TOWARDS RESILIENCE IN CHENNAI

Lakshmi Manohar[1] | **Muthaiah KT**[2]

1 *National Institute of Technology*

2 *Independent*

The world is witnessing an increase of natural disasters due to climate change; inducing strongly, the awareness of building climate resilience globally. But the developing nations are facing challenges due to over population, growing economy and unplanned growth which negatively affects its resilience. One such example is the Indian city Chennai, which like other coastal cities, is vulnerable to cyclones and rains. Though the city has experienced major floods in the past; the recent unprecedented rainfall in the fall of 2015 presented an Indian context of climate change crisis – which is a consequence of expanding cities over existing environmental systems thereby damaging them severely. The city of Chennai, since colonial times, has been filling natural ponds, lakes and marshes to expand the city to allow closer proximity to the city centre for economic development. Thus it is essential to review the planning trajectory of Chennai and to recognise methods of planning used traditionally in the region to survive the environmental disaster, making the city flood resilient. This examination uncovers the traditional, the British Raj-era, the Post-Independence, and the contemporary development context in order to understand the local context for where and when coastal human settlement negatively impacted natural system.

Keywords
climate change, resilience, urbanisation, india, floods

How to Cite
Manohar, Lakshmi; KT, Muthaiah. "Towards resilience in Chennai". In Carola Hein (ed.) *International Planning History Society Proceedings*, 17th IPHS Conference, History-Urbanism-Resilience, TU Delft 17-21 July 2016, V.03 p.251, TU Delft Open, 2016.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

INTRODUCTION

Global mean temperatures have increased, sea levels have risen, snow cover has decreased, glaciers and icecaps have started to melt, thunderstorms and torrential rains have occurred in dry areas, all pointing towards climate change[1]. Scientific researchers have already linked such intense weather phenomena to a changing climate and they unanimously agree that these indicators of climate-warming trends over the past century are mostly due to human activities. The Germany-based Potsdam Institute of Climate Impact Research, in its study, points out that of the total incidents of excessive rainfall that happened in the last 30 years, 12% can be contributed to climate change.[2] The United Nations has endorsed this position and forecasted that around 50 million people will become environmental refugees by the end of this decade. Due to this, most of the world is debating how to reduce greenhouse emissions that causes climate change and how to build resilience to the inevitable effects of climate change through various climate summits. Climate resilience is the capacity for a socio-ecological system to absorb stresses and maintain function in the face of external stresses imposed upon it by climate change[3] and to adapt to prepare for future climate change impacts[4]. Climate-resilient cities should therefore include mitigation and adaptation actions to take care of likely climate impacts, besides increasing the capacities of the population, infrastructure, institutions, and governance. The response mechanisms should also be focusing on preparing for extreme climate events such as storm surges, landslides, and floods.

The scenario in India is not very different. A 2006 study by the Indian Institute of Tropical Meteorology in Pune had shown that extreme precipitation events were increasing in frequency and intensity in India during the period 1950 to the 2000s including the heavy floods in Kolkta Chennai and Mumbai[2]. The case we are presenting today, Chennai, is one of low elevation coastal zone (10m above sea level) and is prone to floods and cyclones as per the study conducted by scientists at the Center for International Earth Science Information Network. Recently, the rains in Chennai have broken a 100-year record (374 mm in just 24 hours) causing a devastating flood. In November 2015 , the city had received 1,218.6 mm (47.98 inches) of rain, which was almost three times more than the average the city receives (407 mm) which was 50 -90 percent above normal in the eastern states. Still more, 345 millimeters (13.5 inches) fell on Chennai in December 1 -2 storms, which were fueled by low-pressure system offshore.

Ironically, the city of Chennai still remains unprepared to combat rain during rainy season and water scarcity during summer season every year.. The current occurrences of flood in the city are a wakeup call to think about how the city has developed without reflecting on its natural physiography, obstructing its natural hydrological system on a larger note and building over flood plains, marshes, lakes and ponds. Poor planning practices and relaxed enforcement of building rules have resulted in encroachment over majority of the city's natural system, affecting the urban ecology.

Its very vital for us to look back into the planning history of the city and problems related to its physical manifestation to understand the impact on environment and to with-stand the impacts of climate change. Unfortunately, the successive governments and authorities of Chennai have allowed weaker plans and poor enforcement of the rules. Amendments that regularise violations and exemptions that will benefit the more affluent has been pushed forward. It is easy to connect the devastation from the unexpected flooding to the results of nature and climate change when actually in fact; it is a result of poor planning and infrastructure. In Chennai,we are experiencing the destruction of our natural buffer zones such as rivers, estuaries, creeks, lakes and marshlands in the name of development.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

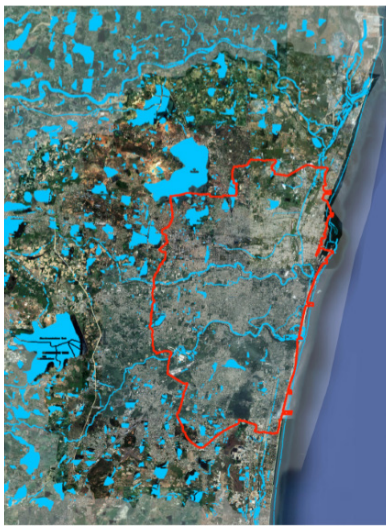

FIGURE 1 Map showing waterbodies of Chennai city

FIGURE 2 Map showing the old settlement pattern in Chennai in the context of the main waterbodies that existed that time.

FIGURE 3 The connection between various typologies of waterbodies are shown in the diagram as Aaru (river)>Yeri (large waterbody)>Kanmaai>Karanai> Thanngal>Yaenthal>Oorani>Kulam (tanks or ponds)>kuttai (small ponds)

APPROACH AND METHODOLOGY:

The paper is drawn from the comparative analysis of Chennai through past to the present structure of the city and its land use planning, physiography, environment planning, hydrological aspects and socioeconomic profile, infrastructure and disaster management. Information and data used were mostly secondary in nature. Reports and publications of different departments and agencies were put into use.

PROLOGUE OF CHENNAI

Chennai (formally Madras) in Southern India on the Cormandel Coast of the Bay of Bengal is the capital of Tamil Nadu State, where the population has grown eight-fold over the past century. Chennai lies along Bay of Bengal in the Eastern Coast of South India where three watercourses meanders through it which are, Cooum River, Adyar River and Buckingham Canal[5]. Chennai is the 4th largest Metropolitan in India having a total population of nearly 47 Lakhs with 13% growth rate and density of 26903. The Chennai Metropolitan Area (CMA) covers 1,189 km^2 and is the third largest commercial and industrial centre.

ANCIENT CHENNAI AND ITS HISTORICAL GEOGRAPHY

The site on which Chennai is situated has a long history. From the early days upto the 16th century AD, the area which constitutes the current city of Chennai saw growth under the Pallava,Chola and Pandya dynasties,later by the Naiks of Vijayanagara dynasty. Small towns in Chennai mainly grew as a major trading centres due to the presence of a sea port and also as an amalgamation of religious centres and settlements around it as seen in areas of Mylapore, Triplicane ,Thiruvanmiyur and Thiruvuttiyur. These centres were formed with respect to trade links sea port and as well river linkages to the inland. The geographer Ptolemy had recorded it in the 2nd century AD that the Mylapore port was known to the Greeks and the Romans. The Port had a flourishing trade with the Roman Empire and received quantities of gold and silver in exchange for products like pepper and fine cloth[6].

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

Chennai had good fertile soil with agriculture and trade as main occupation and developed as rich agrarian society with scattered small settlement around a nucleus of temple. Since the City doesn't have perennial rivers, it mainly depended on monsoon rains alone. Ancient times, a system was devised to conserve the water flowing in the rivers before it reached the sea. This is done through diversion of river water into tanks through dug out of these water channels. Cascading system of tanks has been followed to provide water for the far away villages from the main source of water. This helped in tackling any extreme situation like drought or flooding. Most of these tanks were seen as sacred and temples were built along it. Since their basic livelihood depended on the water-bodies water bodies were considered sacred and this approach helped to conserve them, directly or indirectly respecting the ecological role it has to play.

The water body map shown in Fig 3 showcases the ancient water management system of Chennai. The Yeri is a small body of water formed by damming a natural depression with bunds or embankments on three sides and leaving the fourth side open to the water that flows in from the catchment area. Water is stored for irrigation, drinking and recharging aquifers. Overflows are released through a weir and water for irrigation by a sluice which directs it into channels built to cover the entire designated area.[7] It is a small but precise feat of engineering designed for purely local conditions. There are thousands of these tanks or Yeris across Tamil Nadu.The Kulam shown in the diagram is the Tamil terminology for ponds/tanks. It shows the connections between the water bodies and how the people of Chennai were seen to have lived in a symbiotic relationship with nature and ecology. Other waterfront sites became small sustainable villages which survived on fishing, boat-making etc. Madarasipattanam was only a swampy fishing village.

In the early 16th century, Chennai was a settlement of scattered villages "on a sandy, shelving, breaker-swept beach" for centuries before the coming of the British. The land on which the city is built, forms a level of post-tertiary formation, not very much above the sea level. The eastern part is built on a ridge stretching along the coast. A parallel trough is seen on the west traversed by Cooum River in north and Adyar River in south which divides the city. Both the rivers have formations of sand-bars at their mouths due to the action of the waves which had driven the sand running north, which is characteristic feature of the Bay coast in this part. It is seen that the major settlement happened along these ridges traditionally, which highlights the fact that the people of Chennai built their settlements consciously by inhabiting the areas with slightly higher topography as they anticipated floods in the lower areas.

CHENNAI IN THE BRITISH RAJ ERA

The colonisers, who came in later, did not prefer the already established urban centres of settlement – they rather looked at the under-developed cities as opportunity areas. In the 15th century, only Portuguese started showing interest in small villages and established trade with the traders. They were followed by the Dutch and Armenians in the 16th Century, who settled north of Madarasipattanam. In the 17th Century, the British declared Madras as a British port town and created a fort by 1630. This was when the foundation for the development of the present Chennai was laid (as seen in Fig 2). A white town for colonisers and a black town for the colonized separated by river Cooum came into being. The black town had thriving market and came to be known as George Town. Since City had formed over the ridges, the low lying lands with lot of interconnected lakes systems had remained untouched. The City started spreading in all the directions after the British came, because they concentrated on infrastructure development including roads and railways for their control over the land. Roads were laid towards northeast connecting Calcutta, to Mysore towards west, to kanchipuram and other southwards cities. All these connections were made connecting the existing scattered settlements at higher elevation in that direction. Since the road infrastructure developed in all the directions from Fort St. George, the closer proximity that the low lying lands had as they lay around the main transport axis, eventually were developed slowly, irrespective of the flooding condition.In addition to this, the formation of Royapuram railway station in 1862 induced people to

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

move northwards and settle in Royapuram. This gradually gave rise to the establishment of some timber saw mills and depots in Royapuram. Further, the railway line passed through the present Perambur area, which had so far been lying as swampy wasteland because of its low topographical level. The introduction of the railway line gave development potential to this place which was uninhabited until then.

By 1900s, the city extended over an area of about 70sq.km and had a population of 5.40 lakhs. George Town was the main business centre but substantial parts of it were used for residential purposes also. The main residential areas however were extensions of the older settlements. The areas outside these settlements were covered by gardens and agricultural lands with bungalows of the elite. A large number of tanks that were used for irrigation of cultivated fields started losing its importance and became place for breeding ground for malaria germs.[8] Hence they.were filled up during colonial period as the economy shifted from agriculture to industries and for hygienic reasons as well. The filling of these tanks was a costly affair and it proceeded very slowly. As the water-bodies are connected, filling up of one tank will gradually cause the silting/drying of the other tanks. The larger tanks like the Vyasarpady Tank, the Spur Tank and the Nungambakam and Long Tanks have silted up and have been built over in parts.[2] These areas currently contribute to the large proportion of low-lying flood prone areas during the rainy season and remain dry during the remaining months.

By 1941 the population of the City increased to 8.6 lakhs and occupied an area of about 80sq.km with its extended boundaries. The important developments during the period 1901 and 1941 were the commissioning of the electrified suburban metre-gauge railway between Beach and Tambaram which gave a triger for the development of the outlying suburban areas as far as Tambaram, and the development of the area occupied by the long tank at Nungambakkam was filled up and planned as a residential neighbourhood by the Corporation.

CHENNAI IN THE POST INDEPENDANCE ERA

The 30 years between 1947 and 1977 saw tremendous growth in population and economic activity in and around the City. The population doubled itself in a short span of time. The main reasons for this fast growth can be attributed to the forces of economic activity released after the country obtained independence. The five-year plans and the impetus given by the industrial activity in the public sector brought about the transformation of the City from that of a purely administrative and commercial centre into a metropolis of national importance. Concurrently this period saw the deterioration in water supply and drainage services and mushrooming of many slum areas all over the city. The City's boundary no longer remained well defined. The developments extended into the adjoining areas, particularly, on the north up to Ennore, west up to Avadi and south up to Vandalur.

The land use in Chennai during the year 1973 indicates a predominantly agricultural based land use throughout the city with sporadic residential use, mainly concentrated along the major transportation corridors. Lots of water bodies are seen all through the city. The agricultural use had vanished to a great extent throughout Chennai during 2006 (As seen in Figure 4). Large parcels of land in the northern area of Chennai were lying vacant. Many of the small water bodies had also vanished. During this period, with the advent of Information Technology Policy by the Government of Tamil Nadu, several incentives were extended for Information Technology (IT) and Information Technology Enabled Services (ITES) projects. The Old Mahabalipuram Road was declared as IT Corridor improving the accessibility and permitting IT & ITES uses on either side of the IT corridor for a width of 500m. Declaration of IT corridor, extension of concessions / incentives and special provision for permitting multi-storeyed buildings for IT and ITES purposes throughout Chennai resulted in setting up of several IT Parks and ITES developments.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266
TOC

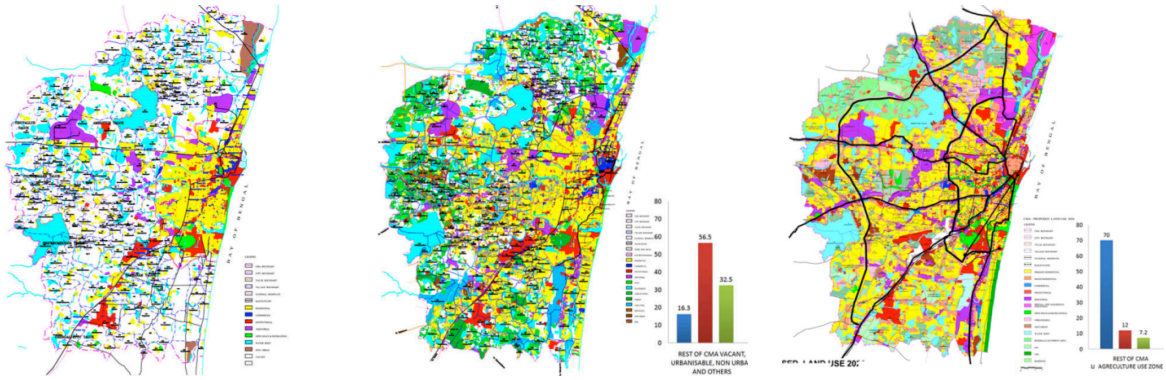

FIGURE 4 Chennai Landuse map 1975, 2006 and 2026 showing urbanisation over water-bodies

UNPLANNED GROWTH OF CHENNAI AND CAUSES OF FLOODS

The growth of Chennai did not take place in a regulated manner nor did it correspond to the available infrastructure facilities. Chennai lacks natural gradient for free run-off which indicates the necessity of an effective storm water drainage system. Sewage system in Chennai was originally designed for the population of 0.65 million at 114 L per capita per day of water supply (further modified during 1989 – 1991) which is now inefficient as it is below the required capacity. The two rivers Chennai, Cooum and Adyar are almost stagnant and do not carry enough water except during rains when they play a major role collecting surplus water from about 75 and 450 tanks, in their respective catchments during floods. Buckingham Canal, built by the British, originally a navigation channel and waterway, now serves only as drainage channel. Chennai being a seafront city is inundated with low-lying areas which have an eco-sensitive relationship with the hydraulic system of the metropolis.

The city experiences floods during monsoon which is the dominant season of the year. During floods, water level of different water bodies rise and flow to different floodplains submerging them. The rapid growth of population which brought in an urgent need for urbanisation lead to encroachment on water bodies and water courses, unplanned laying of roads against natural slope in unapproved layouts and construction of buildings over and above these ecologically significant areas. These activities lead to severe floods during heavy precipitation, causing inundation of dwelling areas. Chennai had experienced such floods during 1943, 1978, 2005 and further, the recent unprecedented rainfall in the fall of 2015 caused by the El Nino phenomenon had collapsed Chennai massivelywith flash floods. Hindsight is important and it can prevent every tragedy before it commences. But unfortunately, it is always been remined after these event. It is indeed a temptation to see how the city might have been saved if the existing natural safeguards hadn't been exploited.

Chennai with the fast pace of developments has witnessed a steady deterioration and decrease in the number of water bodies. It is estimated that more than half of the wetlands have been converted for other uses. Chennai had about 6503 small and big water bodies in and around the city, but today the number has been reduced to less than 30. In many of the water bodies, green cover and natural depressions have disappeared due to negative human interaction and filling with wastes or developments/encroachments leading it to be flood prone areas[5]. Figure 5 compares the flood prone zones and change in urbanisation of the area around a few water bodies in North-West Chennai. It can be seen that the flood prone areas have been declared as new areas for development according to the masterplan.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

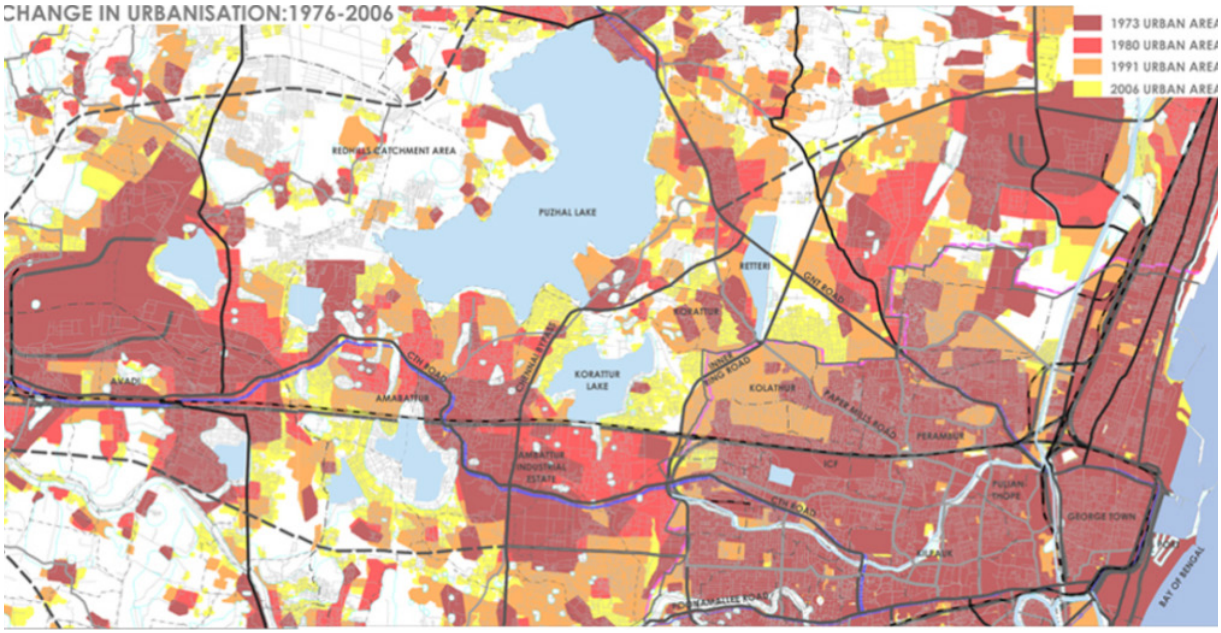

FIGURE 5 Flood prone zones and change in urbanisation along CTS road

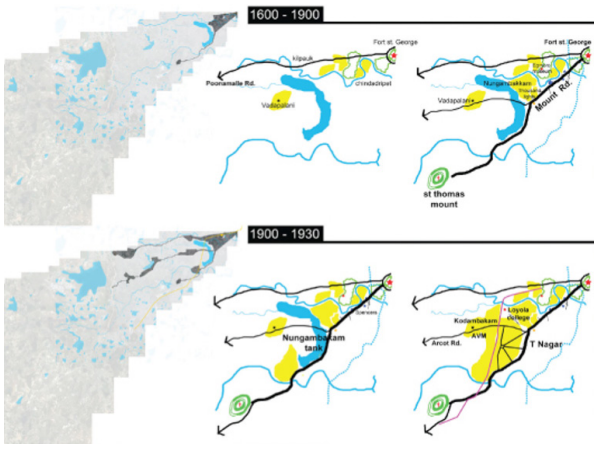

FIGURE 6 Urbanisation, Open spaces and topography of parts of Chennai

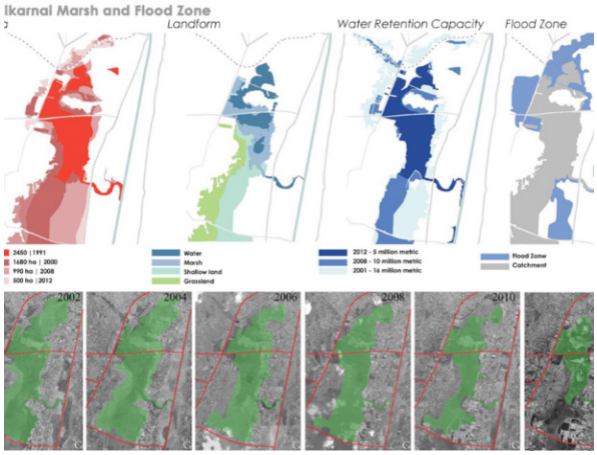

FIGURE 7 Pallikaranai marsh and flood zone

Chennai, a city that is so desperately short of water, is also prone to flooding, especially in so-called low-lying areas. Usually it is worst in the suburbs, though central areas such as T. Nagar and Mambalam which didn't exist on the old maps which is particularly prone to inundation are either on the edge of a lake or was part of a lakebed. It can be observed today that flooding as a result of heavy rainfall is 'naturalised' as being the result of 'naturally low-lying areas'. Though not false, this interpretation ignores the causes of filling in traditional water tanks and their interconnections, which would ultimately lead out to sea.

The old city of Madras was full of Yeris across its length and breadth. A great many of them have been filled up and built upon as we discussed earlier during the British Raj era. For instance, the so-called Lake Area that spans Nungambakkam and parts of T. Nagar is currently one of the perennially problematic localities. Parts of this area had four to five feet of water on the streets, and were unreachable for days after the deluge. Residents were trapped in their homes without power or water. The only food was what they had before the rain started. Dry ground was just minutes away in some cases but there was no way of getting to it.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266
TOC

"Make in Chennai" boom has also helped in worsening the situation. The airport built on the floodplains of the River Adyar, a huge bus terminal in flood-prone low lying land of Koyambedu, a Mass Rapid Transit System constructed almost completely over the Buckingham Canal and the Pallikaranai marshlands, expressways and bypass roads constructed with no regard to the tendency of water to flow, IT corridor and a Knowledge Corridor consisting of engineering colleges constructed on water-bodies, automobile and telecom SEZs and gated residential areas built on important drainage courses and catchments are the result of this.

Most of the area of the IT Park was a freshwater swamp until independence. Pallikaranai, the area close to where the IT park is situated, was once a complete aquatic ecosystem spread across approximately 80 sq km, the city's only surviving wetland and one of the last remaining natural wetlands of south India. It is also a vast drain for the excess of monsoon precipitation in a catchment area of about 235 sq km. Today about 90 per cent of the marsh has been lost to development but the shrinkage was gradual until the IT corridor was designated. This triggered a real estate boom in this area and the marsh was slowly cleared, filled and built upon. Pallikaranai became a part of the Chennai Corporation in 2011 and is one of the country's top investment destinations in residential real estate. A report by global property consultancy Knight Frank estimated that housing prices would increase 93 per cent in the period 2012-17[7]. It's a abode of high-rise apartment for the IT employees. The villages surrounding the marsh also turned into prime real estate. All the warning about drainage, low-lying areas, danger of inundation and experiences of the past floods were completely ignored.

EXISTING AND FUTURE CLIMATE RISKS

There is a substantial increase in the amount of rainfall in Chennai due to the increased precipitations due to global warming and climate change, apart from the usual monsoons. Moreover, coastal regions like Chennai is also vulnerable to storm surges or cyclones. It has been anticipated that the frequency of cyclones in Bay of Bengal is going to decrease whereby the intensity of these cyclones is going to increase. Stagnation of cyclones can cause large amounts of precipitation limited to a smaller area. This phenomenon presents a challenge for urban infrastructure as well as disaster risk measures.

One of the most devastating impacts Chennai is struggling with, are flooding events caused by an immense amount of precipitation in a very short period. One or two days of heavy rainfall leads to ten or even more days of flooding. In a long-term perspective, climate change related sea-level rise has the same effect. It presses water into the rivers and threatens the survival of entire ecosystems like mangroves on Tamil Nadu's coast. With the loss of mangroves, the coastal water quality, biodiversity, and fish habitats will be reduced. Furthermore, sea-level rise can lead to changes in ground water recharge.

While flooding in Chennai is not as common as in many other metropolitan cities in India, it does occur during the northeast monsoon season from October to January. Certain low lying areas of the city are worse affected and the single major reason for this is unauthorised construction of multi-storey structures which fail to follow the principle of zoning, road widths, limits to building heights and the Floor Space Index (FSI). Another disturbing factor for flooding in the city is the encroachment onto water-bodies to build multi-storey structures.

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

CONCLUSION

Every invitation to "Make in Chennai", is leading the city to unmake itself and Chennai is eroding its resilience to perfectly normal monsoon weather events. The infrastructure of big commerce has replaced the existing infrastructure to withstand natural shocks. These are all man-made disasters and we need to take drastic steps to immediately arrest and reverse these developments. It is critical that we have high quality data and knowledge of our urban ecology and built drainage networks in the public domain, the lack of which has crippled the impact of citizens and activists in the city. One immediate need for a map of the current floods would be to identify the most vulnerable neighbourhoods to sharpen the government's response, particularly for the urban poor. By adding information about the contours and elevation of the city we can create zones of risks from future instances of flood and the resulting potential vulnerabilities. We could also use such a map to assess the extent of damage to life and property, and to monitor if the government's current relief and response efforts are appropriate. Such a map can also be layered with information about other public infrastructure, such as primary healthcare centres, dispensaries, storm water drain network etc, to help build resilience and disaster management measures. Mapping information on the extent and nature of violations and encroachments and the ways in which violators compromise public health, safety and convenience of other residents of the city, makes a compelling case for the planning and monitoring authorities to enforce building norms, impose penalties on violators and to reclaim the ecologically valuable areas.

Acknowledgements

This paper is an outcome of the Chennai city study studio by the students of Urban Design 2012-2014 of School of Planning and Architecture, New Delhi under the guidance of Prof Arunav Das Gupta, Prof Mandeep Singh, Ar Ujan Gosh and Ar Nishant Lal. The comments of Prof K.T Ravindran, Prof Ranjit Mitra and Ar Srivatsan as members of the City Study Jury were significant in the formation of this research paper. The making of report and publication used a range of published and unpublished literature and have interpreted for the outcome, their original sources are acknowledged. We express our extreme gratitude to Prof Suzanne Frasier and Prof T.M Vinod Kumar for helping us gain confidence and for guiding us through the preparation of abstract and to Department of Architecture, National Institute of Technology Calicut and Department of Urban Design, School of Planning and Architecture, New Delhi for encouraging us to participate in the IPHS conference.

Disclosure Statement

No potential conflict of interest was reported by the author.

Notes on contributor(s)

First Author: Lakshmi Manohar is now working as an Adhoc Assistant Professor at Department of Architecture, National Institute of Technology Calicut. She got her Bachelor of Architecture from Thangal Kunju Musaliar College of Engineering, Quilon and Master of Urban Design from School of Planning and Architecture, New Delhi. She has 2 years experience in teaching Architecture subjects and is mainly involved in teaching Undergraduate and Post Graduate subjects primarily related to Urban Design and Architecture along with research in the field of Smart City Development and Indian Urbanism.

Second Author: Muthaiah is an Architect-Urban Designer working as Independent Design Consultant .He got his Bachelor of Architecture from SRM University, Chennai, and Master of Urban Design from School of Planning and Architecture, New Delhi. He has 5years experience in the field of Architecture and construction. Muthaiah's thesis was on similar lines which is titled ECOLOGY BASE URBANISM- A strategic intervention for the recovery of Pallikaranai wetlands in Chennai.

Endnotes

1 Neal R. Peirce and Curtis W Johnson, *Century of the City: No Time to Lose*,(Rockfeller Foundation, 2008)
2 Centre for Science and Environment. "CSE PRESS NOTE: Chennai in crisis."cseindia.org. http://www.cseindia.org/content/cse-press-note-chennai-crisis (accessed May 29, 2016)
3 Folke, C . "Resilience: The emergence of a perspective for social-ecological systems analyses".Global Environmental Change (2006)16: 253–267
4 Nelson, Donald R.; Adger, W. Neil; Brown, Katrina. "Adaptation to Environmental Change: Contributions of a Resilience Framework" (PDF). Annual Review of Environment and Resources. (2007). 32: 395–419.
5 Lavanya, Ar K. "Urban Flood Management – A Case Study Of Chennai City Abstract "(2012)
6 CDMA .Master Plan - II for Chennai Metropolitan Area - 2026, (March 2007), Chennai Metropolitan Development Authority, Tamil Nadu
7 G K Rao "who let water into my city"series.fountainink.in. http://series.fountainink.in/who-let-the-water-into-my-city (accessed May 29.2016)
8 Rao Sahib C.S Srinivasachari. "History of the city of Madras". Tercentinary Celebration committee (1939)

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266

Bibliography

Centre for Science and Environment. "CSE PRESS NOTE: Chennai in crisis."cseindia.org. http://www.cseindia.org/content/cse-press-note-chennai-crisis (accessed May 29, 2016)

CDMA .2007. Master Plan - II for Chennai Metropolitan Area - 2026, March 2007, Chennai Metropolitan Development Authority, Tamil Nadu.

Folke, C .2006. "Resilience: The emergence of a perspective for social-ecological systems analyses".Global Environmental Change 16: 253–267

G K Rao "who let water into my city"series.fountainink.in.

http://series.fountainink.in/who-let-the-water-into-my-city (accessed May 29.2016)

Governance Screening for Urban Climate Change Resilience-Building and Adaptation Strategies in Asia : Assessment of Chennai City , India August 2007. 2007, no. August.

Gupta, Anil K, and Sreeja S Nair. 2010. "Flood Risk and Context of Land-Uses : Chennai City Case" 3 (December): 365–72.

Horrison, ArEbin, and Ar Lilly Rose. 2008. "URBAN CLIMATE MAPPING FOR SUPPORTING URBAN PLANNING IN CHENNAI , INDIA," no. Cmda: 0–5.

Introduction, A, B Current Scenario, In Chennai, and Metrospolitan Area. n.d. "Disaster Management," 99–102.

Lavanya, Ar K. 2012. "Urban Flood Management – A Case Study Of Chennai City Abstract :"

Neal R. Peirce and Curtis W Johnson, Century of the City: No Time to Lose, 2008 (Rockfeller Foundation, 2008)

Nelson, Donald R.; Adger, W. Neil; Brown, Katrina (2007). "Adaptation to Environmental Change: Contributions of a Resilience Framework" (PDF). Annual Review of Environment and Resources 32: 395–419.

Planners, Town. 2011. "An Analysis of Growth Dynamics in Chennai Metropolitan Area," no. December: 31–57.

Rao Sahib C.S Srinivasachari. "History of the city of Madras". Tercentinary Celebration committee (1939)

Shekhar, Satyarupa, and Madonna Thomas. 2015. "Chennai ' S Rain Check Fifteen Years and Counting," 1995–97.

Srinivasachari, C. S. 1939. "Introduction". History of the city of Madras written for the Tercentenary Celebration Committee. Madras: P. Varadachary & Co.

Swamidurai, Santhakumar. 2014. "Factors Affecting Urban Land Value in Indian Cities - Chennai City as a Case Study" I (Iii): 31–34.

Image sources

Figure 1: Author, Department of Urban Design. School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

Figure 2: Author, Department of Urban Design School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

Figure 3: CDMA .2007. Master Plan - II for Chennai Metropolitan Area - 2026, March 2007, Chennai Metropolitan Development Authority, Tamil Nadu.

Figure 4: Author, Department of Urban Design School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

Figure 5: Author, Department of Urban Design School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

Figure 6: Author, Department of Urban Design School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

Figure 7: Author, Department of Urban Design School of Planning and Architecture New Delhi, Unpublished report of Chennai City study

DOI: http://dx.doi.org/10.7480/iphs.2016.3.1266