the geographical area of Delhi that increased to 897 sq. km (60.5 %) by 2000–2001 (Government of Delhi, 2006). Huge expansion of industries, reduction in agriculture areas, and rapid population growth caused this change.

The ~~waterbodies~~ water bodies had a total area of 58.26 km<sup>2</sup> in 1997 which got reduced to 27.43 km<sup>2</sup> in 2008 which is about 52.9% decrease in a ten year period especially shallow water bodies de-creased by 10.27 km<sup>2</sup> leaving only 2.82 km<sup>2</sup> (Mohan et al., 2011).

A study conducted on Delhi metropolitan area measured growth between two time periods (1989 and 2011) using Landsat images of 1989 and 2011. This study is based on the detection of change in the urban land cover around Delhi using temporal data of Landsat TM 5 (Thematic Mapper 5). The results showed that there was rapid change in land cover/land use. It was found that there was a phenomenal change in the built-up area in watersheds, loss of forest cover and change in agriculture land.

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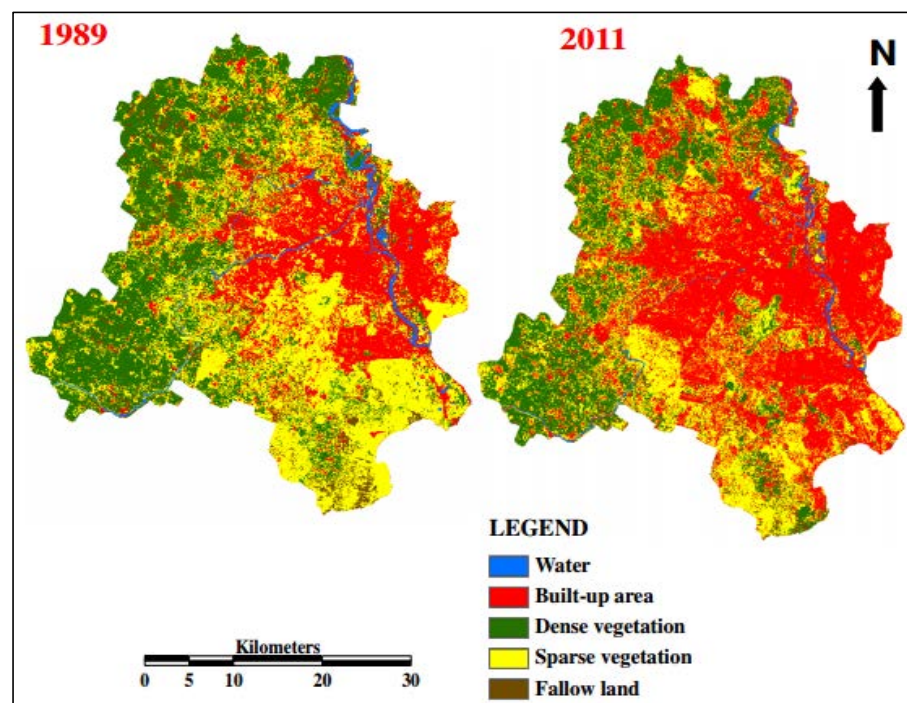


Fig. 4 Land use - land cover maps of 1989 and 2011 (Source: Mukhopadhyay, et al., 2013)

It is evident from the classified map of 2011 that the built up areas have increased to a greater extent than 1989 as most of the Delhi metropolitan area is presently occupied by settlements. Vegetation has decreased to a large extent to provide more area for urban expansion. The major vegetation loss due to urbanization is seen in the western, northern and southern boundary of Delhi during that particular time span. Major portion of Delhi is dominated by the land use class built up area as found from the 2011 image analysis, and also gradual decrease in vegetation and fallow lands in the surrounding area of the city observed (Fig. 4). The land cover statistics of year 1989 and 2011 is given in the Table-5 which shows the sequence of change of individual land cover type over the period of 22 years.

Table 1 Land use Land cover statistics (Source: Mukhopadhyay, et al., 2013)

Land Cover Classes	Year 1989		Year 2011	
	Area (Km <sup>2</sup> )	Area (%)	Area (Km <sup>2</sup> )	Area (%)
Built-up area	373.22	25.17	670.05	45.18
Sparse Vegetation	554.60	37.40	435.51	29.37
Dense Vegetation	470.48	31.73	333.25	22.47
Water Body	29.97	2.02	14.97	1.01
Fallow/Waste Land	54.73	3.69	29.21	1.97
Total	1483	100	1483	100

	Year 1999		Year 2009		Year 2015	
	Area (Km <sup>2</sup> )	Area (%)	Area (Km <sup>2</sup> )	Area (%)	Area (Km <sup>2</sup> )	Area (%)
Barren Land	471.9	31.8	330.9	22.3	387.3	26.1
Vegetation	385.8	26	286.4	19.3	207.8	14
Water	29.7	2	29.7	2	17.8	1.2
Built Up	596.6	40.2	835.5	56.3	871.1	58.7

Source: SPA Study 2015

Urban or built up area of 1989 was only 25.17% which has increased to 45.18% in 2011 showing rapid rate of urbanization during last two decades. Dense vegetation has decreased from 31.73% in 1989 to 22.47% in 2011 and sparse vegetation has reduced from 37.40% in 1989 to 29.37% in 2011 (Mukhopadhyay, et al., 2013).

### 3. Hazards and Vulnerabilities: Delhi

With rapid population growth, the city is getting highly urbanized and becoming prone to floods, heat and cold waves, earthquakes, fires, epidemics, and terrorist attacks. The city vulnerability is increasing due to urban stresses such as rapid urbanization, environment degradation, and infrastructure pressure, housing shortage, and slums and squatters settlements (Prashar, 2012).

To compound the challenges of rapid urban expansion and associated environmental risks, Delhi— like many Indian cities—faces several climate-related challenges and opportunities (Mehrotra, 2009).

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Formatert tabell

**Kommentert [H110]:** From Remote sensing data available with the National Capital Region Planning Board (NCRPB) indicates that the built up area in Delhi was 579 sq. km. in 1986, 603 sq. km. in 1993 and 750 sq. km. in 1999 (includes built up area of rural settlements). (Source: ECONOMIC SURVEY OF DELHI 1999 – 2000) and also Master Plan 2021 also indicated the Built up area of 751 sq.km. in 1999. (Source: MPD 2021)

i. Note: The built up area in above Table is less than

reported in NCRPB as well as MPD 2021

ii.SPA (2015) research study shows 596 sq. km. in 1999, 835.4 sq. km. in 2009 and 871.1 sq. km. in 2015.

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*Temperature and Precipitation Projections*

Fig. 5 & 6 shows a summary of observed and projected temperatures for Delhi Mean extreme temperatures, as well as maxima and minima, are expected to increase by 2 to 4 °C, likely to result in an average surface warming of 3.5 to 5°C within this century. Second, average mean rainfall is projected to increase by 7 to 20 % due to the increase in mean temperature and its impact on the Indian monsoon cycles within the latter half of this century (Fig. 7 & 8) (Mehrotra, 2011).

For a summary of observed and projected temperature and precipitation for Delhi Extreme minimum and maximum temperature events appear to be increasing. In December of 2006, Delhi had the lowest temperature since 1935 (0.2°C), and the media reported the death toll from the cold wave in north India to be over a 100 people in and around the region. The following summer in June 2007, Delhi had a maximum temperature of 44.9°C, once again taking a toll on the people of the city. While these extreme temperatures cannot be directly linked to climate change, the challenge facing Delhi is variability in weather patterns and the potential for exacerbated extreme events due to climate change (Mehrotra, 2009).

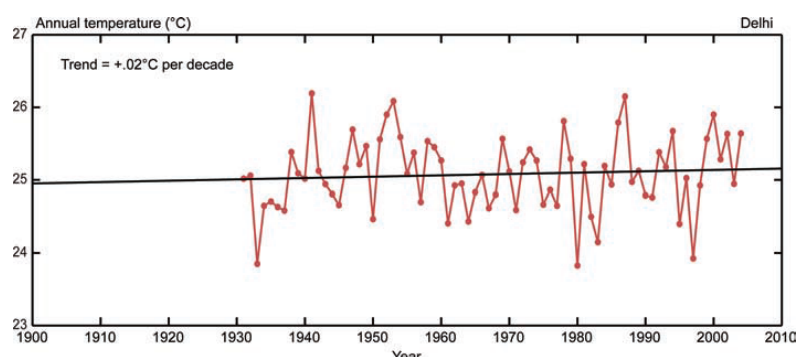


Fig. 5 Observed temperatures, Delhi (Source: Mehrotra, 2011)

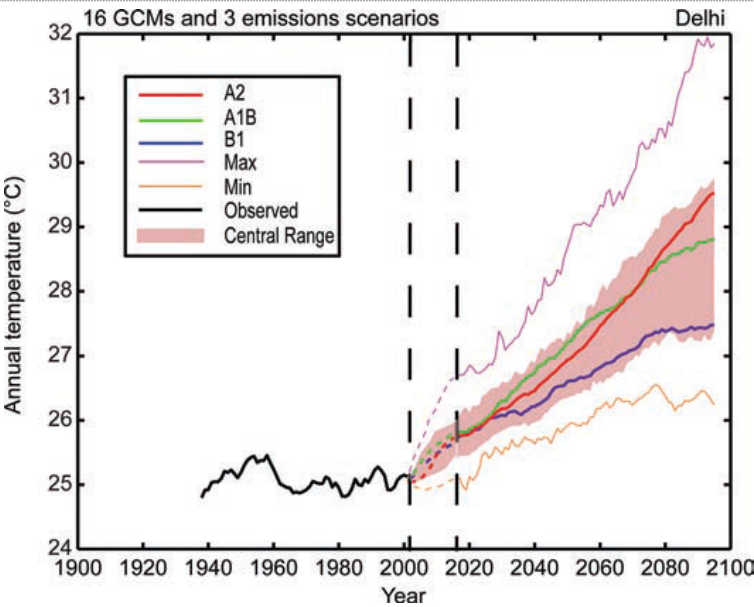


Fig. 6 Projected temperatures, Delhi (Source: Mehrotra, 2011)

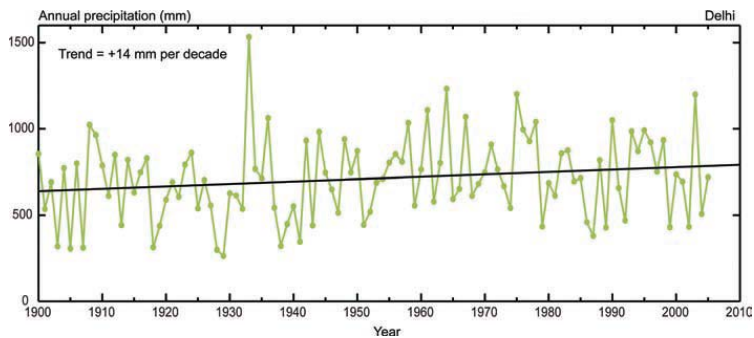


Fig. 7 Observed precipitation, Delhi (Source: Mehrotra, 2011)

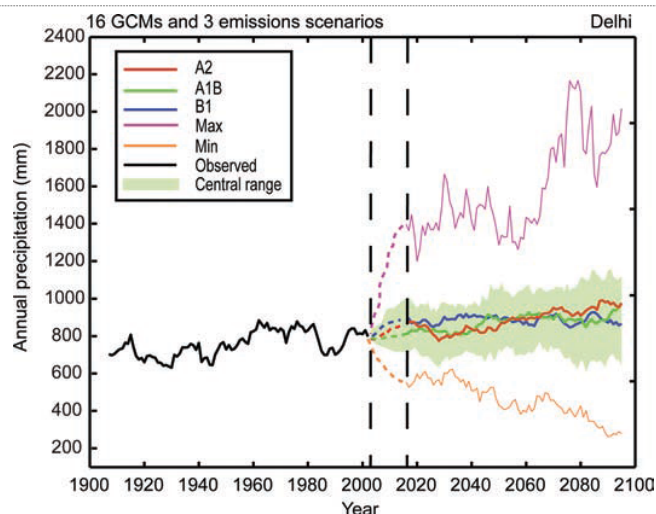


Fig. 8 Projected precipitation, Delhi (Source: Mehrotra, 2011)

#### *Infrastructure, population, transportation: challenge*

Delhi's physical infrastructure, social services, and slum populations make the city highly vulnerable. Demand for basic infrastructure services like water, electricity, and public transport far exceeds supply (Delhi Development Authority, 2005). To add to the existing conditions, climate change-induced variability in rains and temperatures could worsen the severe shortage of drinking water in summers and aggravate the floods in the monsoon season, thus making the existing energy shortage more challenging to address. With regard to transportation, Delhi has the highest per capita vehicular population in India—5.4 million automobiles for 15 million people. This poses a challenge for a city with mixed land use and varying urban densities within the metropolitan region to introduce effective modes of public transport. Carbon emissions from vehicles, traffic congestion, and increasing particulate matter all pose challenges. Further, three million people live along the Yamuna River, which is prone to flooding, where 600,000 dwellings are classified as slums. Although the extent of the impacts remains to be assessed, potential climate change impacts added to current local environmental stresses are likely to intensify this crisis. Moreover, the low quality of housing in slums and their proximity to environmentally degraded land and flood-prone areas further exacerbate the vulnerability of the poor (Mehrotra et al., 2009).

#### *Poorly Managed and Inadequate Drainage Network*

Studies have revealed that there is lack of integrated planning in the drainage for storm water which is not local but has got regional bearing covering areas in Haryana, Rajasthan, U.P. and NCT-Delhi Sub-regions. Untreated sewage continues to flow in most of the drains in the region and ultimately falls into the rivers Ganga and Yamuna. Encroachment by slum dwellers along the drains causes choking of drains and flooding in the upstream areas due to reduced carrying capacity. Dumping of solid waste in the drains also continues causing

blockage. Master Plans have not been prepared district wise. Even the hydraulic survey has not been carried out regularly to assess the conditions of the drains.

The collection and treatment of solid waste is a major problem of the MCD. The city produces 8,000 tons of solid waste every day but only three dumping sites out of 23 are functioning, making the city vulnerable to health-related hazards. The city also faces the problem of flooding caused by an inefficient drainage and sewerage system (Parvin et al., 2011).

It is, therefore, necessary to plan the drainage system at regional level in an integrated manner with adjoining States.

#### 4. Past trends of Floods in Delhi

Increasingly, the city has become especially vulnerable to climate related hazards such as floods caused by unpredictable rainfall patterns. The city has been experiencing floods of various magnitudes in the past due to floods in the rivers Yamuna and Sahibi (through Najafgarh drain). The flow of Yamuna within Delhi is by and large influenced by discharge from Tajewala Headwork 240 km upstream. In the event of heavy rain in the catchment area excess water is released from Tajewala. Depending upon the river flow level downstream, it takes about 48 hours for Yamuna level in Delhi to rise. The rise in water level also causes backflow effect on the city's drains. The city also experiences floods due to its network of 98 drains whose catchment area extends well beyond the city limits.

Since 1900, **Delhi has experienced nine major floods in the years 1924, 1947, 1976, 1978, 1988, 1995, 1998, 2010 and 2013** when the Yamuna River crossed its danger level of 204.83 m. The Table 2 shows that year 1978 witnessed the worst ever flood in Delhi when water level in Yamuna River in Delhi reached at 207.49 m with discharge 2.53 lac cusec at old railway bridge (7.0 lac cusec discharge was released from Tajewala) when 130 villages and 25 urban colonies in Delhi were submerged in water. The river has crossed its danger level 20 times in the last 33 years (DDMA, 2014-2015).

Table 2 Major flood events in Yamuna River in Delhi (Source: Irrigation and Floods Control Deptt.)

Year	Gauge (m)
1976	206.70
1978	207.49
1988	206.92
1995	206.93
1998	206.36
2010	207



2013	207.32
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District North-East, East, Central, and South East of Delhi are most affected by floods in the city. Most settlements situated along the Yamuna River are prone to the flood hazard. A study on “Urban Flooding and its Management” by the Irrigation and Flood Control, Government of NCT of Delhi identified East Delhi under the flood plain region and vulnerable to floods (Pareva, 2006). During the monsoon, low-lying areas adjacent to Yamuna receive floods. Delhi was flooded in September 2010 and most of the areas along the Yamuna River were flooded, and a heavy damage to life and property was recorded. Hundreds of informal settlements were submerged under water, and 169 relief camps were set up by the Delhi Government to tackle the flood in the capital city.

The Yamuna River produced most of the major floods and experts believe that the flooding in the city has many explanations: heavy rainfall, urbanization, unauthorized colonies, trespassing on storm water drains, siltation of drains, siltation of water bodies, choked water carriers, poor water and sewerage management, deficiencies in the drainage system, failure of pumping installation, and multiple authorities with no responsibility (Pareva 2006).

In addition, ecosystem services are poor due to the low quality of district’s characteristics in terms of soil, air, water bodies, and biodiversity. For example, the land department of DDA has identified six water bodies in this district that need greater consideration in the Master Plan of Delhi (MPD)—2021 due to lack of green area. The river bed in this region is considered as the city’s life sustaining need for ground water recharge. It has suddenly changed in the late 1990s and 2000s. In addition, land use in natural term is poor due to loss of urban green space. A major part of city is covered by residential areas (Prashar, 2012).

From storm water drain point of view, Delhi can be divided in six drainage basins ultimately discharging into river Yamuna, namely - Najafgarh Drain, Barapulaah Nallah, Wildlife sanctuary area discharging thro’ Haryana , Drainage of Shahdara area, Bawana drain basin and other drains directly out falling into river Yamuna. The NCT of Delhi is prone to flooding from river Yamuna, its catchment in Haryana and from Sahibi River (Rajasthan) via Najafgarh drain. The low-lying Yamuna flood plains (Khadar) are also prone to recurrent floods (Pareva 2006).

Another effect of the need for more land to be urbanized, is that water bodies, low lying areas (water retaining plains), near or around the city which act as flood absorbers are gradually filled up and built upon due to urbanisation pressure. Earlier there were 800 water bodies in Delhi, which has now reduced to 600, which are also silted to a great extent. The consequence of this is that, Delhi now has fewer water retention points. This decreases the Time of Concentration, hence increasing the Peak discharge and does increasing the chances of Urban Flooding.

In a report on Urban Flooding and Management, the National Institute of Disaster Management identifies inadequacy of the local drainage system as a factor contributing to Urban Flooding. Often water treatment plants like Bhagirathi, Haiderpur etc discharge sediments into storm water drains causing siltation. Thus, it is reducing the capacity of the drains. It further states old drainage and sewerage system has not been overhauled nor is it



adequate for the present drainage requirement. Back flow from main drains into city drains to sewers during high floods is a very common scenario.

Urban Flooding Urban floods are a great disturbance of daily life in the city. Roads can be blocked; people can't go to work or schools. The economic damages are high but the number of casualties is usually very limited, because of the nature of the flood. Consequently, flooding occurs very quickly due to faster flow times, sometimes in a matter of minutes. Encroachments are also a major problem in many cities and towns. Natural streams and watercourses have formed over thousands of years due to the forces of flowing water in the respective watersheds. Habitations started growing into towns and cities alongside rivers and watercourses. As a result of this, the flow of water has increased in proportion to the urbanization of the watersheds. Ideally, the natural drains should have been widened (similar to road widening for increased traffic) to accommodate the higher flows of ~~stormwater~~storm water. But on the contrary, there have been large scale encroachments on the natural drains and the river flood plains. Consequently the capacity of the natural drains has decreased, which results in flooding. Improper disposal of solid waste, including domestic, commercial and industrial waste and dumping of construction debris into the drains also contributes significantly to reducing their capacities. It is imperative to take better operations and maintenance actions (National Institute of Disaster Management, n.d.).

Increasing trend of urban flooding is a universal phenomenon and poses a great challenge to urban planners the world over. There has been an increasing trend of urban flood disasters in India over the past several years whereby major cities in India have been severely affected. Urban flooding is a major disaster. Rise in water level of river augmented by poor drainage system can cause serious damage due to water logging. Chronic flood prone areas of the city need to be on high alert during pick rain fall periods. Message regarding Yamuna water level at Old Railway Bridge is being regularly disseminated to district administration.

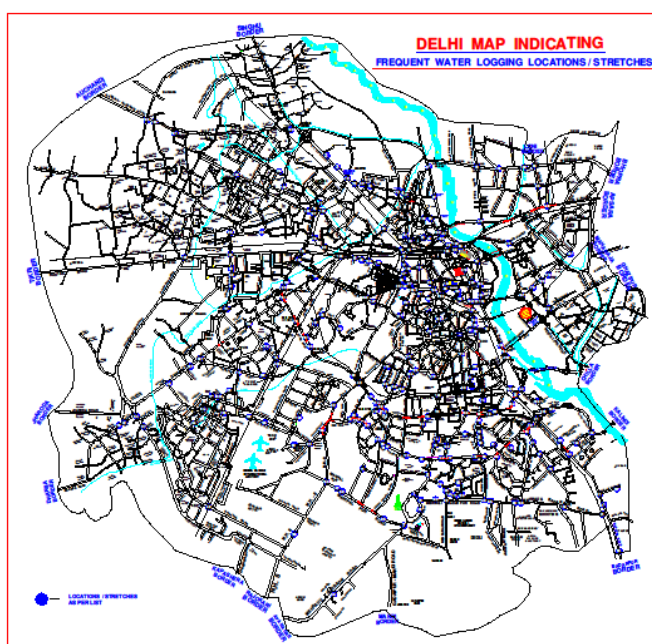
## 5. Conclusion

A significant phenomenon which has been increasing during recent years is that of local flooding. Urban areas are characterized by a high area under impervious surfaces (Roads, pavements, houses etc). High rates of development along with the resultant loss of soft landscape has led to high surface water run-off rates. This results in flash floods in the low lying areas even after moderate precipitation. Another factor adding to this effect is that of river because the river is already flowing at a higher level within its embankments. Thus, the water gets logged in the city areas and it takes several days to mechanically pump it out and bring the situation under control. Similarly, during the past few years, flooding due to the city's 18 major drains has also become a common phenomenon. Already under the pressure of the city's effluent discharge, these drains experience reverse flow from the Yamuna, which is in spate, and as a result they tip their banks, flooding the neighbouring colonies.

Given the presence of a gentle slope in Delhi, as such, there shouldn't be any incident of water logging in this area. But rapid urbanization in this area has led to flattening of the slope and an increasing urban area. Thus, the city is now encountering a number of the Urban Flooding incidents. Local flash floods and water logging increased surface run-off due to high ratio of hard surfaces leading to flash floods. This in turn badly affects the low

lying areas, particularly the unplanned colonies which get water logged. Figure below shows ~~Waterlogged~~**waterlogged** stretches/ areas identified by Delhi Traffic Police.

The existing approach toward disaster management in Delhi is weak in terms of several aspects. For example, risk reduction measures are not or less integrated into the city development plan. Investment in terms of human and infrastructure planning for disaster risk reduction is also low in the relevant sectors. Finally, there is lack of capacity of local authorities to implement disaster risk reduction measures.



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