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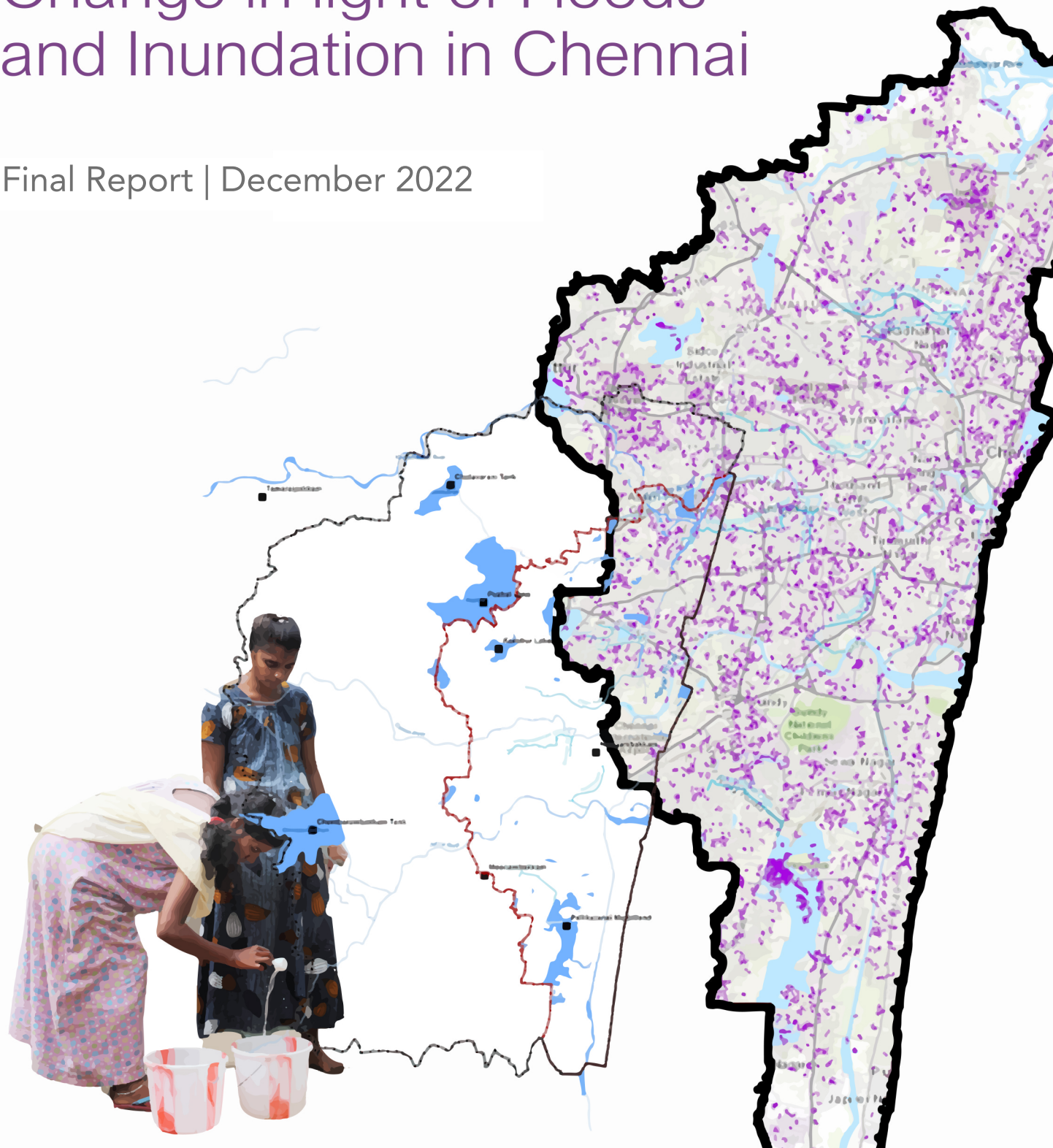
Study on Impacts of Climate Change in light of Floods and Inundation in Chennai

Final Report | December 2022



December 2022

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Executive Summary

November 2021 brought with it a deluge of heavy rainfall to Chennai, inundating many of the city streets, and reminding residents of the horrors faced during the 2015 floods. It was indicative of a broader trend of heavy and intense rainfall events being more frequent during the North-Eastern monsoon season in Tamil Nadu. Chennai is one of the many coastal cities across the world that is facing the worst impacts of climate change as the weather events become more erratic and extreme. While the state broadly, and Chennai specifically, has learned many lessons from the 2015 floods and was much better prepared in 2021, there is a lot of work that needs to be done to make Chennai resilient to climate impacts and flooding.

This study attempts to map out the impacts of flooding in lieu of climate change to understand the most crucial intervention areas. The research investigates the following themes pertaining to Chennai and its climate reality:

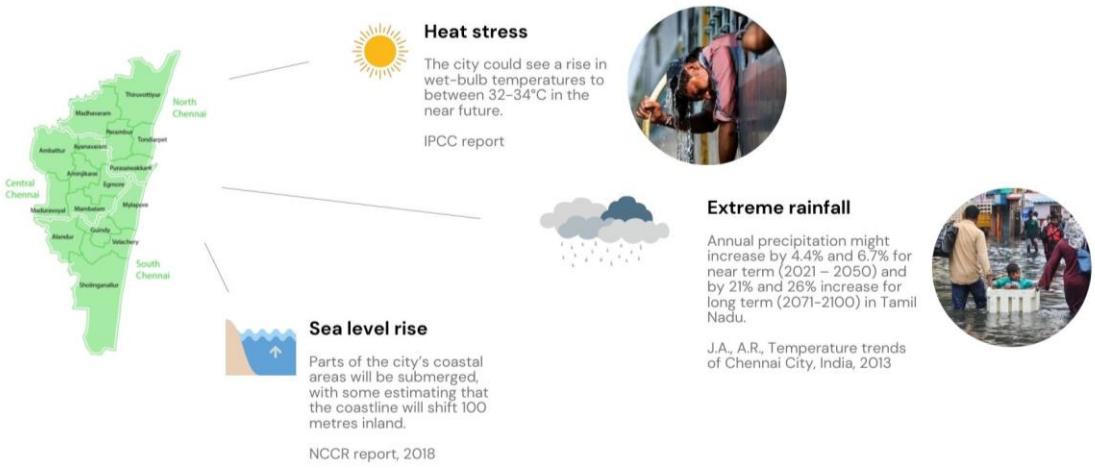
1. Comparing 2015 and 2021 floods in terms of impacts and preparedness measures
2. Impacts of climate change on the lives of Chennai residents through extreme weather events like rainfall and flooding
3. Pathways for Chennai to become more resilient to future climate disasters

We use scientific research, media reports, policy reviews, and primary data analysis to map out the vulnerability of Chennai's communities to inundation, the challenges they face, the improvements made over the years, and what remains to be done to ensure that future monsoons do not drown the city's activities to a standstill.

Climate vulnerability of Chennai

Chennai's location makes it particularly prone to facing extreme rainfall events. Being a coastal city, it is also prone to hazards like cyclones, tsunamis, coastal erosion and sea level rise. Climate Change has disrupted many normal wind cycles through processes like excessive heating of ocean waters, disruption in air temperature etc. which leads to erratic weather phenomena across the world where heat waves, heavy rainfall, and cold waves are all becoming increasingly common. These effects are most severe near the seas, which is what puts coastal cities like Chennai most at risk.

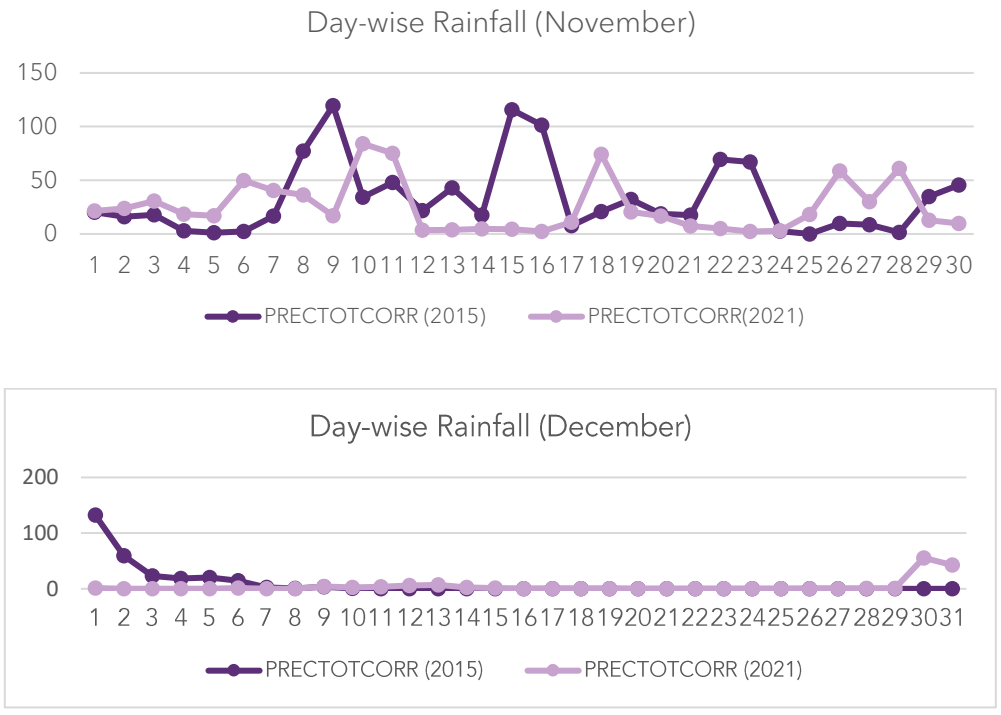
Further, Chennai is also dependent on regular monsoons for its water supply, so while a heavy monsoon threatens to flood the city, deficient rainfall means there is threat of the city's ground water running out. In addition, as a tropical city next to the ocean, it experiences hot weather throughout the year. With the temperature bound to increase in the coming years, the threat of heat waves and heat stress is also exacerbated.



Climate change impacts on weather are most acute near the oceans, which is why Chennai faces this myriad of challenges to become climate resilient. All these effects are exacerbated by excessive urbanization and development in the city, which has led to the depletion of water tanks, vegetation areas, and other natural features which act as natural drainage. The reduction of natural drainage places additional pressure on the city's existing storm water drains which are often overwhelmed by heavy monsoons.

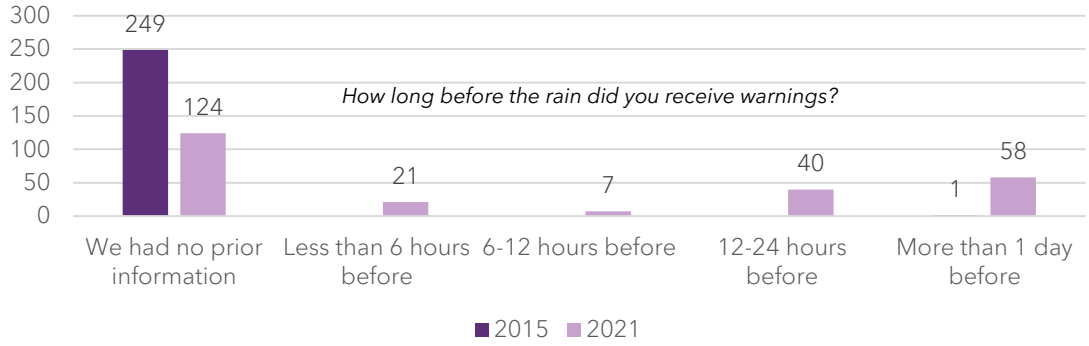
2015 vs 2021 Floods: A comparison

In 2021, the flooding severity was somewhat lesser than 2015 as the floods were characterized by quick bursts of very intense rain. The overall annual rainfall in 2021 was higher than that of 2015 but the amount of rainfall in the more erratic and extreme north-east monsoon was slightly lesser than 2015.



Graph showing the day wise rainfall data for Chennai during the months of November and December in 2015 and 2021

From the study, it is clear that the people appreciate the strides made by the city's corporation in terms of disaster resilience while recognizing many areas for improvement. *The weather systems had improved from 2015 but still were inadequate, failing to provide people timely intimation and warnings before the heavy rains*. When it comes to a comprehensive approach towards early warning, there is much to be done in terms of weather tracking, generating localised early warnings and disseminating them.



One of the major improvements from the 2015 floods was the better management of reservoirs and water bodies. The Greater Chennai Corporation had desilted large expanses of the stormwater drainage network, many tanks and pits, and other crucial rain management systems which helped in managing the rains. *While the government's efforts have been effective in reducing flooding and ensuring it gets cleared up faster than in earlier years, heavy rainfall still significantly impacts people's lives*. The current infrastructure needs to be improved to cater to extreme rainfall events.

While the discourse on climate change in the media remains quite limited, the government has actively been taking many steps by recognizing the very real and immediate danger posed by climate disasters. The city has tried to restore its three rivers as well as rejuvenate the old systems of water canals. Additionally, the City Disaster Management Policy directly tackles flooding, inundating, day zero crisis, and climate change and makes plans that once implemented, would significantly improve the city's ability to withstand climate impacts. Real-time weather forecasting has been one of the key lacunae in preparedness for many years, and the government plans to remedy that with over 100 localized weather stations as per the NDMA recommendation post 2015 floods. The state government also committed a part of its fiscal budget to climate resilience, which indicates that this is a priority action area for the state's policymakers.

While loss to life and property has been minimized, further interventions to address the economic, social, and educational disruptions caused by flooding are crucial, as are better drainage systems that minimize flooding. More concerted and integrated efforts are needed to close the persisting gaps in preparedness and to chart out resilience pathways for Chennai.

Recommendations

Robust, integrated early warning system: A communication network integrating the different levels from the IMD (national) to the various community systems would help in spreading the information to the communities faster. Upgrading the existing and installing new automatic weather stations as per the NDMA recommendation is also crucial for better preparedness.

Addressing the drainage woes: Upgrading the sewage lines is crucial as these are decades-old systems which are woefully inadequate for increasing rainfall amounts. When it comes to city-wide action, upgrading and maintaining the storm water drainage systems is the priority as better drainage can prevent flooding to a great extent.

Management of water bodies for water resilience: There are good signs when it comes to the management of water bodies and dedicated climate budgets in the state government. Rejuvenation of the existing water bodies should be carried out and also regulations be put in place to prevent encroachments.

Community participation and interventions: The government needs to carry out resilience drills in dry months so that people are aware of the best protocols to follow during floods. Identifying and promoting community based local innovations and innovators would also contribute to climate change adaptation and flood resilience.

*Climate budgeting***:** Further action needs to be taken to identify the most climate-relevant and the most climate-sensitive programs and sectors across the state, and especially within Chennai, to then target the climate budgets towards these sectors which will produce the most impact in terms of increasing resilience.

Chennai has taken a lot of steps toward improving its disaster management since the 2015 floods which destroyed life and livelihood in the city. The city is better prepared with better protocols and alerts, and more proactive government and citizens. Yet, a lot remains to be done because the scope and magnitude of climate impacts continue to grow, and it is crucial for Chennai to not just become resilient to the disasters of the past, but the possible disasters of the future, and their unknown magnitude. A community centric and technology backed approach is required for a resilient future of Chennai.

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1 Introduction

Over the past few years, Chennai has witnessed bouts of very heavy rainfall as a part of the annual monsoon cycles. The worst of it was experienced during the 2015 floods, but since then, inundation and flooding have become a common feature of the northeast monsoon (October-December) cycle. On an average, Tamil Nadu gets 440.4 mm during North-East monsoons, accounting for around 48% of the total rainfall. However, in 2015, Chennai alone received 883% excess rainfall between 1st December and 5th December. According to the 2015 Flood Memorandum by Government of Tamil Nadu, between November and December, 470 lives were lost in the state out of which 49 were reported from Chennai. Again in 2021, repeated low pressures and depressions over Bay of Bengal brought heavy to extremely heavy rainfall in many districts causing extensive damages to life, property, and other critical infrastructures. This time the number of lives lost between November and December was 74 for the state as reported in the 2021 Flood Memorandum, significantly lower than 2015. This simultaneously highlights the improved preparedness measures and quick response by the government and other stakeholders based on the learnings from 2015, and the continued flooding threat faced by the coastal capital of Tamil Nadu.

Despite better preparedness, the increased frequency of extreme weather events across the world is emblematic of the effects of climate change, and Chennai is no stranger to it. According to the latest IPCC report[1], human-induced climate change has caused *widespread adverse impacts* and related *losses and damages to nature and people*, beyond natural climate variability. This means that even in the most hopeful scenarios of limiting global warming, the persistent effects of historic warming will ensure that extreme and erratic weather events will become more frequent and more dangerous. Climate change is manifesting as a variety of extreme weather events across the world, be it extreme heat waves, rising water levels of the seas, or erratic and extreme rainfall patterns across the world.

In that context, this report is an attempt to map Chennai's vulnerability to climate disasters, specifically flooding resulting from heavy rainfall, and its impact on the city's most vulnerable communities, as well as the scope for policy intervention to mitigate these effects. The study aims to keep climate change at the forefront but understand its impacts from the ground-up by bringing together scientific data on climate change and rainfall with the lived experiences of Chennai's communities, as well as the actions being taken by key stakeholders involved in disaster mitigation and response. An amalgamation of various perspectives will provide a holistic understanding of the issue at hand and allow for better policymaking and action planning that responds to community needs and addresses the impending risk of climate disasters becoming more and more frequent.

[1] IPCC, 2022: *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. In Press.

1.1 Research Questions and Scope

The broad research questions of the study are as follows:

- What are the impacts of climate change on the lives of Chennai residents through extreme weather events like rainfall and flooding?
- What are the persistent gaps in institutional capacities and disaster management frameworks and response which hamper the city's disaster resilience?
- How can Chennai become more resilient to future climate disasters?

The scope laid out by these research questions includes:

- Reviewing climate data for Chennai, especially the data on rainfall in the recent past to analyse the prevalent trends and indicate the impacts of climate change
- Critical comparison of the rainfall data leading to the 2015 and 2021 floods- similarities and differences between the underlying weather patterns that resulted in extreme rainfall.
- Analysing the urbanisation patterns and their relevance for understanding the impact of flooding and climate change on the city
- Review media reportage of the flooding events and assess their focus on climate change
- Spatial and temporal variation of the impact of the rainfall and floods to identify the most vulnerable areas of Chennai, as well as how the vulnerabilities have evolved.
- Using the data from the 2015 and 2021 events, indicate how short-term weather forecast and real-time weather data could be used to reduce Chennai's vulnerability to flooding

1.2 Methodology

The study's primary focus is to understand the climate change impacts on the city of Chennai, especially with respect to flooding and inundation. The approach here is to first look into the relevant scientific projections available for climate change and then further break the climate science down to understand its intersection with policies and actions specific to the city.

- The report relies on secondary research including research papers and climate data portals for understanding the climate projections for Tamil Nadu and Chennai.
- Rainfall patterns have been analysed using precipitation data from the Indian Meteorological Department (IMD).
- GIS mapping and analysis using satellite data has been done to understand waterlogging patterns in the city during flooding events and urbanisation and growth patterns.
- Review of relevant policies and reports including the Tamil Nadu State Action Plan on Climate Change, IPCC reports, and the City Disaster Management Perspective Plan 2021 by GCC.
- Review and analysis of media reports on 2015 and 2021 floods

- Primary research in 10 locations across the city using transect walks, household surveys, unstructured interviews, and focus group discussions

The report is structured in five broad sections: the first introduces the need and scope of the study, the second section focuses on laying out the context of the study with respect to existing discourse on climate change and initiatives undertaken by the government. The third section focuses specifically on Chennai's climate vulnerability to droughts, floods, and heat waves and how these interact with each other to create an extremely difficult policy challenge. The fourth section discusses results of the primary survey we undertook to understand people's experiences of flooding and climate change. Lastly, the fifth section lays out specific recommendations by synthesizing the learnings of policy and media reviews with the data collected from the ground to understand the most pressing concerns.

2 Context

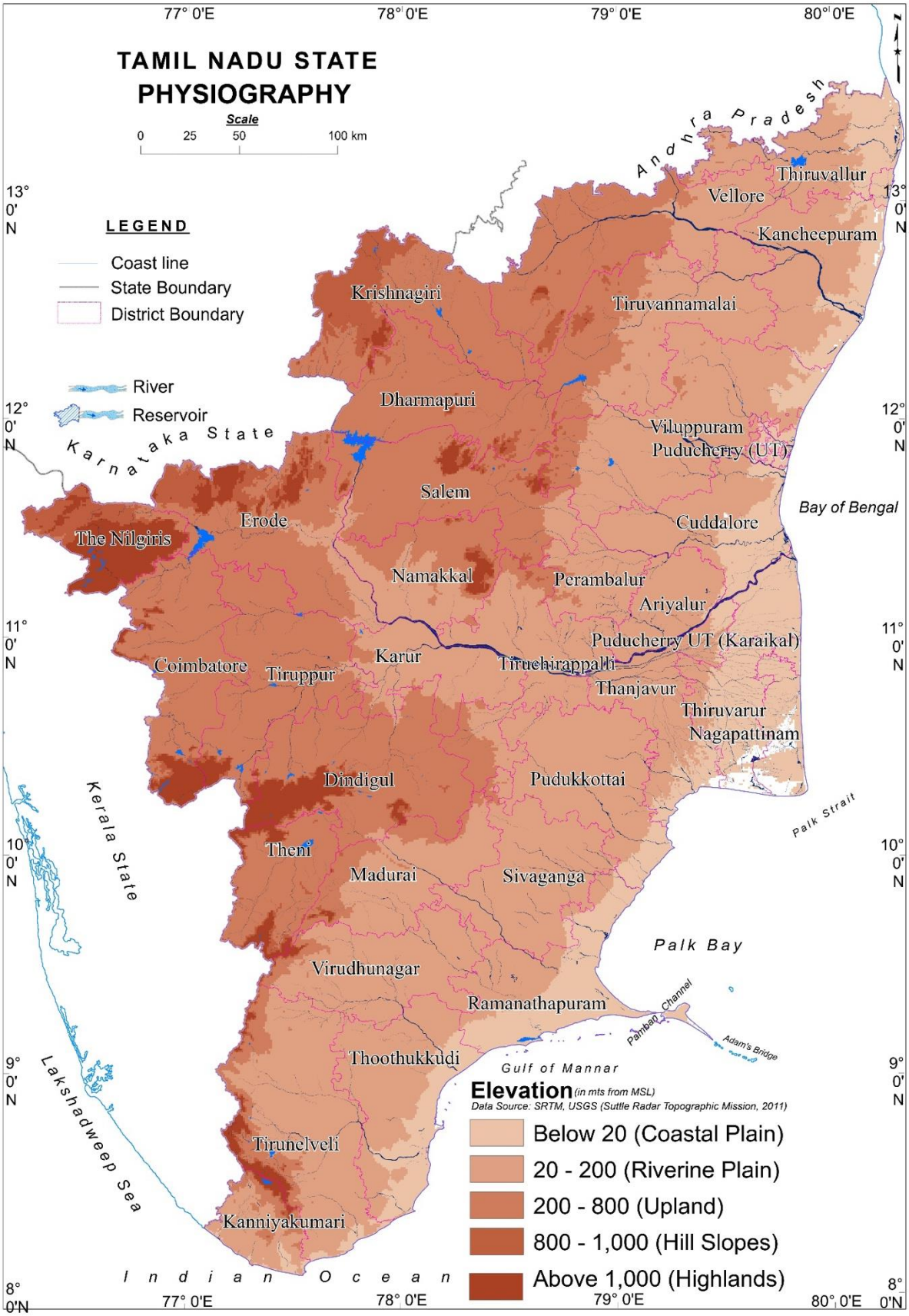
This section lays out the context for the research study by discussing the general characteristics of Tamil Nadu and Chennai that play a role in determining vulnerability to adverse impacts from extreme weather events. We discuss the broad features of Tamil Nadu's weather and the challenges it creates, as well as discussing the particular case of Chennai and how land-use change, and rapid development have worsened its vulnerability to flooding over the years. In addition to discussing urban growth, we also present a chapter on the current state of reporting over climate change, and the discussions around the impact it has had and would have on Chennai. Lastly, we highlight some of the key initiatives taken by the government, especially since recognizing their importance after the 2015 floods, which has helped ameliorate the stress caused to Chennai's citizens and systems by heavy or extreme rainfall.

2.1 Tamil Nadu

Tamil Nadu's unique location of being bordered by the Eastern Ghats to the West, the Bay of Bengal to the East, and the Indian Ocean to the South, makes its climate patterns also unique. It has long coasts along with significant hills towards its western border, and their confluence is responsible for much of the peculiarities of Tamil Nadu's weather, and particularly its monsoon patterns (See Map1). The state's proximity to the coast ensures that the temperature remains largely stable across the year with little variation across seasons or months, exhibiting a typical tropical climactic condition. Hot temperatures feature throughout the year with very little winter to speak of, although climate change trends are projected to create some extremities in summer and winter temperatures (See Figure 2-1). Along with temperature, proximity to the sea also ensures that the humidity remains high throughout the year. Unlike many other parts of the country, the major monsoon source here is the North-east monsoon during October, November, and December. These monsoons are often extreme and unpredictable, exposing the state to extreme weather conditions like floods and droughts depending on whether the erratic monsoon brings about deficient precipitation or an excess.[2]

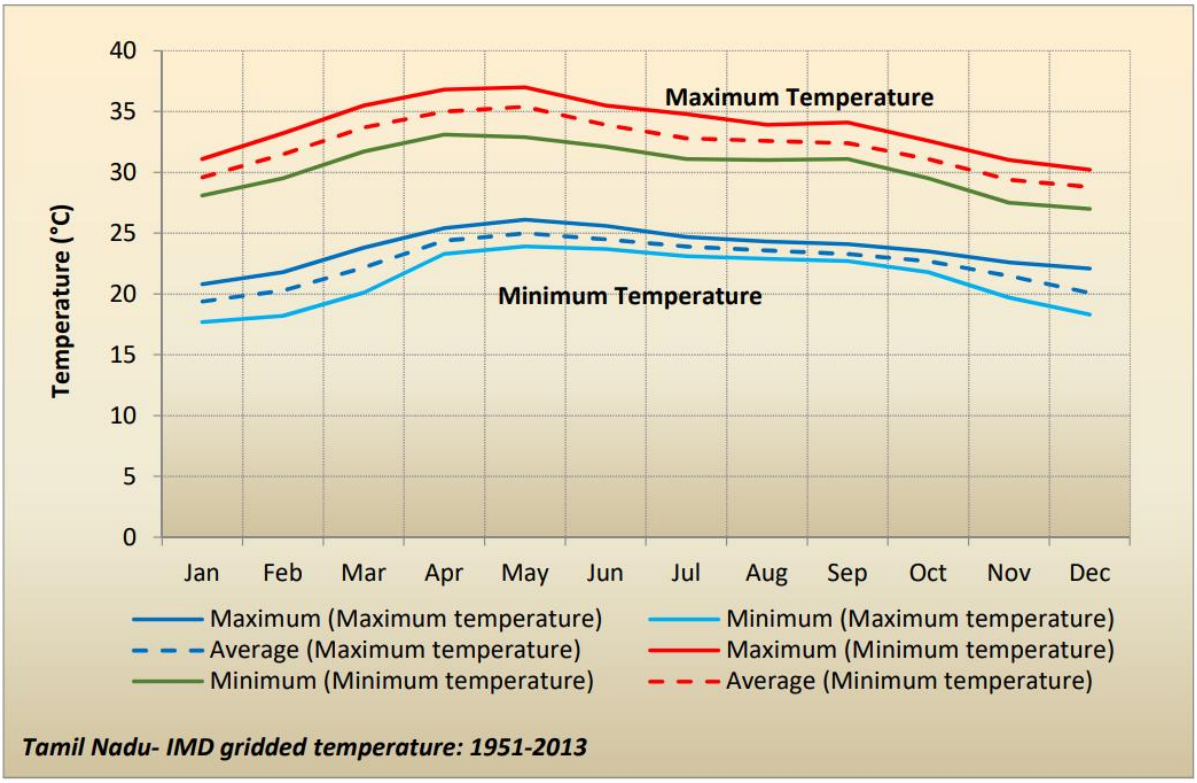
Tamil Nadu's proximity to the sea makes it among the first states to feel climate change. Tamil Nadu's mean annual maximum temperature is 32.2 degrees Celsius, with the highest levels before the monsoon season and the lowest following. Coastal locations are warmer than many Eastern Ghats-areas inland[3]. The coastal districts of Chennai, Kancheepuram, and Cuddalore have the highest annual rainfall at 987 mm. Pre-monsoon rains account for 12.4% of the state's rainfall, while the main (southwest) monsoons bring 34.4%. Post (northeast) monsoon rains from October to December provide the most.

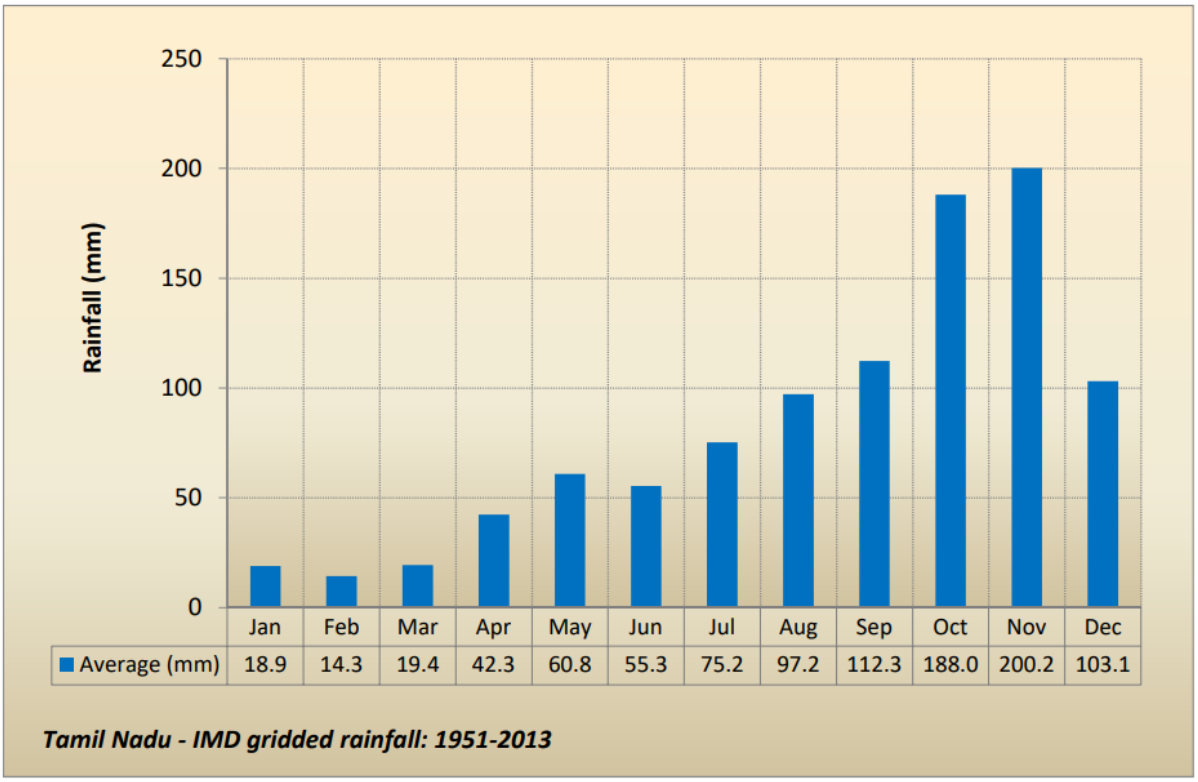
[2] https://moef.gov.in/wp-content/uploads/2017/09/Tamilnadu-Final-report.pdf
[3] https://www.environment.tn.gov.in/Document/tnsapcc/Chapter%203.pdf



Map 1: Physiography Map of Tamil Nadu; Source: State Disaster Management Perspective Plan 2018-2030

Figure 2-1: Temperature and Rainfall by Month for Tamil Nadu; Source: IMD





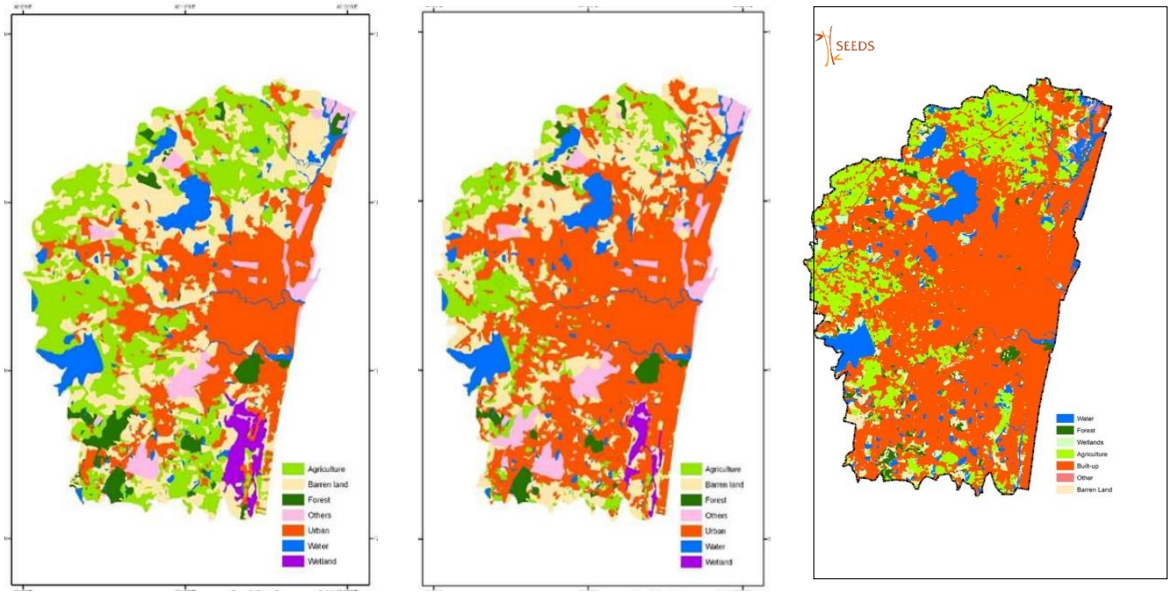
Climate change's effects are quite significant for Tamil Nadu, as in addition to the temperature heating up, it has adverse effects on the functioning of a state that has historically had somewhat regular monsoons to back on. Completely erratic and extreme monsoons can render Tamil Nadu helpless against climate-related disasters like flooding and drought. The overall rainfall has increased, while the number of rainfall days has somewhat fallen, meaning that rains are falling less frequently, but with significantly more intensity and extremity.[4] Over the last 60 odd years, the number of short bursts of rain, either 1-day or 5-day precipitation events, have slowly increased.

Most scientific literature also points to increasing warmest temperatures, and higher intensity rainfall events, although overall amount of annual precipitation may increase or decrease. The annual mean temperature in the state could rise somewhere between 1.7-3.4 degrees Celsius depending on the level to which global warming continues or is curtailed, and the current trend of similar temperatures across the year is also likely to be bucked in the favour of higher summer temperatures.[5] Meanwhile, average precipitation level is likely to either be unchanged, or have small deviations, an increase or decrease of 5% at max. However, that does not mean precipitation itself will be unaffected as the amount of rainfall in the stable June-September monsoons is projected to reduce while the amount of rainfall in the more erratic and extreme north-east monsoon is projected to increase. Cold and warm spells are also likely to become more common occurrences, and higher unpredictability of rains will mean that the state will need to be prepared for both absorbing excessive precipitation in rainfall abundant years or tackling droughts in deficient years.

2.2 Chennai

Chennai is located in the north-eastern part of Tamil Nadu right along the Bay of Bengal coast, having a coastal line of more than 40 kilometres. Chennai lies in a plain low-lying area with very low average height from mean sea level ranging from 2 to 10 metres. The city is mainly characterized by a flat plain and a few hills that slope towards the Bay of Bengal and drain in it. The city's jurisdiction currently extends to 426 square kilometres over 3 districts: Chennai and parts of Kanchipuram and Thiruvallur. This has been expanded in 2011 from the earlier jurisdiction of 174 square kilometres.[6] The city is densely populated with an overall population of 6.6 million people according to the dated 2011 census, with projections[7] for 2022 estimating over 11.5 million people. The city and its population are simultaneously prone to flooding in extreme rainfall years as well as drought and water shortage in rainfall deficient years. Lastly, its proximity to the Indian Ocean also means that it is always at risk for tsunamis, best exemplified by the devastating Indian Ocean tsunami of 2004.

[4] https://www.environment.tn.gov.in/Document/tnsapcc/Chapter%203.pdf
[5] https://cag.gov.in/uploads/media/tamil-nadu-climate-change-action-plan-20200726073516.pdf
[6] https://weatherspark.com/y/110123/Average-Weather-in-Chennai-India-Year-Round#:~:text=In%20Chennai%2C%20the%20wet%20season,or%20above%20103%C2%B0F
[7] https://worldpopulationreview.com/world-cities/chennai-population

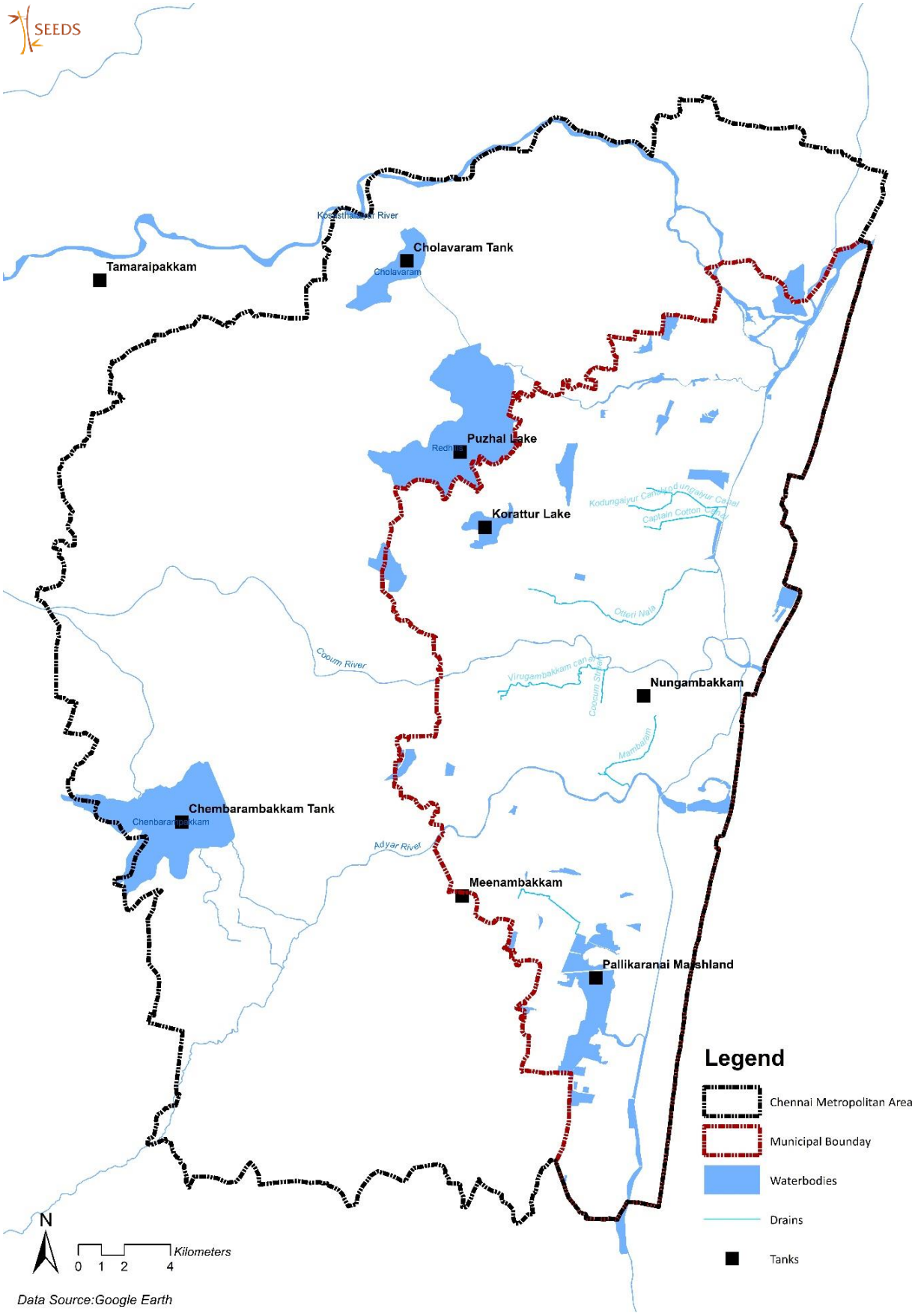


Map 2: Chennai Land Use Map for 1991 (Left), 2010 (centre) and 2021 (right)

Map 2 shows the change in land use of Chennai from 1991 to 2021. An analysis of the changes in land use from 1991 to the present day, reveals a stark contrast. In 1991, land use was evenly divided with settlement, agriculture, and barren land having almost equal shares. However, the present-day Chennai is characterised by significant proportion of built area. Over the years, the amount of vegetation has reduced, and forest areas have disappeared while the water bodies (especially the rivers) have also shrunk in size. In 1990, more than 4% of Chennai's land was under forest cover providing natural protection against flooding and wetlands to drain rainwater. These wetlands have halved in size three decades later, and so has agricultural land, as the settlement area increased rapidly and currently occupies a majority of Chennai's land use. Agricultural land being used for settlement and water scarcity for irrigation are also some of the reasons why Chennai's agricultural industry has struggled while settlements have increased by more than 70%. Urban land usage has increased rapidly as forest land, water bodies, and wetlands have dwindled. The degradation of wetlands is particularly concerning for a city that faces frequent flooding and inundation during the monsoon. The reduction in urban green cover and dense green cover has also been significant and particularly affects microclimatic conditions over the city.[8]

The city has a rich history of water reservoirs, canals, and rivers (See Map 3), but is now dependant on water tankers and water trains from other places, due to lack of appropriate management of water resources over the years. There are three rivers passing through the city: Coovam, Adyar, and Kosasthalayar. While the water bodies of Chennai are still crucial for dealing with excessive as well as deficient rainfall to counter drought or flood risk, areas which have dried out have been used for settlement purposes.

[8]https://www.researchgate.net/publication/348530717_Challenges_in_Chennai_City_to_Cope_with_Changing_Climate



Map 3: Water Channels and Tanks of Chennai

This has increased the number of low-lying areas significantly, which are also areas with the highest inundation and flooding risk as any sustained rainfall is bound to move towards these areas due to the city's natural contours. Some of the most flood and inundation prone areas are ones around water bodies built-in low-lying areas through reclamation projects. Such reclamation projects are increasingly posing major challenges to Chennai's ability to absorb excess rainfall.

2.3 Discourse on Climate Change

The discourse around climate change is quite limited in popular media. Most media outlets that report the impacts of the rains do not mention climate change as a possible factor for erratic weather conditions, and more extreme weather as witnessed by the heavy rains in Tamil Nadu which led to the floods. Various media articles note the impact of climate change and the corresponding vulnerability of Chennai to adverse impacts. Chennai is uniquely placed as it is vulnerable to both extremes – dry and wet. Niti Ayog's Composite Water Resource Management report in 2018 lists Chennai as one of the cities in India on the cusp of 'Day Zero' – a scenario when there will not be a single drop of water remaining[9]. Majority of the articles frame the resulting scenarios as a failure of governing systems – particularly of the shortcomings of urban infrastructure[10]. Few articles also emphasise that the incidence of extreme weather events will increase due to climate change in the future.[11] International media also note the stark reality of climate change impacting people's everyday lives in the backdrop of the global negotiations at the 2021 United Nations Climate Change Conference (COP).[12]

Specifically, in the context of Tamil Nadu, one article cited Tamil Nadu's climate action plan which predicts that by 2100, the average annual temperature will rise 3.1°C from the levels witnessed between 1970-2000, and yearly rainfall will reduce by around 9%. A key aspect of the climate prediction is that there will be a significant reduction in the southwest monsoon (June-September), but the increased intensity of the flood-prone winter cyclone season, when the state gets most of its rain from the northeast monsoon.[13]

However, there is little consensus among experts when it comes to the influence of climate change on weather patterns and whether the conditions witnessed in Tamil Nadu are a consequence of climate change or not. It is important to note here that the effects of climate change are often gradual and when it comes to the impact on weather conditions, they can always be dismissed as erratic weather phenomena. However, the increased incidence of erratic weather phenomenon is itself globally considered a consequence of climate change

[9] https://www.news9live.com/knowledge/looming-water-crisis-in-india-check-list-of-5-cities-that-are-likely-to-go-dry-by-2030-196887
[10] https://thefederal.com/opinion/wonder-why-chennai-suffers-floods-and-drought-its-the-poor-infrastructure-stupid/
[11] https://indianexpress.com/article/opinion/editorials/chennai-floods-weather-rain-7615607/
[12] https://www.washingtonpost.com/weather/2021/11/13/extreme-weather-cop26-glasgow-world/
[13] https://www.hindustantimes.com/editorials/chennai-flooding-don-t-just-blame-the-rains-101636358400245.html

having disturbed the natural patterns of oceanic currents. This is consistent with research by Clemens et al. (2021) that the amount of rainfall in South Asia and extreme variations in rainfall are bound to increase due to the higher levels of greenhouse gases in the atmosphere, atmospheric carbon dioxide levels, and extra supply of moisture from the Indian Ocean due to warming of the oceans.[14]

In that light, the specific disagreement for the 2021 Tamil Nadu monsoon is as follows: many experts have warned that changing rain patterns are an effect of climate change and we must learn to strengthen warning systems and work under the assumption that such extreme, unpredictable events will only keep increasing in the future.[15] However, some experts posit that weather conditions are responsible for these heavy rains, and not climate change.[16] They argue that the chances of above-normal rainfall in November are generally very high, and specifically the presence of the Madden-Julian oscillation (MJO) and a favourable Indian Ocean Dipole (IOD) creates low-pressure systems that lead to heavy monsoons. Weather department officials say that extreme rains have been happening for many decades with 1976 still holding the record for highest rainfall in Chennai in a single day of November. They compare the effects of the MJO and IOD to the conditions of 2005 when repeated low-pressure areas made their landfall over Tamil Nadu.

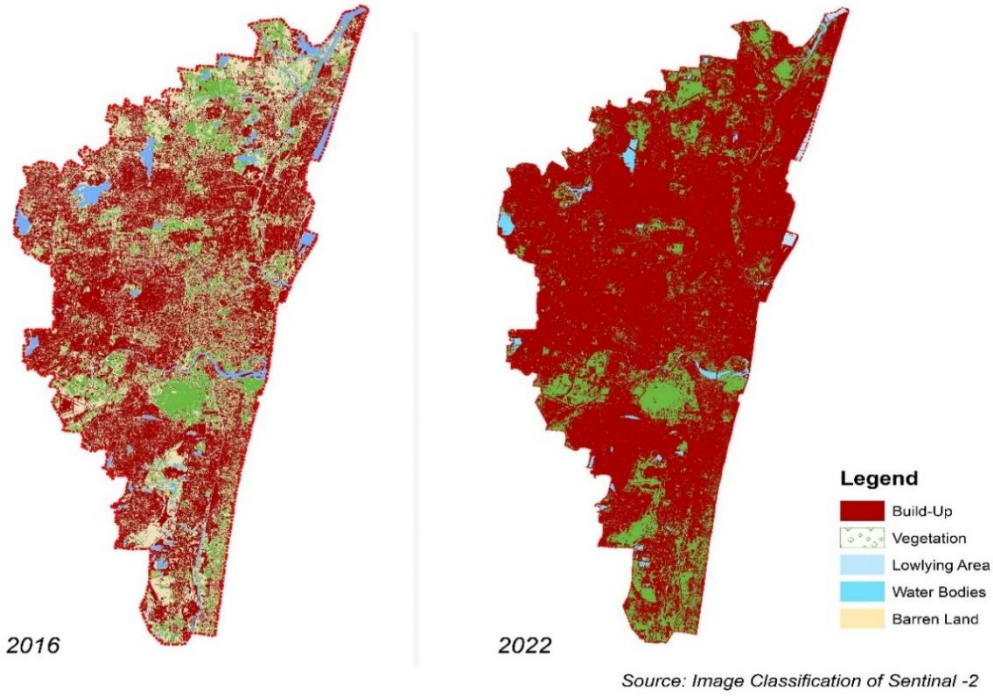
There are a few salient things about the arguments made by those who deny that the rains are a consequence of climate change. On the one hand, while it is certainly true that the rains can be traced back to some oceanic phenomenon, the irregularity of weather and increased incidence of these phenomena can themselves be traced to the effects of climate change, as has been discussed by Clemens et al. (2021). Additionally, it remains concerning that there is a dearth of reportage on climate change in mainstream media. Aside from one line mentioned in articles, it is largely missing from reporting, and this lack of discourse around climate change is concerning because it does not create awareness about the very real and dire impact climate change is already having on lives across the world and in India. The effects of climate change are largely perceived to be future threats and there is little recognition of the very real and immediate threat they pose, and there is an urgent need for media houses to report that more consciously and actively.

2.4 Urban Growth and Development

Chennai's paradoxical precarity with respect to water availability is human induced in many ways. Over the years, water bodies have been encroached by development projects, the three major rivers have diminished in size, and incessant garbage dumping means that many of the erstwhile water sources are no longer fit for consumption. Despite having above average annual rainfall, amongst the major metropolitan Indian cities, Chennai has

[14] https://www.science.org/doi/pdf/10.1126/sciadv.abg3848
[15] https://www.hindustantimes.com/india-news/imdissues-red-alert-in-kerala-heavy-rainfall-continues-in-tamil-nadu-101636916712910.html
[16] https://www.hindustantimes.com/india-news/weather-conditions-not-climate-change-responsible-for-chennai-rainexperts-101636310570590.html

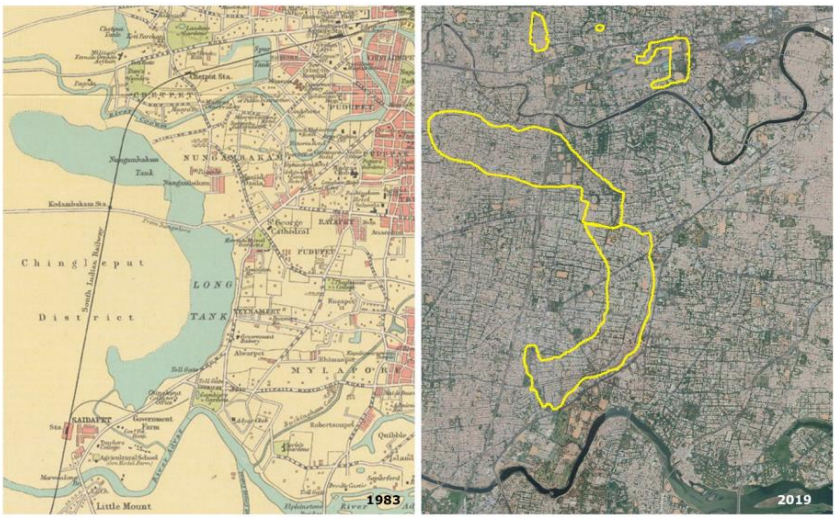
the lowest per capita water availability as piped water supply remains rare and erratic. Consequently, its growing population has relied on wells and other groundwater sources for water, leading to their continued degradation and depletion.



Map 4: Land use land cover (LULC) map of Chennai

Map 4 shows the land use land cover in Chennai during 2016 and 2022. The maps indicate the possibility of a stark increase in the built-up area of the city. While built up area has consistently increased in Chennai over the past few decades in response to demographic demands and growing populations, the city has also reclaimed water bodies as land for development projects.[17] This double whammy against sustainability means that its water resources reduced, as well as creating more flood prone areas as these reclaimed lands are often in low lying areas. The trends of built-up area for Chennai can be seen in the following maps 5 and 6:

[17] https://ic-sd.org/wp-content/uploads/2020/11/Bhrigu-Kalia.pdf



Map 5: Example of Conversion of water bodies into construction land in Chennai (1983-2019)

Map 6: Example of reclamation of water bodies for building housing in Chennai (2001-2022)

According to the City Disaster Management Perspective Plan 2021 by Greater Chennai Corporation, the frequent urban flooding in the city is due to the following reasons:

- The plain terrain of Chennai with an average altitude of 7 metres above sea level.
- Sand bar formations at the mouths of rivers which slow down the discharge rate.
- Clogging of the drains due to indiscriminate dumping of solid waste and construction debris.
- Inadequate design capacity of storm water drains in highways and other roads.
- Lack of continuous connectivity of storm water drainages with macro drainage and absence of storm water drain network in added areas.
- Encroachments to drains and other water clearing mechanisms.
- Influence of high and low tide which increases vulnerability of coastal areas.
- Flow of excess surplus water exceeding the designed carrying capacity of minor water bodies through release of water from upstream tanks.
- Construction of fewer cross culverts or vents with inadequate sizes wherever the road is passing across the water flow.

2.5 Key Initiatives

Rejuvenation and restoration of water resources: Restoring the city's water resources, canals, and rivers is crucial for catering to water scarcity and flooding challenges as they provide water resources in dry years and can carry excess water to the sea during wet years. The city set up the Adyar Poonga Trust in 2006, and its work remains a daunting but important task, to restore the three rivers of Chennai as well as the Buckingham Canal which has shrunk more than 100 metres in width in some parts of the city[18]. Rejuvenating the city's old system of water canals and tanks will mean that it has water resources to cope with droughts, and these systems have the potential to absorb excess rainfall in the case of intense precipitation events and above average rainfall years.

Weather and flood monitoring: The government of Tamil Nadu and the Greater Chennai Corporation created a new and revised disaster management policy for the city which was released in August 2021.[19] One of the major improvements proposed under the program, which has been recommended by the NDMA in the past and is an absolute necessity, is the introduction of hyper-local real-time weather and flood monitoring. This decision has been taken in light of the repeated floods witnessed in Chennai's urban and peri-urban areas. The government plans to study and implement a "Real-Time Flood Forecasting and Spatial Decision Support System for Greater Chennai Corporation and the river basin areas of Adyar, Cooum, Kosasthalaiyar Rivers and Kovalam" which will work on forecasting rain and flooding risk to help the government better prepare for any bursts of rain and help communities also be more proactive in disaster management. These systems which will include automatic weather and rain gauge stations, internet-linked lake inflow and outflow meters, and river flow level meters are planned to be installed in various parts of Chennai with over 100 stations consistent with NDMA's recommendation for *one station in every four-square kilometre*. The government estimates that this plan will be implemented within the next 30 months.

Further, the government is also utilizing Unmanned Aerial Vehicles (UAV) for photogrammetrically mapping the flood-affected districts and surveying various vulnerable and disaster-prone areas for better planning and provision of relief materials. However, the step towards better weather monitoring is crucial and would be immensely beneficial for future management and prediction of heavy rainfall and floods. The National Centre for Coastal Research under the Ministry of Earth Sciences has developed a disaster (flood) preparedness decision support system for Chennai called C-FLOWS[20] to assist the Tamil Nadu Government in flood mitigation and relief operations. A web-based multi-hazard potential impact assessment and emergency response tacking system (TN-SMART[21]) was created by the Government of Tamil Nadu to utilize weather forecast products to assess potential impacts and evaluate and disseminate impact management options with a robust

[18] https://www.bbc.com/future/article/20210105-day-zero-how-chennais-wetlands-could-save-it-from-drought
[19] https://chennaicorporation.gov.in/gcc/pdf/ALL%20IN%20ONE_CDMP%20BOOK_3_9_21.pdf
[20] https://www.nccr.gov.in/sites/default/files/C-FLOWS%20Brochure.pdf
[21] https://play.google.com/store/apps/details?id=int_.rimes.tnsmart&gl=US

data management system for managing and processing weather, disaster risk and emergency response resources data. The Tamil Nadu Pollution control board (TNPCB) also conducts pre monsoon awareness campaigns on rainwater harvesting, sewage treatment etc in collaboration with RWAs in the city. Under the National Air Quality monitoring program, air quality monitors were also setup across the city.

Heatwave action plan(2019): The state has developed a heatwave action plan based on NDMA guidelines[22]. The heat action plan outlines the responsible departments at state and district levels for each action from early warning to capacity building and long-term mitigation measures and the guidelines for action. These guidelines are aimed to improve the effectiveness of the health infrastructure of the state. The plan also outlines the measures at local scale like cool roofs, bio shields, solid waste management etc.

Tamil Nadu State Action Plan for Climate Change 2.0: On the policy level also, many positive steps have been taken by the government to address climate change. The draft Tamil Nadu state action plan for climate change 2.0 is an important step in this direction. The draft plan builds on the previous state action plan and has identified agriculture and allied sectors, water resources, forest and biodiversity, coastal area management, sustainable habitat, energy efficiency and knowledge management as the sectors most vulnerable to climate change in the state. The document outlines the impacts of climate change on the vulnerable sectors, strategies for climate change adaptation and mitigation. Operationalising the plan would be a seminal step towards the climate resilience pathways for the state.

Overall, the state is among the most progressive in the country in having committed Rs. 500 crores as part of the budget dedicated for climate resistance, which was presented in the 2022-23 Assembly. The next section discusses the particular features and phenomenon that have made climate change and related flooding events such an important consideration for the government.

[22] https://tnsdma.tn.gov.in/app/webroot/img/document/heatWaveAction2019.pdf

3 Climate Vulnerability

Chennai's coastal setting help to keep the city's temperature at an almost constant level the year-round. The summer season can be extremely hot and humid, and the monsoon season is characterised by extreme rainfall events, particularly in the last two months of the year, when the Indian eastern coast is also bombarded by cyclonic activity in the Bay of Bengal and Indian Ocean.

The city is predominantly subject to the following climatic conditions: summer, winter, and monsoon. The north-east monsoon, which is well-known for its intense and unpredictable character, is the source of the majority of the yearly precipitation that is received in both Chennai and Tamil Nadu.[23] This not only increases the likelihood of storm tides occurring during the monsoon season, but it also puts Chennai at risk of floods during years with abundant precipitation and drought during years with little precipitation. This section explores a number of climatic and meteorological occurrences that highlight Chennai's susceptibility, including the potential for the city to run out of water during periods of drought, also known as "Day Zero," its susceptibility to high levels of heat and humidity, temperature forecasts for the foreseeable future, and extreme rainfall events that occur during the North-East monsoons. The effects of climate change contribute to the worsening of all of these phenomena, but they are most significant to the increase of sea levels, which threatens the communities that are located along Chennai's coast.

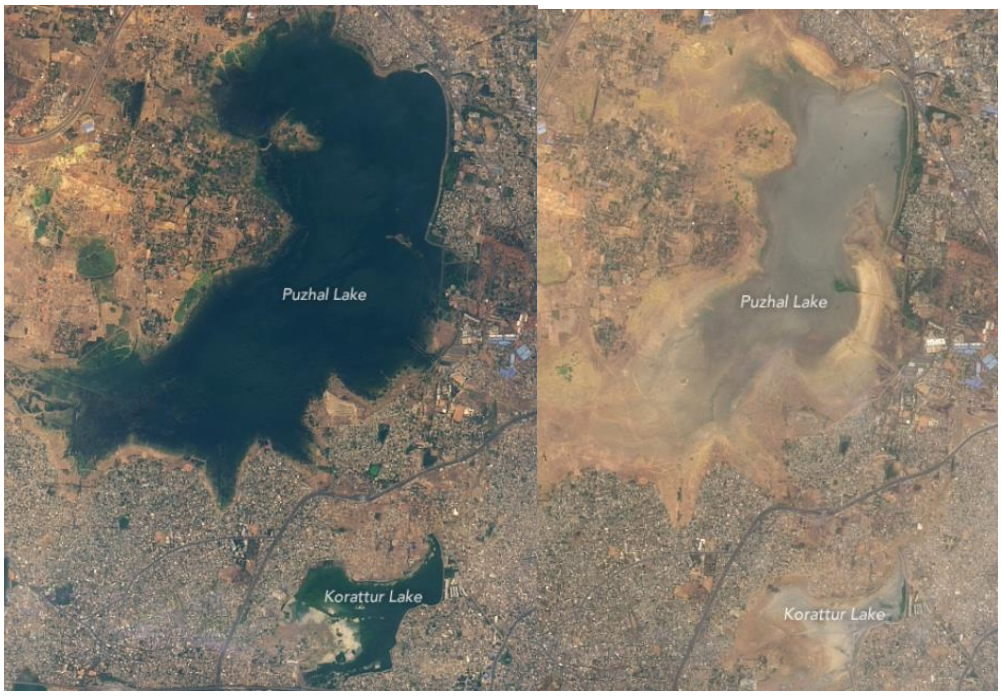
3.1 Chennai's Day Zero

Day zero scenarios are becoming a growing concern around the world as a result of the depletion of water supplies that is occurring in many cities as a direct result of droughts, overexploitation of groundwater, and other effects of climate change. The phrase rose to prominence after Cape Town, South Africa, became one of the first internationally renowned cities to come dangerously close to running out of drinking water. At that time, the city's taps were required to be turned off in order to prevent further depletion of its dam water resource, which had depleted to as low as 13.5 percent of its capacity.

Water scarcity is becoming increasingly prevalent in many cities across the world, but Chennai is a unique and rather paradoxical feature on that list because it simultaneously faces flooding from intense rainfall as well as increasing groundwater depletion. This places Chennai in a rather precarious position. Even though it was hit by severe flooding in 2015 and 2021, which was repeated in the middle of the excessive rainfall, a drought year in 2019 led to the city's water reserves being depleted as some of the main reservoirs ran out of water, which put its population at risk of running out of water. Even though it was hit by severe flooding in 2015, which was repeated in 2021, in the middle of the excessive rainfall, a drought year in 2019 led to the city's water reserves being Because three of the city's four main reservoirs ran dry entirely and the fourth one, Poondi, had less than one percent of its

[23] http://www.tnenvis.nic.in/WriteReadData/UserFiles/file/1_CHENNAI_TEMPERATURE.pdf

full capacity left, the city was compelled to search for water sources outside the city using tankers and water trains. The Puzhal lake was one of the primary reservoirs that ran dry, and the status of the lake can be seen in satellite images (See Map 7) taken in May 2018 (left) and June 2019 (right), which was taken after the lake had fully dried out.[24]



Map 7: Puzhal Lake on May 31, 2018 (Left), and June 19, 2019 (Right).

3.2 Chennai's Heat Vulnerability

The effects of heatwaves are one of the primary worries for the city when viewed through the perspective of climate change. Other primary problems include water shortages and water surpluses. The city continues to be at an extremely high risk of heat stress all year round on account of its coastal location and consistently high relative humidity. A study[25] comparing four metropolitan cities namely Kolkata, Chennai, Delhi and Mumbai indicated the total number of heatwave events is highest in Delhi, but the risks of extreme heat stress and dangerous-heat stroke events in the Chennai region during heat wave periods are higher than those experienced in other metropolitan cities due to high temperature with higher values of relative humidity. Figure 3 compares the number and duration of heatwaves in Kolkata, Chennai, Delhi, and Mumbai from 1990-2019. The study also compares the thermal discomfort levels and comparative heat stress for the four cities. Wherein Delhi has the highest number and longer duration for heatwaves, Chennai has the highest thermal discomfort and comparative heat stress among the four cities (See and Figure 3-3). This means that, even when there aren't heatwaves going on, there is always a significant chance of feeling quite uncomfortable in Chennai.

[24] https://ic-sd.org/wp-content/uploads/2020/11/Bhrigu-Kalia.pdf
[25] Priyankar K., Abhishek R., Anup U., Arun C., (2022) 'Analysis of heat stress and heat wave in the four metropolitan cities of India in recent period', Science of The Total Environment, Volume 818

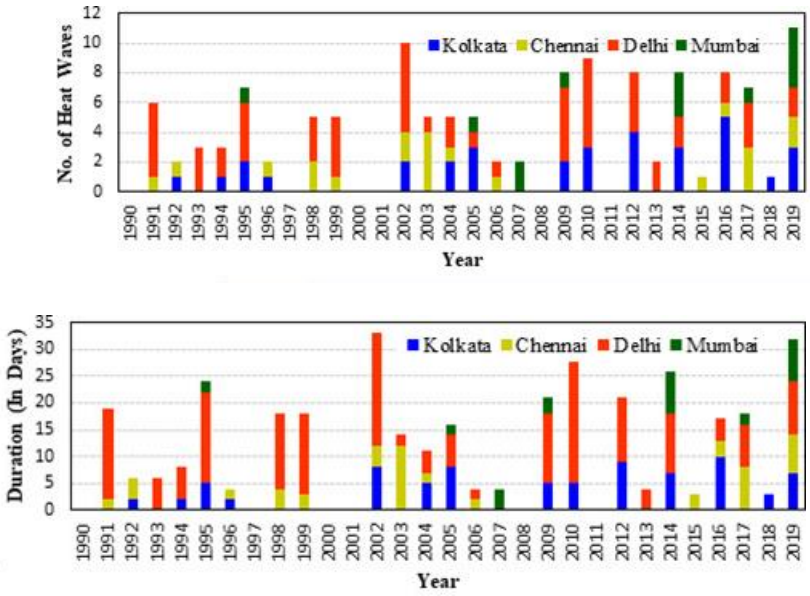


Figure 3-1: Number and duration of Heatwaves (1990-2019)

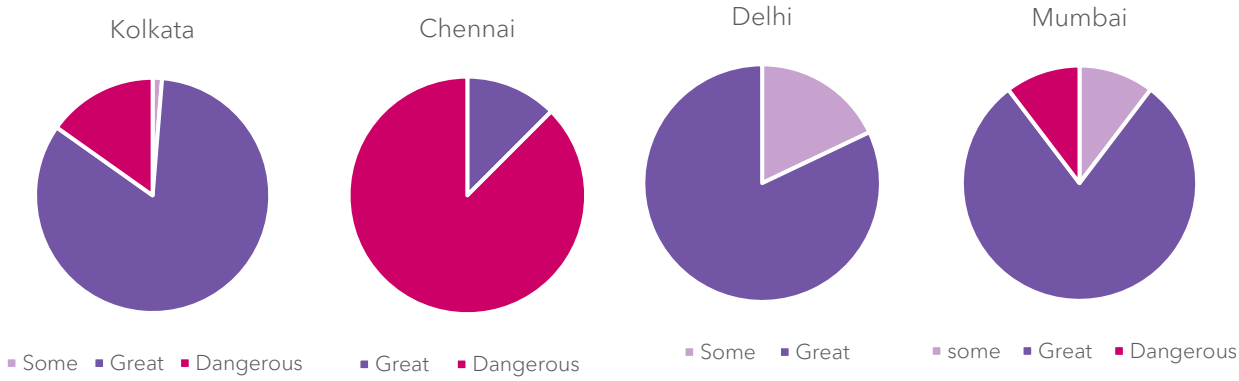


Figure 3-2: Thermal discomfort level for Indian cities

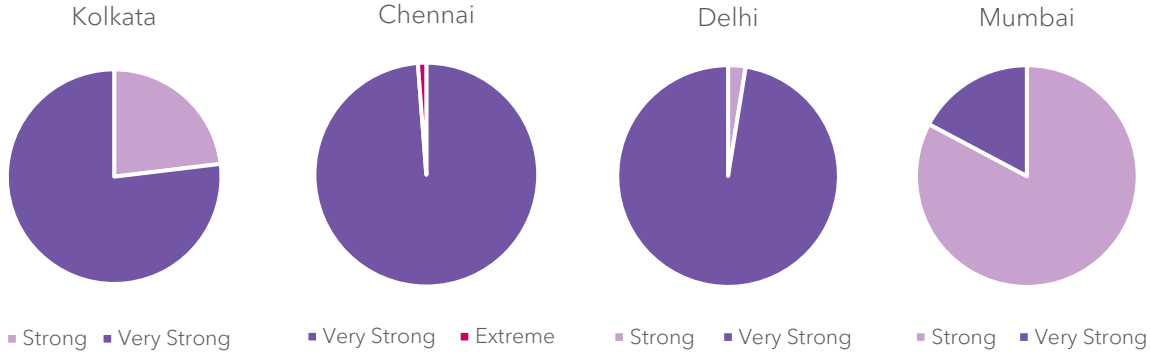
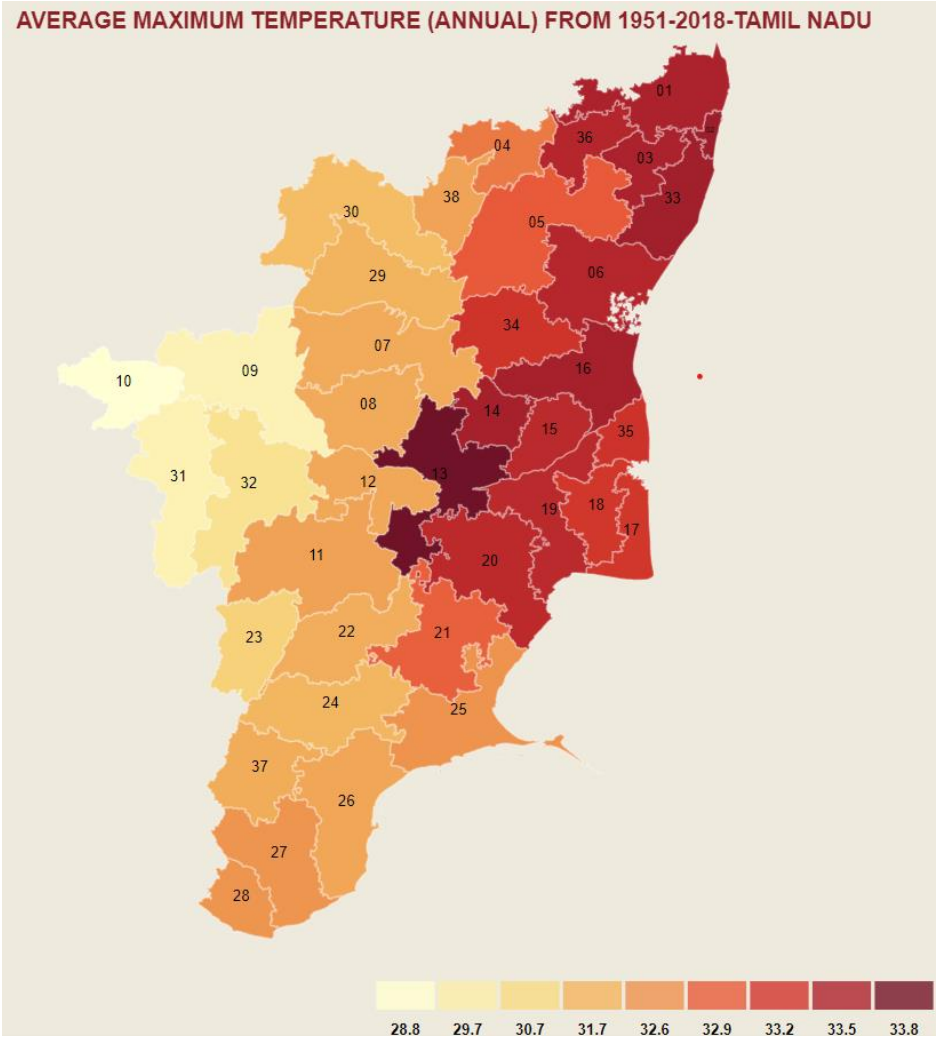


Figure 3-3: Comparative Heat Stress for Indian Cities

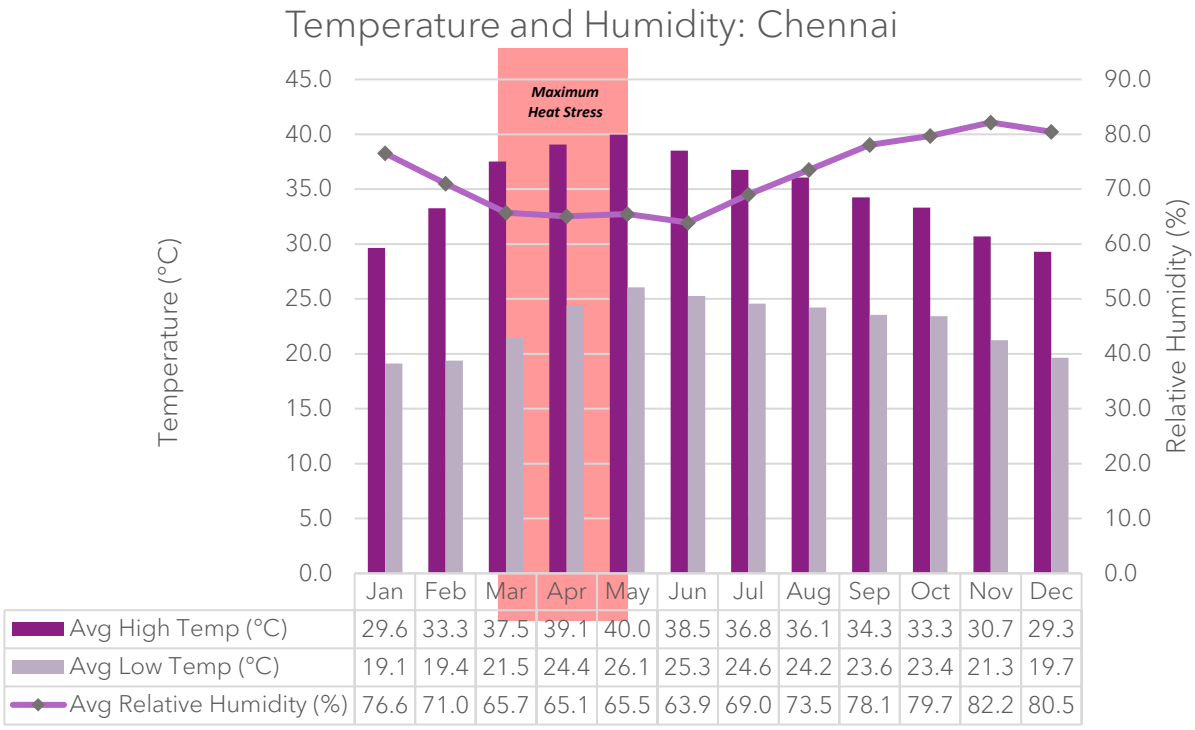
3.3 Temperature Patterns and Projections

Temperature variability across the state remains high with north-eastern districts including Chennai exhibiting some of the highest maximum average temperatures (See Map 8). While these trends are based on historical data (1951-2018), climate projections have been drawn from scientific literature against RCP scenarios. RCPs are greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. It supersedes Special Reports on Emission Scenarios (SRES) published in 2000. In general terms, RCP 8.5 represents a rampant increase in fossil fuel energy use by the end of the century, and no mitigation to control Carbon Dioxide concentrations. While RCP 4.5 represents a future where energy use increases; however, in this scenario the extra energy use is offset by a substantial growth in renewable energy resources by the year 2050. The regional climate change projection for the Tamil Nadu shows an increase in maximum temperature by 1.0 °C and 1.2 °C and minimum temperature by 1.2°C and 1.4°C under RCP 4.5 (low) and RCP 8.5 (high) for near term (2021-2050). Similarly, for long term (2071- 2100), shows an increase in maximum temperature by 1.7°C and 3.4°C and minimum temperature by 2.2°C and 3.8°C RCP 4.5 (low) and RCP 8.5 (high) respectively.



Map 8: District-wise temperature for Tamil Nadu; Source: climatevulnerability.in

Figure 6 shows the trend in monthly temperature and humidity for Chennai. The average maximum temperature is highest in the month of May (40%). This high temperature coupled with a high relative humidity would lead to heightened thermal discomfort and heat stress



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg High Temp (°C)	29.6	33.3	37.5	39.1	40.0	38.5	36.8	36.1	34.3	33.3	30.7	29.3
Avg Low Temp (°C)	19.1	19.4	21.5	24.4	26.1	25.3	24.6	24.2	23.6	23.4	21.3	19.7
Avg Relative Humidity (%)	76.6	71.0	65.7	65.1	65.5	63.9	69.0	73.5	78.1	79.7	82.2	80.5

Figure 3-4: Monthly Temperature and Humidity for Chennai (2011-2021); Source: MERRA-NASA

Chennai is witnessing a clear increasing trend of temperature during the past 60 years, and it has increased 1.2 °C during 1951- 2010[26]. The Intergovernmental Panel on Climate Change (IPCC) report has listed Chennai as among the cities that are at risk from climate change. The report predicted that the city could see a rise in wet-bulb temperatures to between 32-34 degree Celsius by mid-century. While the climate simulations over the Chennai Metropolitan Area under IPCC SRES A1B scenario shows predicted rise of temperature 2.4°C to 2.5°C by mid-century (2041-2070) and 3.3 °C to 3.6 °C increase towards the end of the century (2071-2098).

3.4 Rainfall Patterns and Projections

Rainfall across Tamil Nadu displays high variation with the average annual rainfall (1951 – 2018) in Chennai being 4th highest when compared with other districts (*See Figure 3-5*). The annual precipitation projections, shows increase by 4.4% and 6.7% for near term (2021 – 2050) and by 21% and 26% increase for long term (2071-2100) under RCP 4.5 and RCP 8.5 respectively.

[26] Jeganathan, A., Andimuthu, R. Temperature trends of Chennai City, India. *Theor Appl Climatol* 111, 417–425 (2013).

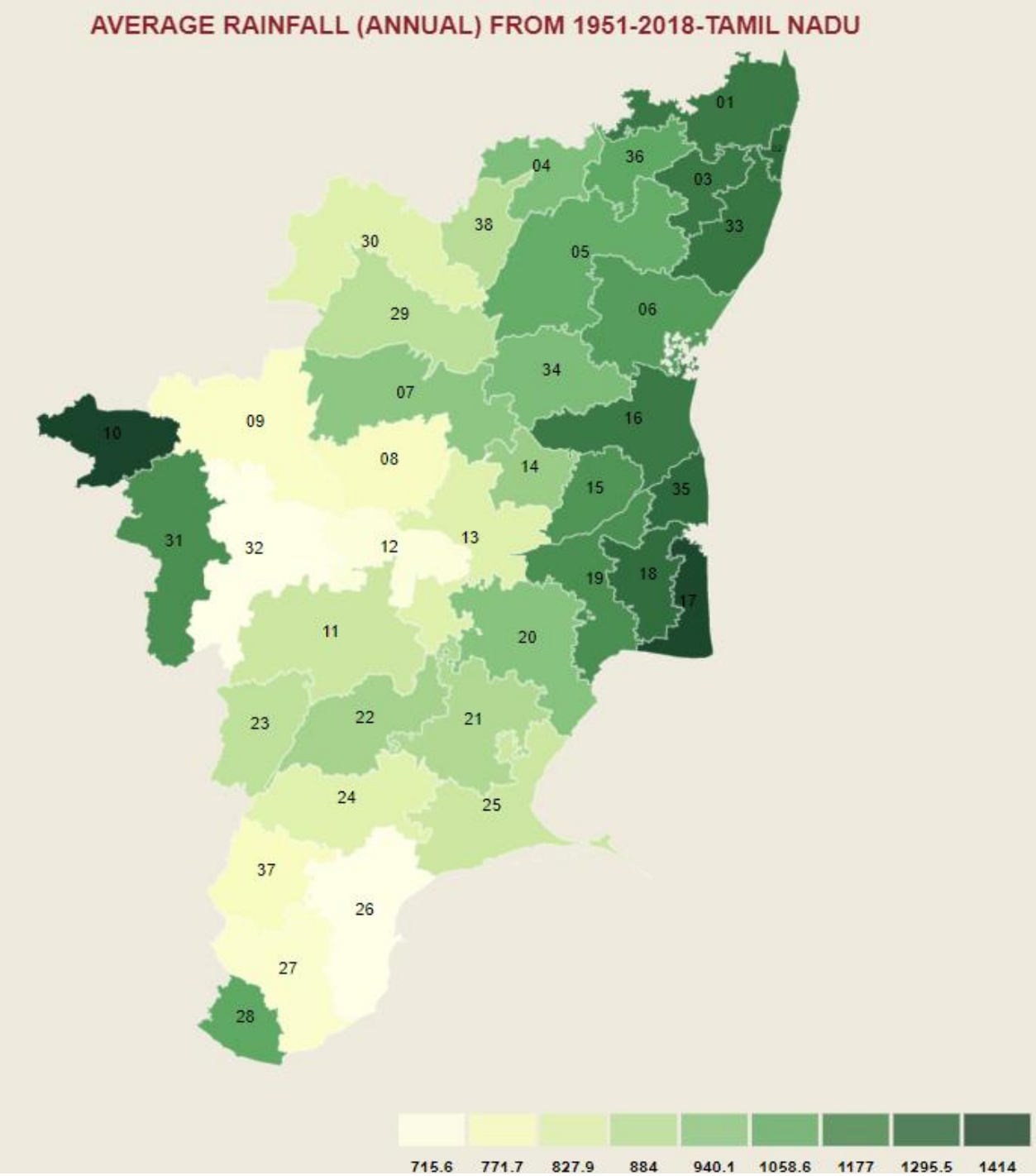


Figure 3-5 District wise average annual rainfall for Tamil Nadu; Source: climatevulnerability.in

Chennai experiences two monsoons annually, namely South-West from June to September and North-East monsoon from October to December. The average rainfall of South-West Monsoon is 459.20 mm. The North-East monsoon contributes most of the rainfall in the city with about an average rainfall of 770mm. The average rainfall of the city throughout the year is about 1,300 mm (See Figure 3-6). In 2015, the annual rainfall was recorded to be 2057.6 mm and for 2021 it was even higher, a total of 2259 mm. The highest yearly rainfall in the city has been recorded to be 2,570 mm in 2005. The formation of cyclones in the Bay of Bengal also greatly influences the city's climactic conditions.

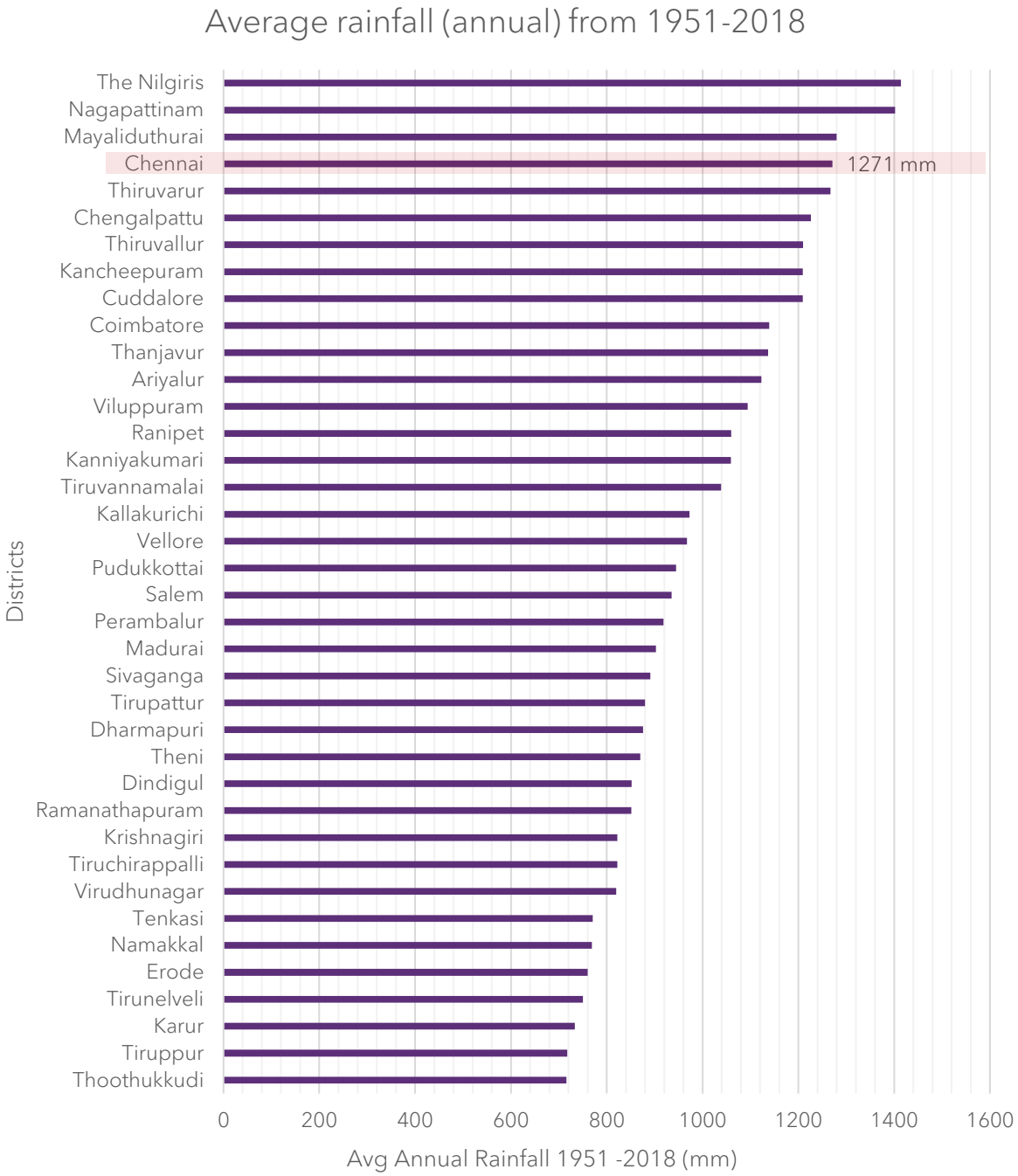


Figure 3-6: District Wise Average Annual Rainfall: Chennai; Source: climatevulnerability.in

The south-westerly winds are the ones that are most common in Chennai between the months of April and October, while the north-easterly winds are the ones that are most common throughout the other months of the year. From Figure 3-7, it can be seen that the city experiences the highest rainfall throughout the month of November, and as a direct result, the majority of its floods takes place during the months of November and December. The long-term study that was done on the trends of rainfall in Chennai (1813-2009) showed that there was an increase in the amount of rain that fell during the annual and monsoon seasons, but that there was only a marginal rise in the amount of rain that fell during the winter and after the monsoon season. According to the available evidence, the years 2006,

2007, 2008, 2010, 2015, and 2021 all witnessed many instances of devastating flooding in Chennai.

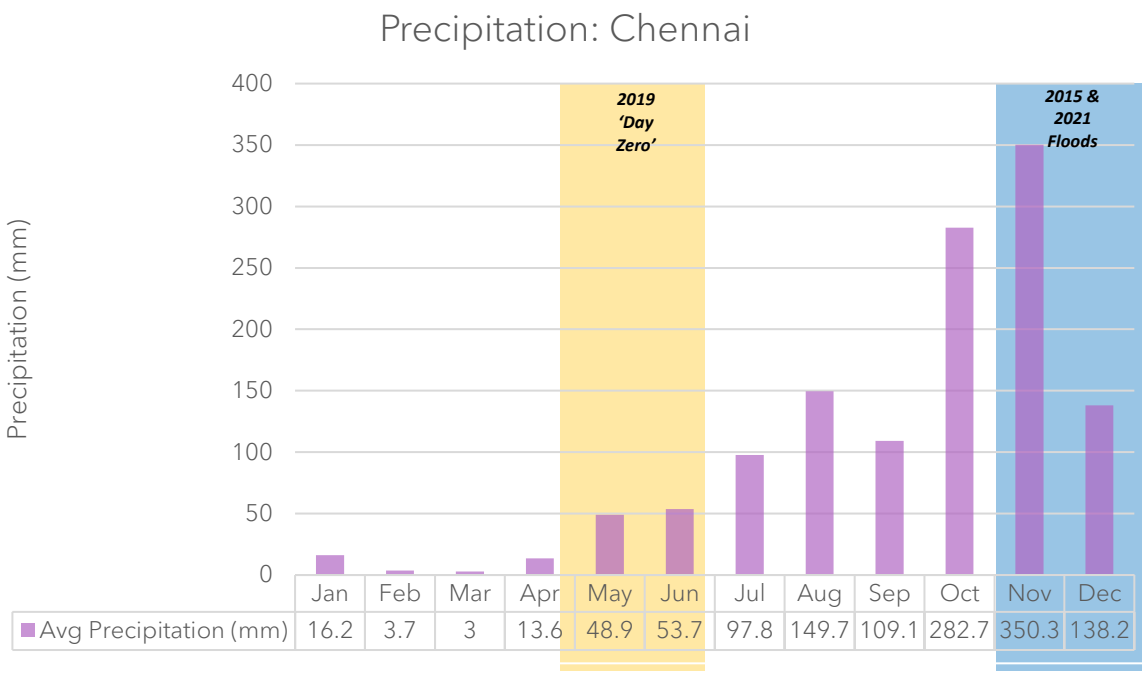


Figure 3-7: Monthly Precipitation for Chennai; Source: IMD

3.5 Case of 2015 and 2021

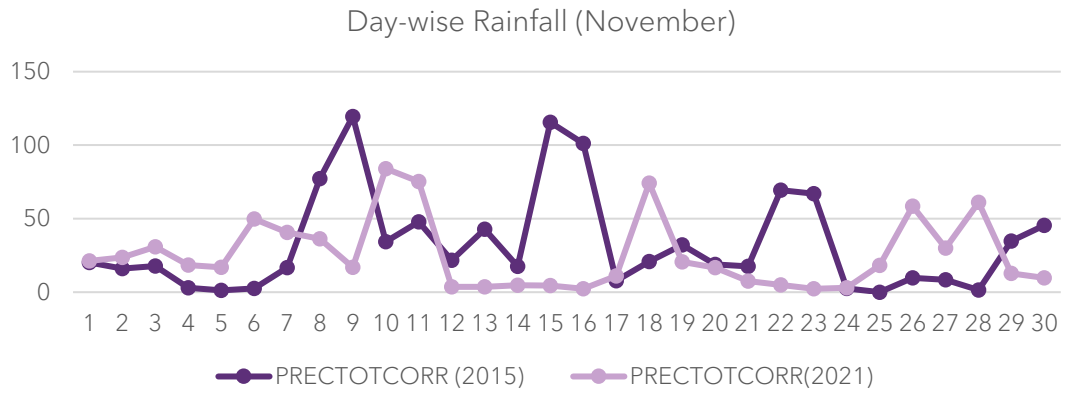


Figure 3-8: Daywise rainfall in Chennai 2015 vs 2021 (November); Source : MERRA-NASA

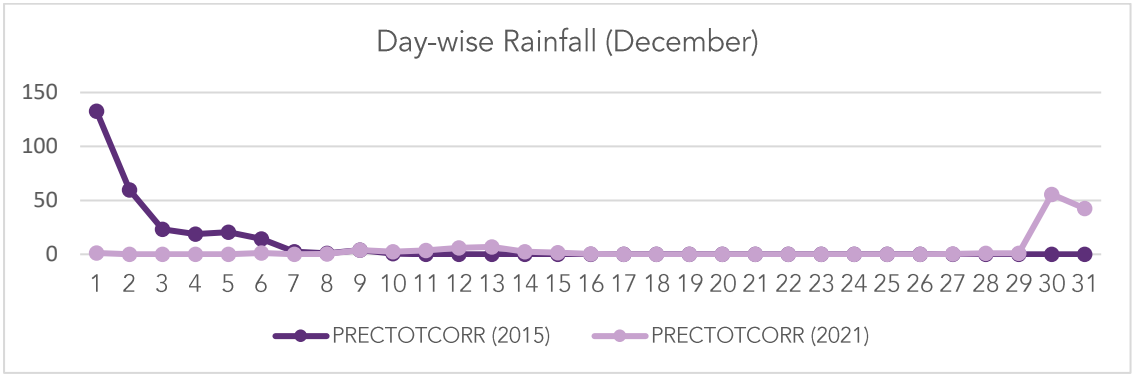


Figure 3-9: Daywise rainfall for Chennai 2015 vs 2021 (December); Source: MERRA- NASA

The North East monsoon commenced late in 2015. Three weather systems also formed over Bay of Bengal between 8th of November and 4th of December. These successive weather systems – a deep depression over Bay of Bengal and two low pressure areas over South west Bay of Bengal- contributed towards the heavy rainfall in short spans and subsequent flooding in the city (See Table 1). From Figure 3-8, it can be seen that in 2015, there were stark spikes in rainfall in 9th and 16th of November coinciding with the weather systems and on December 1st. According to the flood memorandum by Tamil Nadu government, Chennai district received 2.5 times its normal rainfall in 2015. Chennai recorded a rainfall of 922.9mm in the period from 1st to 18th October in 2015 which marks an 80% departure from the normal rainfall of 513.9mm. In 2015, the heavy rainfall also extended to the initial days of December.

Table 1: Rainfall data from 1st- 16th November 2015, Source: Flood memorandum 2015

Date	Rainfall recorded in (mm)	Weather Phenomenon
1/11/2015	16.33	
2/11/2015	4.20	
3/11/2015	9.03	
4/11/2015	22.96	
5/11/2015	4.94	
6/11/2015	10.52	
7/11/2015	10.42	
8/11/2015	29.45	Deep depression over Bay of Bengal
9/11/2015	42.63	Deep depression over Bay of Bengal
10/11/2015	5.37	Deep depression over Bay of Bengal
11/11/2015	10.01	
12/11/2015	19.00	Low Pressure area over South west Bay of Bengal
13/11/2015	7.35	Low Pressure area over South west Bay of Bengal
14/11/2015	11.87	Low Pressure area over South west Bay of Bengal
15/11/2015	42.49	Low Pressure area over South west Bay of Bengal
16/11/2015	6.51	Low Pressure area over South west Bay of Bengal

In terms of the trends over the years, 2021 was only the 6th worst year for Chennai in terms of the North-East monsoon and 3rd worst in terms of annual rainfall, with Chennai breaking the 1000 mm barrier for total annual rainfall in November 2021. The annual rainfall in Chennai for 2021 overtakes that of 2015 by 5%. However, the rainfall during the northeast monsoon season was lesser than in 2015(see Figure 3-8). For Tamil Nadu too, it was the 4th

worst year when it comes to the North-East monsoon cycle. This underlines the fact that while the overall volume of rainfall was significant, it was not the worst Chennai had seen. The problems primarily arose due to the short bursts of extreme rainfall that characterized this monsoon cycle. In total, between November 7 and 12, Chennai received almost five and a half times more rainfall than the normal levels with a total of 46 cm of rainfall against the normal average of 8 cm. This is a consequence of the various weather depressions and low-pressure areas in the seas which have made their landfall in the Tamil Nadu-Andhra region.

There are a series of weather phenomena at play in these rains. The La Nina winds are generally perceived to be unfavourable for northeast monsoons in Tamil Nadu, but the presence of other circumstances overrode the negative effect of La Nina to create surplus rain. This includes the Madden-Julian Oscillation (MJO) and inter-tropical convergence of rain-carrying winds over the state, which are touted to be the reasons behind the excessive rainfall in Chennai. Low-pressure systems get created as a consequence of the MJO and other related factors, and these low pressures made their landfall in Chennai and surrounding areas, leading to massive rains. Even towards end of December, Chennai was lashed with heavy rainfall as both the meteorological department and the weather watchers failed to predict the intensity of the rains.

Table 2:Warnings Issued by IMD in November 2021

Date	Rainfall (mm)	Warning Issued	Details of Warnings Issued	Weather Phenomenon
01/11/2021	30.8	**Orange**	Regional Met Centre and IMD gave Orange Alert (Heavy Rainfall) till 4th November	Northeast Monsoon
02/11/2021	33.1	**Orange**		Northeast Monsoon
03/11/2021	21.9	**Orange**		Northeast Monsoon
04/11/2021	4.7	**Orange**		
05/11/2021	15.4	**Orange**	NDMA Weather Warning for Heavy to Very Heavy Rainfall till 11th	
06/11/2021	126.5	**Orange**		
07/11/2021	67.8	**Red**	IMD issues Red Warning for Chennai as heavy rains pour down	Low Pressure Area over Southeast Bay of Bengal
08/11/2021	45.5	**Red**	IMD Red Alert for 10-12 November	Low Pressure Area over Southeast Bay of Bengal
09/11/2021	18.8	**None**	IMD warning for Heavy Rainfalls till 11th November	Low Pressure Area over Southeast Bay of Bengal
10/11/2021	124.4	**Red**		Low Pressure Area over Southeast Bay of Bengal
11/11/2021	58.2	**Red**		Low Pressure Area over Southeast Bay of Bengal

17/11/2021	22.1	**Red**	IMD issued Red alert for Chennai and neighbouring districts	Low Pressure System in North Andaman Sea moving Northward, joining Southeastern Bay of Bengal, and making landfall in Andhra-TN region
18/11/2021	2.3	**Red**		Low Pressure System in North Andaman Sea moving Northward, joining Southeastern Bay of Bengal, and making landfall in Andhra-TN region
19/11/2021	12	**Red**		Low Pressure System in North Andaman Sea moving Northward, joining Southeastern Bay of Bengal, and making landfall in Andhra-TN region
26/11/2021		**Yellow**	IMD Regional Centre issued Yellow Warning for 26-30 November	

On 31st December 2021, many parts such as Nungambakkam, Mambalam, and MRC received over 100 mm of rainfall in less than 24 hours while areas like T Nagar, Alwarpet, and Mylapore received over 200 mm of rainfall.[27] The regional Meteorological centre explained that they expected heavy rains from December 31st originally but changing of certain climactic factors pushed forward the heavy rainfall.[28]

The overall north-east monsoon rainfall has become record breaking for both Tamil Nadu and Chennai with the trends of more intense and heavier monsoons seemingly continuing to get worse year-on-year. The total excess rainfall from average was almost 80%, representing an almost doubling of the normal average rainfall from the North-East monsoon as the last three months of 2021 brought with it repeated flooding and intense bouts of rain.[29] The key feature of the 2021 northeast monsoon has also been very heavy and intense showers rather than sustained low intensity showers which have been harder to predict and have lashed the city unexpectedly at times.[30]

Chennai and Tamil Nadu at large have a thriving community of citizen 'weather watchers' or 'weather bloggers'. This community of weather watchers post regular forecasts and updates on social media platforms like Twitter and Facebook, by analysing weather models, cyclonic patterns, wind charts, and publicly available satellite imagery. They use visual tools to break down information by recapping the weather phenomenon that characterised the previous day, what the weather presently looks like, and the different predictions coming from different models for the next day. They analyse various models to get the different

[27] https://www.thenewsminute.com/article/chennai-sees-heavy-rains-imd-issues-warning-dec-31-and-jan-1-159321
[28] https://www.hindustantimes.com/india-news/record-rain-batters-chennai-more-predicted-for-four-districts-in-tamil-nadu-101640972568982.html
[29] https://www.hindustantimes.com/india-news/chennai-logs-wettest-november-with-record-rainfall-of-882-4-mm-101638124461735.html
[30] https://indianexpress.com/article/cities/chennai/chennai-tamil-nadu-rains-live-updates-7640287/

results and often advise people to be braced for the worst possible outcome to ensure maximum preparedness. The underneath figures show some of the rainfall pattern trends as analysed by one of Chennai's weather watchers.

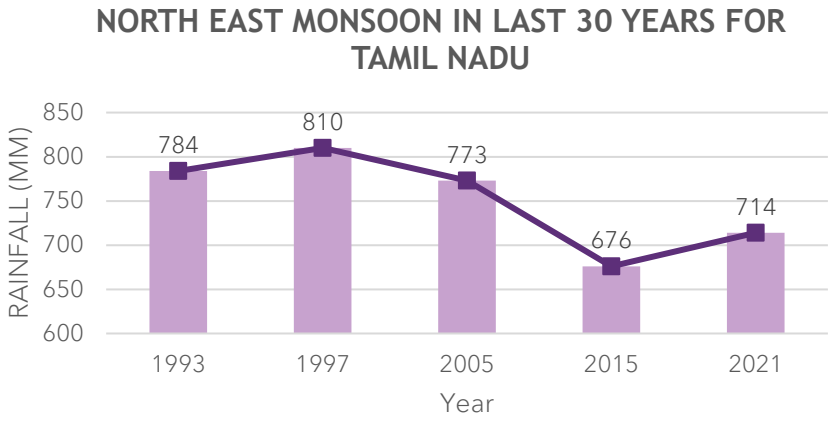


Figure 3-10: Comparative highest NE Monsoon rainfall for Tamil Nadu; Source: Pradeep John (weather blogger)

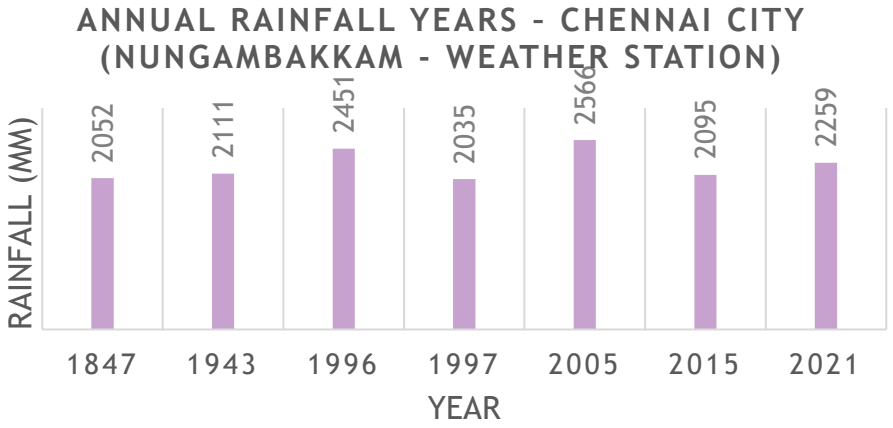


Figure 3-11: Comparative highest total annual rainfall for Chennai; Source: Pradeep John (weather blogger)

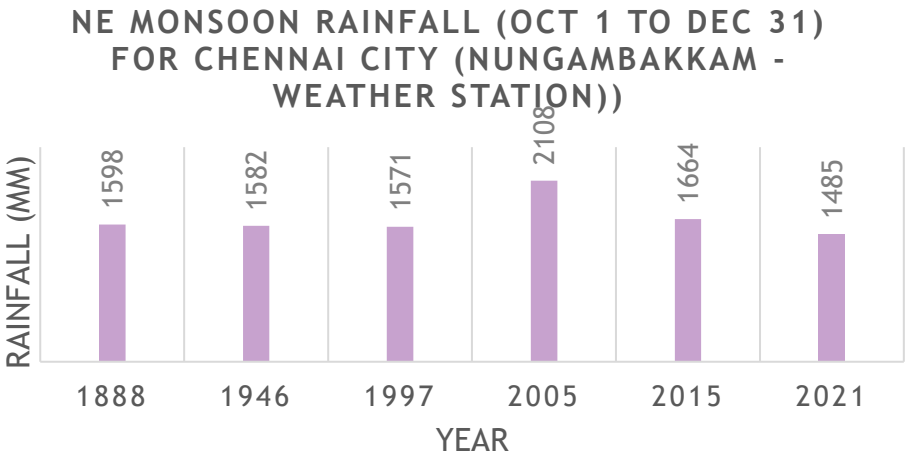


Figure 3-12: Comparative highest total NE Monsoon rainfall for Chennai; Source: Pradeep John (weather blogger)

Figure 3-10 indicates that for Tamil Nadu, the amount of rainfall received in 2021 was higher than the rainfall received in 2015. But for Chennai however the case is reversed (see Figure 3-12). While the November rains have been consistently intense, the extreme rainfall event towards the end of December was one of the most intense bouts of rainfall experienced in Chennai. The unpredictability of the final bout of extreme rainfall was due to a variety of factors including rare weather disturbances which some climate scientists described as 'freak events' the likes of which have not been seen in many decades. The short bursts of rain also made it harder to predict as climate models with limited predictive power can attest to larger trends of weather much better than short aberrations and bursts of intense rain.

3.6 Sea Level Rise

Projection of climate change-induced sea-level rise are based on the assessment presented in the IPCC Sixth Assessment Report relative to a 1995-2014 baseline. Based on IPCC, a future characterized by SSP2 4.5[31], which is a hopeful target, indicates a 0.07 metre rise by 2030 and 0.45 metre rise by 2100 for Chennai and its surrounding areas. As a consequence, it is highly likely that some part of the city's coastal areas will be submerged, with some estimating that the coastline will shift 100 metres inland. This would significantly impact the communities living in these coastal areas, requiring them to not just completely shift inland from the coastal areas, but also to find alternate means of livelihoods as they often depend on fishing and other marine activity. Consequently, the government will have to ensure not just resettlement but also rehabilitation of income and livelihoods.

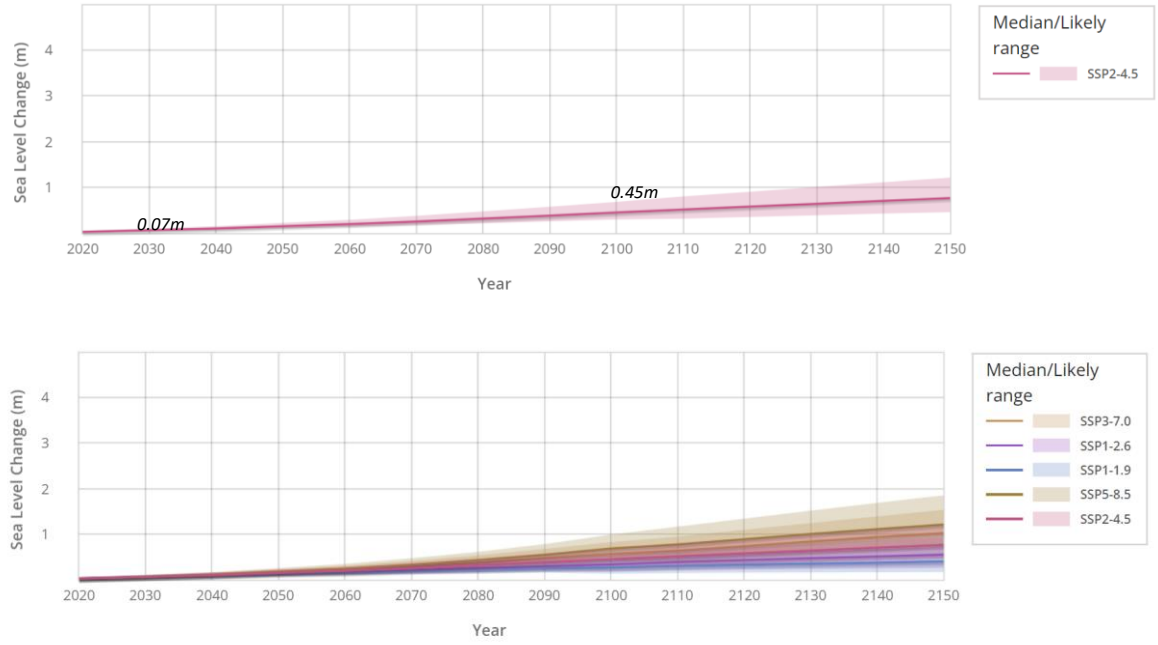


Figure 3-13: Sea Level Rise Projections for Chennai; Source: IPCC

[31] https://en.wikipedia.org/wiki/Shared_Socioeconomic_Pathways

We can see that Chennai's challenges are myriad and would require holistic disaster risk management to ensure that people's lives are not severely impacted. It faces a combination of droughts, flooding, and heat waves that necessitates making policy that addresses overall disaster resilience rather than just one aspect. For example, it would be easy to try addressing excess release of water from the city's reservoirs and tanks by maintaining a low level in them, but in a year of drought, that would spell catastrophe for the city. Consequently, balanced policymaking is needed such as constant monitoring of water levels and gradual release of water in case of impending rainfall, which addresses multiple threats simultaneously.

3.7 Pollution

Water pollution is a major challenge for the city. The usability of water reduces due to issues like salt-water intrusion, affluent discharge from industries, and other sewage. The industries in and around the city is a major factor for contamination of water bodies. Water samples from Cooum and Adyar rivers have exhibited high levels of heavy metals and other pollutants[32]. According to a study by National Centre for Coastal Research (NCCR), the Ennore estuary has shown high contamination of metals like cadmium and lead that are detrimental to health. Further Kosathalayar river, which connects with Ennore creek and Pulicat lake also shows a high presence of micro plastics which can further act as heavy metal carriers, as indicated in a 2020 study. Many of the tanks in the city also shows a high percentage of TDS, which renders the water unfit for consumption[33].

From the focus group discussions held as part of this study, it was also seen that the open drains were used for sewage purposes. This meant that all sites witnessed flooding with a mixture of rainwater and sewage water, which was stagnated in the streets. Further, this also polluted stored drinking water, forcing people to resort to using canned and bottled water for nearly a month.

Figure 3-14: An open sewage in Manali, Chennai. (Source: FGD)

[32] https://timesofindia.indiatimes.com/city/chennai/adyar-cooum-waters-still-polluted/articleshow/88654827.cms

[33] https://www.newindianexpress.com/cities/chennai/2019/jun/10/3-of-13-lakes-identified-to-fetch-drinking-water-too-polluted-1988167.html

In addition, with the over extraction of ground water, there is an increase in salt water intrusion into the aquifers thus dwindling the sources of water in the city. According to research by Anna university, the excessive extraction of ground water and increased constructions resulted in an increased concentration of total dissolved solids (TDS) in the ground water. With the climate change and sea level rise, more aquifers would face the risk of salt water intrusion, thus creating a pressure on usable water sources.

Chennai was considered a non attainment city under the National clean air programme. A non attainment city is where the air quality does meet the national ambient air quality standards. When compared to the other major non attainment cities in the country, Chennai has moderate air pollution levels. PM 2.5 and PM 10 are suspended solids in air, higher concentrations of which can be detrimental to human health. According to an analysis under the national clean air program, Chennai was the only non attainable city among the surveyed cities, which had permissible levels of PM2.5 and PM10[34].

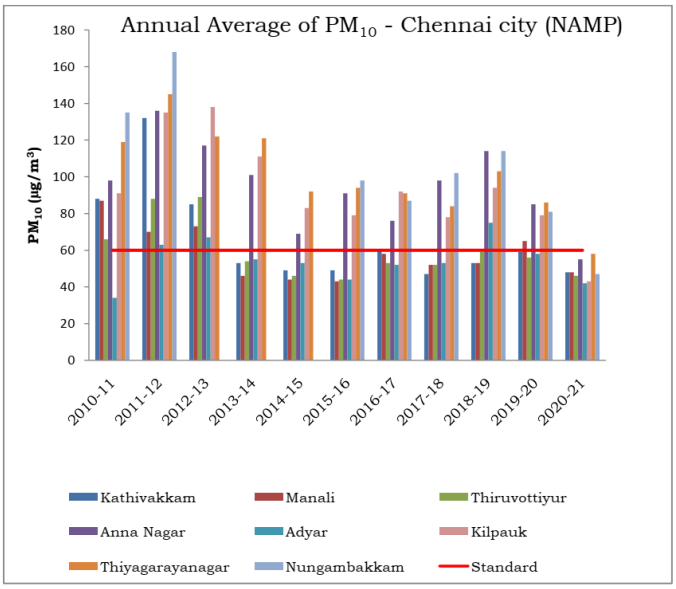


Figure 3-15 Annual average PM10 concentration in Chennai (Source: Action plan for control of air pollution in million plus city of Tamil Nadu, TNPCB)

The above figure shows the PM10 readings in the different air quality monitoring stations in the city. From 2017, the PM 10 levels in the city has remained in the satisfactory category. It can also be seen that, the concentrations show a drop in the years 2020-2021, coinciding with the initial periods of the pandemic.

[34] https://www.thehindu.com/news/national/tamil-nadu/chennai-scores-high-as-pollution-stays-within-permissible-limits-ncap-tracker/article65666644.ece

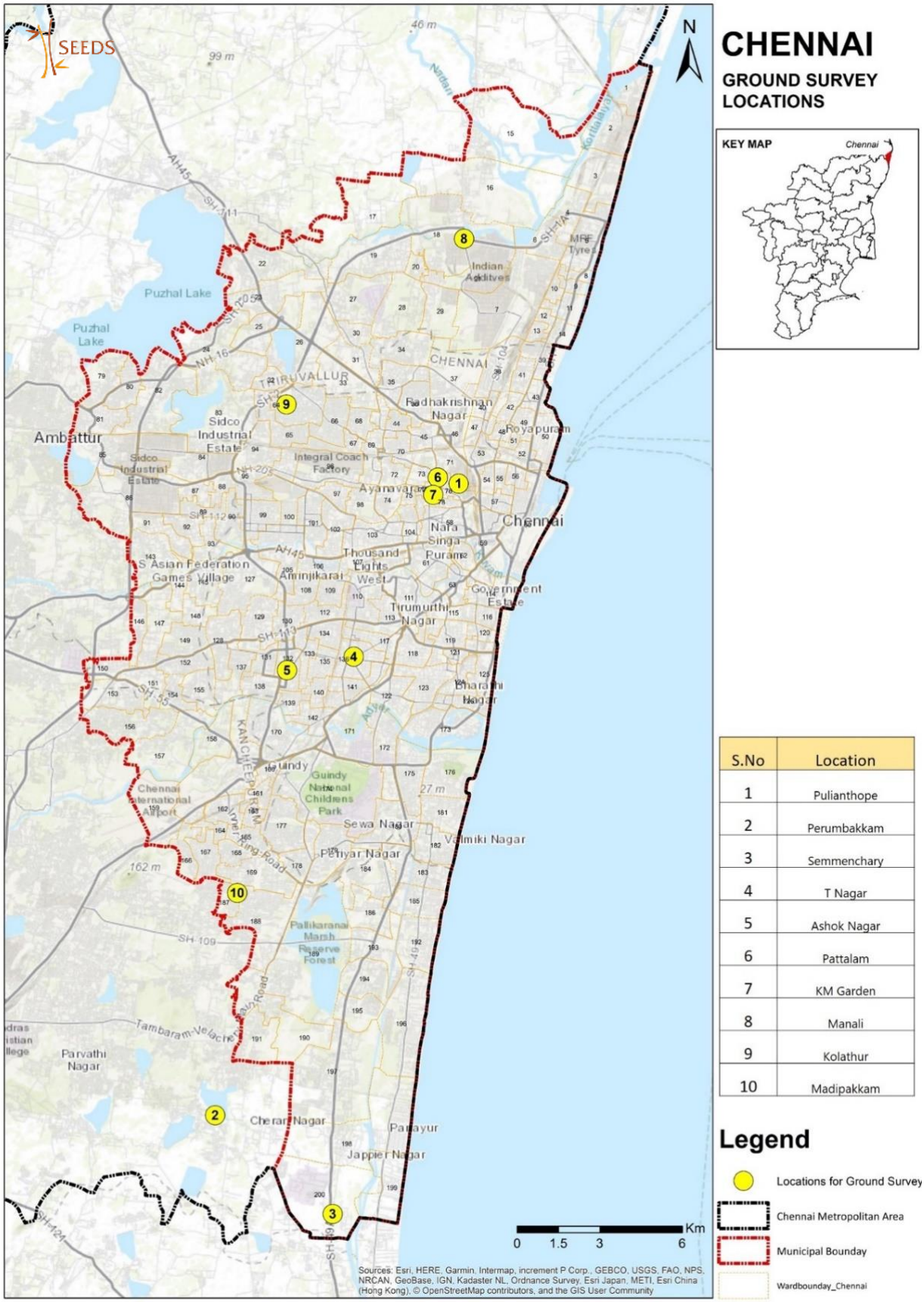
4 Empirical Observations: 2015 vs 2021

One of the key priorities of this study was to substantiate the challenges faced by people due to climate change and flooding and supplement a theoretical understanding of Chennai's policy needs with narratives from the ground to pinpoint the many improvements that have been made in the city since the 2015 floods, as well as areas where further inroads need to be made to keep Chennai citizens safe during monsoons and protect them from climate change impacts. To that end, we conducted a primary research study comprising of household surveys, interviews, focus group discussions, and transect walks to understand people's experiences of floods from a variety of perspectives.

The primary research was conducted in 10 locations spread across the city (See Map 9), to capture the lived experiences of the communities that have been impacted the most through the flooding events. The main objective was to capture the difference between the impacts from 2015 and 2021 floods in order to highlight the improvements and gaps which persist in responding to such events.

- Site selection was done based on the available studies, research reports and media reports during 2015 and 2021 floods
- In each site, the localities which are most vulnerable and affected worst were identified through transect walks by the survey team with the support of the local population
- 25 in-depth household surveys were conducted in each locality, the houses were selected randomly on basis of availability of the inhabitants
- A pilot survey was conducted in the Manali area in north Madras and then based on the responses and feedback; a few modifications were made in the final household schedule.
- For generating qualitative information Focus Group Discussions (FGD) were conducted in all sites. These were conducted after the survey was completed in the site, ensuring that the survey team was familiarized with the site and could appropriately facilitate the discussion.
- Each FGD covered 10-12 local residents with a minimum of 30% participants being women.
- Data analysis of the survey and editing was done using the Statistical Package for the Social Sciences (SPSS) to create frequency tables and also meaningful cross tables and charts to use in the report.

Figure 4-1 Images from Focus group discussion



S.No	Location
1	Pulianthope
2	Perumbakkam
3	Semmenchary
4	T Nagar
5	Ashok Nagar
6	Pattalam
7	KM Garden
8	Manali
9	Kolathur
10	Madipakkam

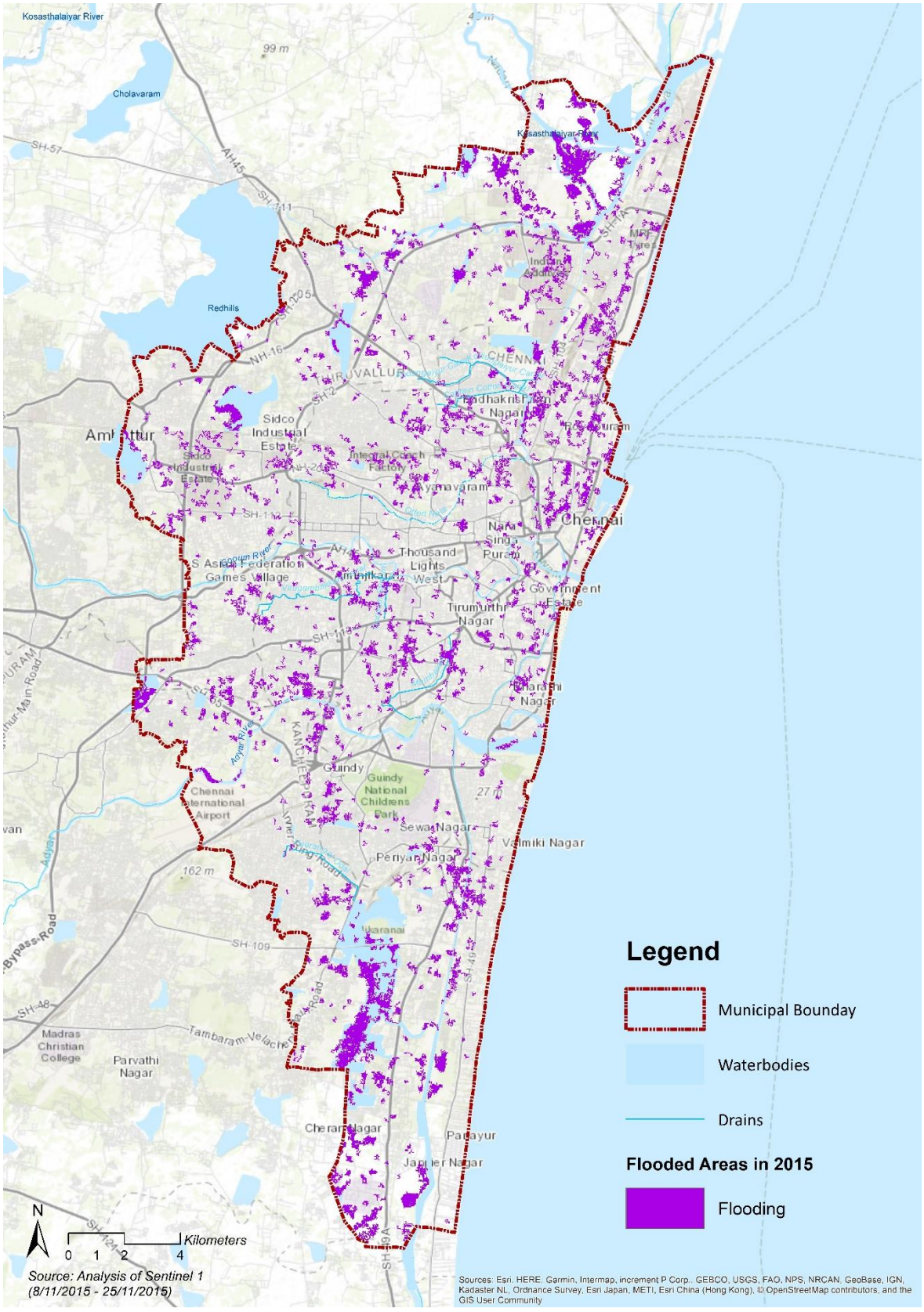
Legend

- Locations for Ground Survey
- Chennai Metropolitan Area
- Municipal Bounday
- Wardbounday_Chennai

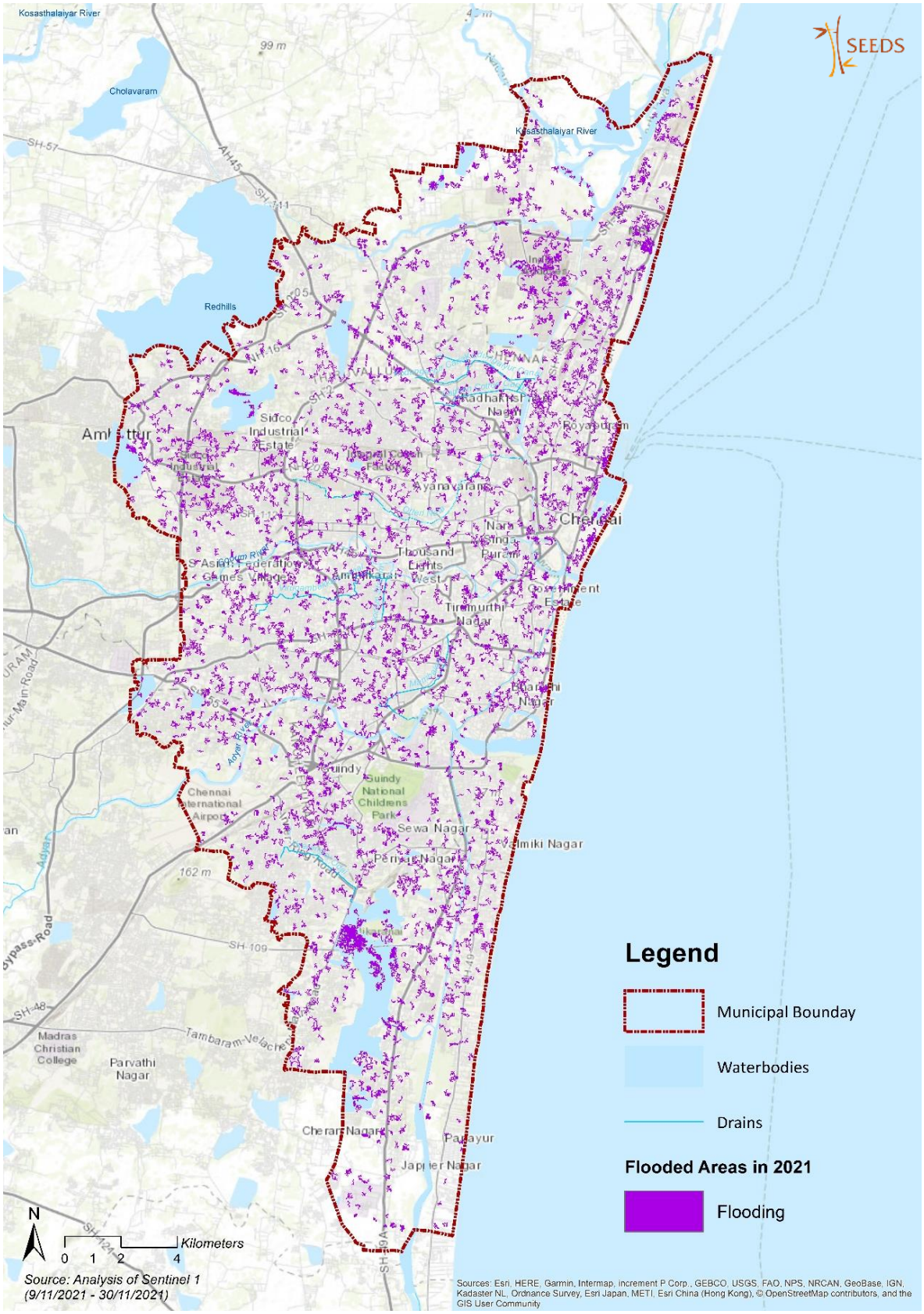
Map 9: Primary Survey Locations in Chennai

4.1 Comparing 2015 and 2021 floods

	2015	2021
Lives lost	49	0
Cause of flooding	Sudden bouts of rain coupled with unregulated water release from reservoirs	Sudden bouts of rain
Rainfall (northeast monsoon)	1664mm	1485mm
Early warning and weather watching	Number of weather stations were less (three weather stations)	• Number of weather stations have increased to 14 but still not enough to cater to the needs of the city.
Reservoir and drainage management	Unregulated release of water from upstream water bodies.	• Water bodies were better managed with a phased reduction of water level beginning in July to allow for more water capacity during rains • Desilting of drains carried out.
Government interventions (relief and response)	• Restoring services took almost a month	• Successful last mile delivery of relief materials • Disrupted services restored faster
Community preparedness	Majority of population did not receive warnings and were caught off guard. More people were in need of relief	People were more prepared. Comparatively more people received alerts. Many people also evacuated before the situation worsened.



Map 10:Flooded Areas in 2015; Source: Sentinel 1 satellite data



Map 11: Flooded Areas in 2021; Source: Sentinel 1 satellite data

4.2 Early Warning Systems

Weather tracking and warning systems remain a critical challenge even after the perils faced in 2015 when delayed warnings meant people could not protect themselves or their property from damage due to rainfall. One of the challenges of the 2021 monsoons were that the weather systems failed again, and people did not get prior intimation for the first rains. The prolonged period of repeated heavy rains meant that people were better prepared for later bursts, but for the first set of rains, the early warning systems had failed primarily as a consequence of weather prediction systems collapsing. Two out of the three main radars were dysfunctional at the time of the first showers which reduced community resilience and the community's ability to prepare for the rains[35]. The state authorities and the people were largely caught out by the lack of accurate weather predictions. The NDMA guidelines post 2015 flood had highlighted the need to set up one automatic weather station for every 4 sq.km, which yet needs to implemented completely. Out of the 100 weather stations required, only 14 have been setup so far.

Televisions remain the main source of weather information for people, as they tuned to news channels for any updates of the weather during monsoons. This comes with the downside of being completely cut off from their primary source of information in case of TV line breaks or electricity outages. Consequently, radio and loudspeaker messaging are still considered crucial for delivering information in the most vulnerable areas of Chennai.

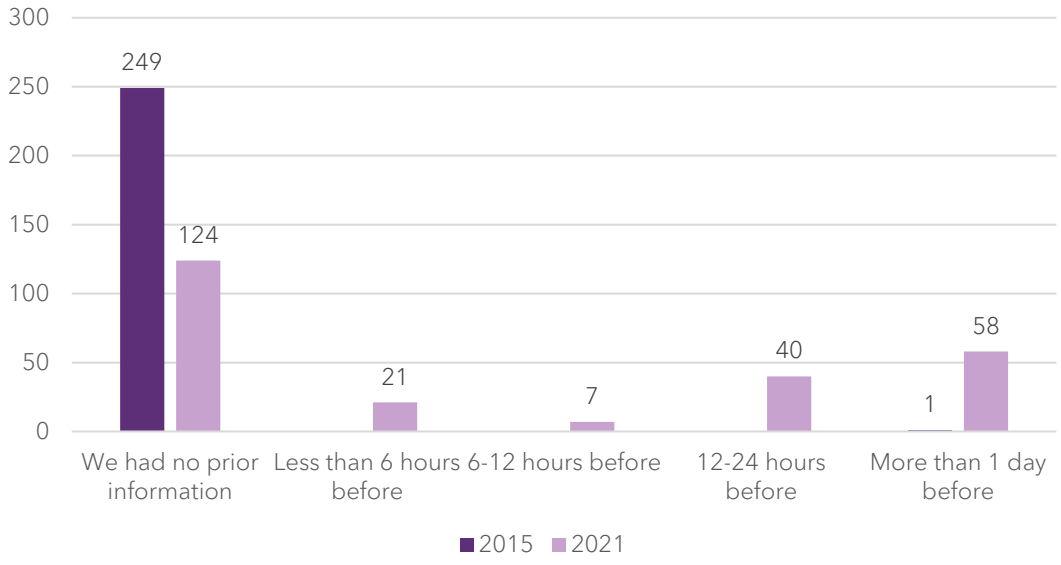


Figure 4-2: Before the First Floods, when did you know that Heavy Rainfall was going to occur (Source: Ground survey)

People were more informed about the heavy rainfall in 2021 when compared to 2015. But still only a few said that they received the warnings a day prior (see Figure 4-2). Social media played a huge role in allowing people to be prepared for the floods in 2021 as a combination of weather watchers and speculative warnings helped people be aware and

[35] https://www.thenewsminute.com/article/broken-radars-and-conflicting-weather-reports-added-chennai-s-flood-chaos-157416

ready for any disaster. The challenge with using social media to spread information is that smartphones are often primarily accessed by male members of the family and the information dissemination often does not reach the women. Consequently, traditional warning systems need to continue being strengthened, and more active messaging and warnings need to be incorporated such that the systems are as prompt in delivering messages as social media usually is but continue reaching the masses.

The number of people who got no weather intimation has drastically reduced from 2015 but is still pretty high with 1 in 2 people not getting any information. Both at the level of creating warnings through better weather tracking, and disseminating them through better delivery systems, there is a lot to be desired when it comes to a comprehensive approach towards early warnings.

4.3 Impact of Floods

People were much better prepared compared to the 2015 floods, managing to avoid some of the more severe losses of lives, property, and other assets. This was a result of a combination of several factors: people were more prepared for such events having experienced the horrors and pains of 2015, the social media channels gave some degree of early information to people, and the rain came down in heavy bursts with some gaps in between which allowed citizens to regroup resources and prepare for the next bout. The intensity of rainfall was often higher than it was in 2015 but the persistence and duration was lesser giving time for people to save whatever they could.

Residential areas were flooded heavily with some affluent ones deploying pumps whereas others lost their dwellings. Figure 4-3 compares the level of flooding experienced by the respondents in the year 2015 and 2021. The water stagnation levels across the two years reflect this as many more survey respondents reported high levels of submergence in the streets and houses in 2015 compared to 2021. Ankle level water inundation was much more common in 2021 which was enough to cause disruption of lives but not cause widespread damage.

Marginal improvements in drainage systems and short bursts of rains also meant that the flooding duration was shorter in 2021 as the water got time to clear off. Figure 4-4 shows the duration for which there was water stagnation around the respondents houses in 2015 and 2021.The duration of water stagnation was much longer for 2015 as 37.6% people reported it taking longer than a week for water to recede with a further 25.2% saying it took 4-5 days. On the other hand, most people responded that water receded in 2-3 days in the latest 2021 floods.

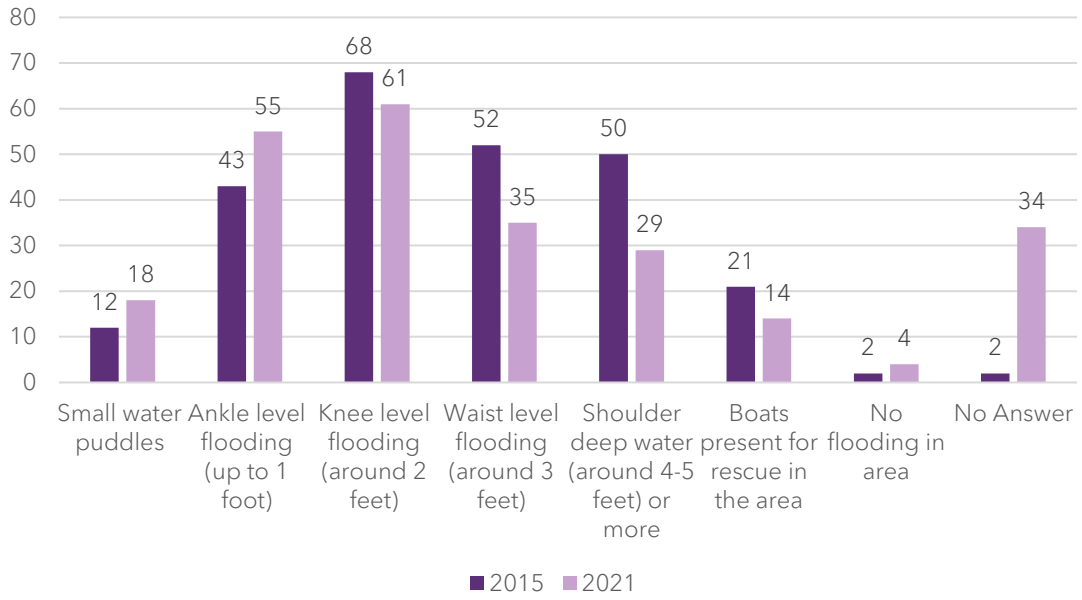


Figure 4-3: Level of Flooding experienced (Source: Ground survey)

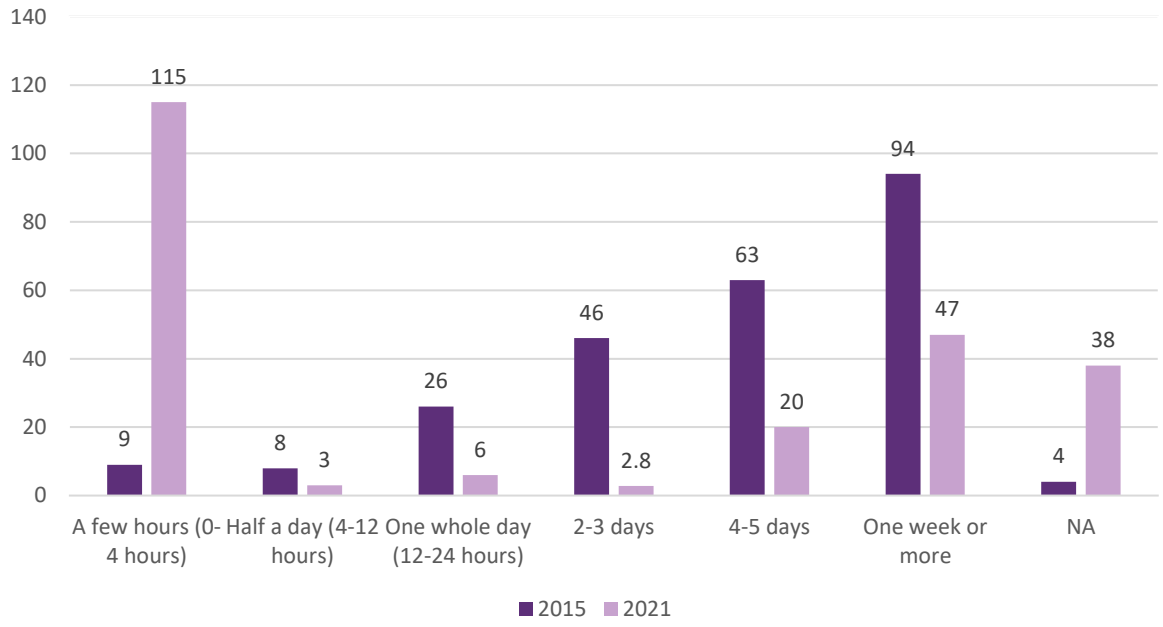


Figure 4-4: Duration of water stagnation experienced (Source: Ground survey)

Out of the 10 survey locations, more than 40% respondents from Pattalam and Kolathur said that they experienced flooding for more than a week in 2015. The corresponding number for other areas is also quite high with more than 20% respondents having experienced submergence for a week or more. On the other hand, in 2021, there are only a few areas that experience significant incidence of more than a week of water stagnation: T Nagar, Perumbakkam, and KM Garden. Most other areas report relatively quick turnover times as the water stagnation lasted either for a day, or less than 3 days. Puliyanthope is the other location which witnessed long duration of water stagnation with more than 60% households having water stagnated for 4-5 days.

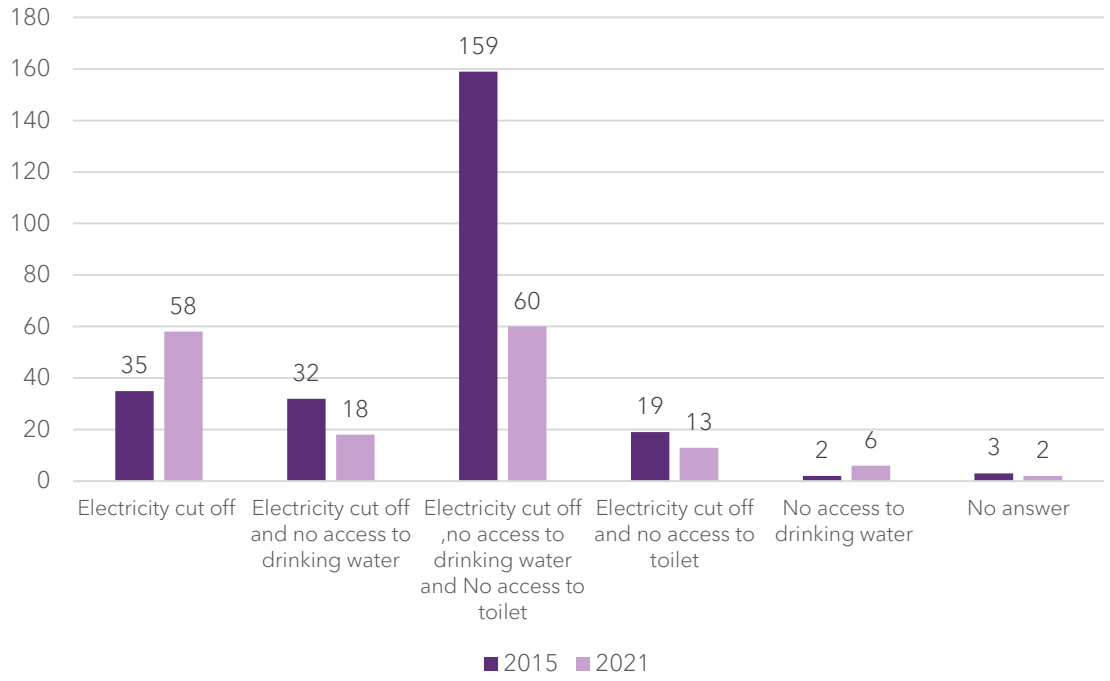


Figure 4-5: Services Disrupted during floods (Source: Ground survey)

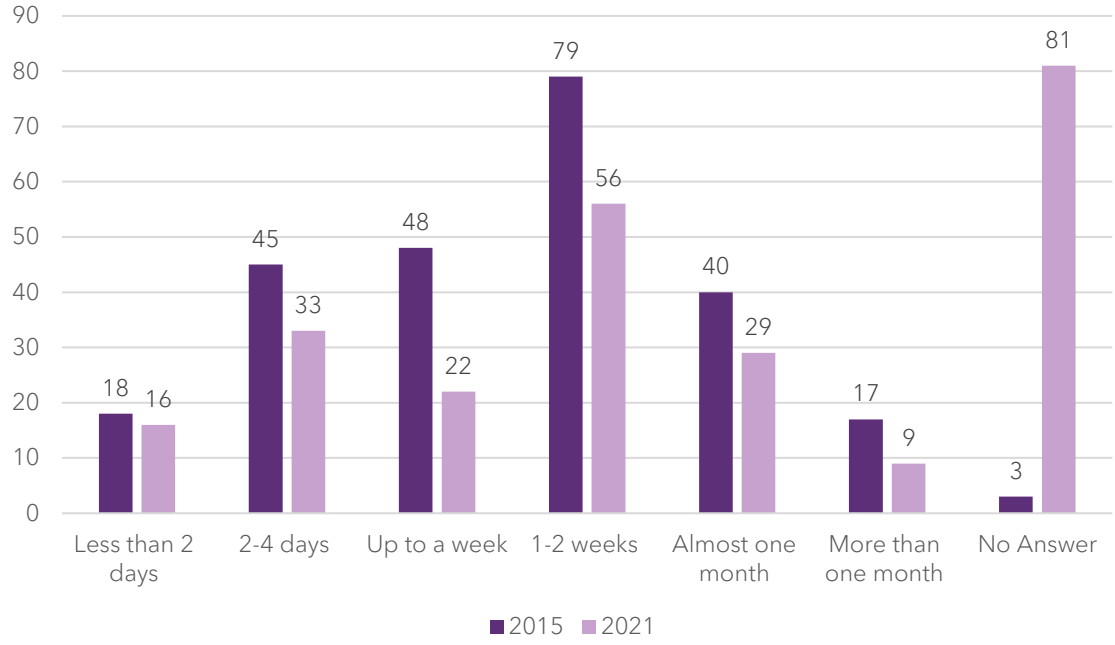


Figure 4-6: Duration of services resuming after disruption (Source: Ground survey)

Disruption of services was also much less in 2021 when compared to 2015 as seen in Figure 4-5. Around 63.6% respondent said that in 2015 electricity was cut off and they had no access to toilets and clean drinking water. 24% of the respondents said they faced similar multiple service disruption in 2021. Electricity shortage and disruption of essential services was also fixed within 2-3 days in 2021 while it took weeks for these services to resume in the most precariously positioned areas in 2015 (See Figure 4-6). Shorter duration of

inundation and better preparedness meant that the services could be restored faster in 2021.

More than 90% people agreed that the floods affect their livelihoods significantly, indicating that even in years where lives are not lost and property survives, the impacts of wage loss for daily wage workers would be quite significant and needs to be addressed. Livelihood of wage labourers, semi-skilled workers, and other categories like drivers, washermen, and street vendors were affected for at least two to three weeks.

People working in private companies were also paid half salary during this period as they could not go to office. Some of the women who were working as domestic workers lost their jobs as they could not travel to the homes they worked at, and the owners appointed other women. Some of the auto drivers and people who used smaller vehicles for transportation lost their vehicles and subsequently lost their livelihoods. More than 28% people also report that their family members' health suffered due to the flooding.

4.4 Government Interventions

The community consensus is clear that the government action and preparedness had markedly improved from the floods of 2015. The one area where assistance was lacking was monetary assistance, possibly due to the lack of perceived financial impact as loss of life and property was ameliorated. However, that masked the fact that many people lost livelihoods, if not permanently, then temporarily as they were unable to go their workplaces or find clients. This is particularly significant for daily wage workers, and this makes the lack of financial assistance a significant issue because families relying on daily wage incomes will be distraught with the loss of even a week's worth of wages which was not uncommon during the floods. Nonetheless, when it comes to progress, except for weather alert systems which are bound to be improved by a series of localized weather stations being set up under the City Disaster Management Perspective Plan after the recommendation by the national authorities, other factors already showed significant improvements.

The government provided food and rations for 21,000 families in Perumbakkam and set up medical camps to help prevent the spread of communicable and water-borne diseases. The Corporation set up 160 relief camps across the city and used the chain of central and community kitchens to provide food for those in need. Deployment of boats for relief work was much quicker, and so was the restoration of electricity and other services after the flood caused disruption. Due to the lesser impacts of the 2021 floods, only 14% people reported getting any government aid compared to 52% people in 2015.

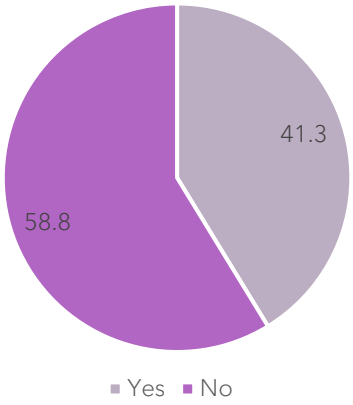


Figure 4-7: Awareness of any Safe Shelters accessibility during Disasters (Source: Ground survey)

Although the government set up relief camps and shelters, most people still reported not being aware of any shelter near them. This indicates that a greater level of awareness needs to be generated among public on where they can find relief camps.

While drainage continues to be a worry and was the most commonly cited improvement in the survey with respect to interventions that needs to be made, the focus group discussions revealed that the situation had improved over the years. The general agreement was that the Corporation took precautionary steps prior to the rains, which helped reduce the damage caused by the floods on people's lives. This included prior warnings about floods being possible and what actions people must take to protect themselves and their belongings, using both television and regular updates on smart phones. Some respondents reported that the Corporation officials carried out desilting even while it was raining which significantly improved drainage and helped fight flooding. Electric supply was restored much more promptly which was a necessary improvement as many people's information access and lives relied on it. Some vulnerable areas also witnessed people being evacuated even before the floods worsened in anticipation, which allowed them to be safe in schools and other shelters before the flooding got worse. Lastly, one major difference was also noticed in the management of reservoir water. Our data showed that a more gradual release of water prior to monsoons in preparation for a deluge helped the Corporation release water in a planned and safe manner unlike the 2015 floods where it was released in a burst and caused massive destruction. People living in vicinities of these water bodies noted this change and appreciated the regulated release of flooded water that helped them avoid severe damage.

4.5 Community Efforts and Vulnerability

Chennai's most vulnerable communities are some of its poorest populations that have been resettled into low-lying or reclaimed lands which are prone to flooding. One such community, Perumbakkam, faced high levels of flooding to the extent that it was among the few places where the government had to deliver food, rations, and other aid which was

otherwise not required in most other areas. Relocation for developmental or urbanization programs into these flood prone areas has left these communities in an extremely vulnerable position every year as even moderate rainfall is enough to flood these areas.

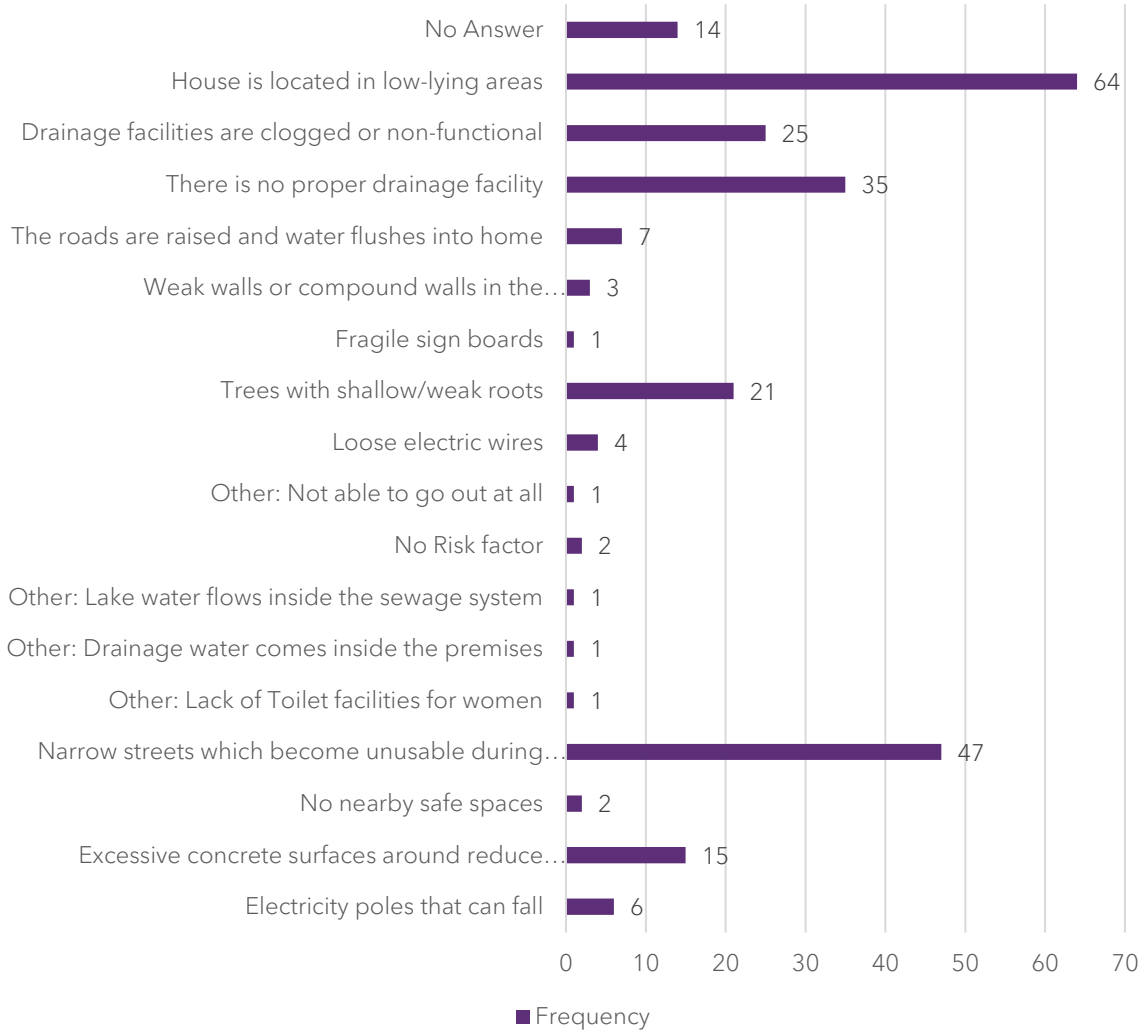


Figure 4-8: Factors in Surrounding Areas that Increase Risk during Disasters (Source: Ground survey)

Figure 4-8 shows the factors that were the most cited cause of vulnerability to flooding in the survey locations. Majority of respondents had their houses in low lying areas made them most vulnerable to flooding. This along with lack of proper stormwater drainage facilities, and blocked drains were reported to be the major causes of flooding in people's homes. Narrow streets in poorer communities also become unusable during floods which cuts off their access to daily groceries and essential resources. This also makes it difficult for people to evacuate and carry out response operations. This highlights the need to regulate the constructions and settlements in such low lying areas Excessive concretisation of the surroundings means that there is very less area for water to percolate to the ground, thus causing flooding. Surrounding features like weak rooted trees, weak walls and electric poles also act as a threat as these can fall over and cause structural damages to the infrastructure and also cause loss of life.

One of the key facets of Chennai's community resilience are its network of weather watchers or weather bloggers. With the fast advent of social media and smart phones, their role became much more pronounced as it was these accounts that spread early warning information and managed to make people aware of the possibility of flooding even as the official government channels took time to catch up. The pandemic further increased people's reliance on smartphones and social media, which also created a space for this network of active weather bloggers and watchers to intervene before the crisis. They use a wider amount of data compared to the government meteorological department, which allowed them to be more aware to the possibility of impending flooding and heavy rainfall.

Further, another facet of Chennai's community resilience that was hardened during the 2015 floods was the provision of free and hotly cooked food to those in need. A network of community volunteers, NGOs, central kitchens, and community kitchens ensured that people would not go hungry no matter how severe the conditions. The government also recognized the role of these local volunteers and collaborated with them to prepare for the floods and distribute food materials in local areas as these volunteers had local expertise the corporation officials did not necessarily possess. While these NGOs were much more active in providing relief material during the extended crisis of 2015, they were still present to address emergency calls and distribute food during 2021 whenever the need arose.

Local residents had also learned a lot of valuable mitigation lessons from the 2015 floods. Affluent communities installed pumps to drain water, not having to wait for any government interventions. People were more careful in storing their valuable assets and documents prior to the monsoon season, sealing them, or placing them at higher levels to avoid damage. Overall, the broad conclusion seems to be that the people recognize and appreciate the improvements made by the Greater Chennai Corporation in tackling heavy rainfall, but also realize that extreme weather events are becoming a regular occurrence in Chennai, and properly managing them at every level is absolutely necessary. While loss to life and property has been minimized, further interventions to address the economic, social, and educational disruptions caused by flooding are crucial, as are better drainage systems that minimize flooding.

5 Looking Forward: Building Resilience

The primary goal of this research was to identify a roadmap for Chennai's future resilience. As climate change effects continue to worsen across the world, the coastal city of Chennai and its over 1 crore residents will be at the forefront of nature's wrath against decades of human destruction. While the efforts to mitigate climate change impacts cannot be sufficiently carried out by individuals or even cities, and require global cooperation, the adaptive capacities of people and cities towards the day-to-day effects can be improved. From across our research, we have outlined certain avenues where interventions can be made to improve the resilience of Chennai. We outline possible policy interventions by theme: discussions on improving communication and warning systems, addressing drainage concerns, management of water bodies, facilitating community resilience, and climate budgeting for the future.

5.1 Communication: Early warning and Weather Watching

People having access to prompt and updated warnings is of utmost importance for them to be prepared in the face of any extreme event. This can be clearly seen when comparing the cases 2015 and 2021 where more people had received the information and alerts regarding heavy rainfall. A robust, updated, and well-connected communication network is essential to make sure that the information reaches the communities in time, and they can action. Some of the actions that can be taken in this regard are as follows:

- A communication network integrating the different levels from the IMD (national) to the various community systems.
    - The weather watchers and bloggers actively post regular forecasts and updates on social media platforms like Twitter and Facebook, by analysing weather models, cyclonic patterns, wind charts, and publicly available satellite imagery. Identifying and working in tandem with such community initiatives would proof very effective.
    - In addition to creating an automated network of weather systems, it is also important for the government to disseminate their findings and information promptly. Direct automated messages or calls going out to residents warning them about any impending extreme event would also be needed delivering information.
    - Existing systems such as C-FLOWS and TN-SMART could be utilized by the Greater Chennai Corporation in improving early warnings.

- Training community volunteers for creating a city-wide network of disaster information volunteers that will help in disseminating warnings and other information to the communities in the modes most accessible and appropriate for

their particular communities. Existing mechanisms such as Aapda Mitras[36] can be leveraged for trained community volunteers.

- The impact of heavy rainfall would have differential impacts within the city owing to the various physical and geographic features in a particular area. Thus, the same amount of predicted rainfall could cause flooding in one neighbourhood and not in the other. There should be hyper local risk assessments to understand these differential impacts and to see which areas are more vulnerable than the rest.

- Weather prediction is crucial in preparing the city for any disaster. Upgrading the weather systems is already underway through the City Disaster Management Plan and it is crucial that hyperlocal real-time weather mapping and predictions are created.
    - The NDMA guideline of having 100 automatic weather stations for the city (one for every 4 square km) should be implemented fully. This would give more localised weather data based on which preparedness measures can be better calibrated. Daily recording of local weather data would also give a better picture of the weather trends and patterns within the city
    - Leveraging technology like AI for impact based early warning at a local level can help create specific alerts for local residents in case of any threat of extreme weather thus helping them to be better prepared.

5.2 Let the Rain Drain: Addressing Drainage Woes

One of the most crucial concerns witnessed evidenced in every possible manner is the lack of proper drainage facilities in Chennai that can deal with heavy rainfall. The existing drainage system is outdated and almost a century old, and any upgrades made on that are still inadequate to address the heavy rains witnessed in the past years. While this is not necessarily a fault of previous planning, since the significant increase in extreme weather events which has occurred due to climate change was not anticipated, it is certainly a major concern for the future. The city needs to protect itself from extreme rainfall, not just in the immediate term, but also for the next few decades as climate change impacts will continue to worsen. Some of the proposed solutions include:

- The existing storm water drainage system is in a dilapidated condition, necessitating the construction of new storm water drainage canals with increased capacities, as well as widening existing canals for increasing drainage.
    - Areas where existing storm water drains are under construction or are being refurbished need to be given priority such that these works are completed before every monsoon season.
    - Residents argue that there are many encroachments on the canals such as houses, shops, and other structures, which can be removed to widen the canals, improve maintenance, and increase their capacity.

[36] https://www.ndma.gov.in/Capacity_Building/Admin_Coordination/Aapda-Mitra

- Many residents said that the level of roads being higher than the adjoining level of houses was a major challenge which meant that the water stagnated on roads entered people's homes rather than draining away.
    - Proper milling should be incorporated in next rounds of road construction and repair to reduce the levels of roads so as to address the issue of water stagnation.
    - The increasing construction of non-permeable roads in Chennai over the past couple of decades has also reduced ground water seepage.
    - Residents from Perumbakkam propose that constructing new bridges on the Old Mahabalipuram Road will facilitate more waterflow towards the other side and reduce flooding in the area.

- The existing sewage pipeline network, which was laid three decades ago, is proving insufficient to deal with the city's growing demands and needs to be upgraded.
    - It is important to extend closed sewage drainage to all houses, in order to avoid the gruesome mixture of stormwater and sewage flooding streets during monsoons.
    - As a mitigation measure while the sewage lines are being extended to serve everyone in the city, residents proposed that the Corporation provide sewer water collection through lorries at subsidized rates.

- Timely and proper management and cleaning of the storm water networks so that they are not overloaded during monsoons.

"Storm water drains are clogged due to dumping of solid wastes; all of us are responsible, residents, road site eateries, petty shops, GCC etc. Awareness about solid waste management is very important for keeping the storm water drains clean and allow water flow without clogging and stagnation."

– Common voice in the FGD at T.Nagar

5.3 Managing Water Bodies: Prioritizing Water Resilience

Chennai is blessed with a large amount of water bodies which have historically been extremely helpful in carrying away storm water and acting as a natural drainage network. However, encroachments and land reclamations have led to a rapid decline in the size and number of these water bodies. Existing water bodies need to be deepened to improve the amount of water they can retain. Many water bodies have been reclaimed which means the

total capacity of water bodies to absorb extra rains has reduced. Tackling this requires enhancing and protecting the water bodies which are abundant in Chennai.

- Strengthening and closing gaps in the river bund to prevent water from overflowing and entering residential areas is important, especially in areas close to the Kosasthalaiyar river.

- Surplus water discharged from the nearby lakes is a major cause of flooding for many areas, instead of rainwater from the monsoon. Consequently, better management of the level of water bodies such that no surplus needs to be released during heavy rainfall periods, would reduce flooding in such areas.

- Existing water bodies need to be deepened to improve the amount of water they can retain. Many water bodies have been reclaimed which means the total capacity of water bodies to absorb extra rains has reduced. Tackling this requires enhancing and protecting the water bodies which are abundant in Chennai.

- Chennai needs to protect its few remaining lakes and prevent encroachment by individual house owners, big construction companies, and offices in South Madras as these have reduced the storage capacity of these lakes, which increases the threat of flooding in nearby areas.

Rethinking the growth and development patterns of the city to ensure that the water bodies are not encroached, and projects are regulated in extremely flood prone areas. Enforcement of laws regarding rainwater harvesting needs to be made more stringent and it is crucial to increase its prevalence in the city. It should be made mandatory for any new real estate or construction projects, and incentives should be given for existing buildings and houses to incorporate rainwater harvesting.

- The existing rules state that rainwater harvesting structures must be implemented in all houses created by the Tamil Nadu government, and in houses that already have rainwater harvesting structures, these should be properly maintained.

- The residents suggest that the government should provide 50% support to encourage owners to create and maintain rainwater harvesting infrastructure in existing houses as otherwise they have no incentive to do so.

"One of the major issue needs to be addressed is the unregulated urbanization, here many huge structures were allowed to come up in the water ways and water body- since the water ways are blocked and water bodies are encroached water stagnates in our area no way for draining and no storage space."

– It is a common voice from the participants in the FGD at Perumbakkam.

5.4 Community Participation and Innovations

One of the major complaints from the community that was particularly expressed during the focus group discussions was the lack of consultations with communities. A reconsideration of disaster management approaches that places communities at the centre of disaster response and resilience is necessary as community leaders and participants are best aware about their concerns as well as the resources at their disposal to tackle any challenge. This would also give insights into the current capacities of the communities. Some of the possible methods are listed below.

- People should be given proper monetary compensation from the government to immediately buy the most essential items during crisis. Monetary relief should also be considered for quick restoration of livelihood opportunities.
    - People living in flood prone areas need to be supported with suitable insurance policies for their property and belongings such as home insurance, vehicle insurance, and health insurance.

- During floods, people from outside are often unable to reach the interiors of flooded areas due to inundated streets. Including local community, who are typically the first responders, in planning for provision of essentials during flooding will help understand means through which these relief materials can be delivered, as well as existing community resources that can be utilized.
    - The corporation should identify leaders in every community who can be trained for executing disaster management plans at a micro-level, and can be consulted while creating plans that respond to the particular spatial and demographic features of the area and are tailored to the local realities.
    - Similarly, better engagement with local NGOs or volunteer organizations can improve last mile delivery of relief materials massively.
    - Local youth associations and self-help groups are crucial for distributing aid during times of crisis, but due to inundation of roads, they often find it difficult to properly reach the most vulnerable areas.

"Youths (members of a local youth association) in our area done a great job, walked in the waist deep water to the other side bought essential items to us, helped the NGOs to properly distribute the aid and relief materials, and arranged boats to evacuate the vulnerable first."

-Common voice from the participants of the FGD at KM Garden.

- There is an urgent need to build and/or identify relief shelters or create community spaces such as community halls and schools where people can save themselves from any extreme weather event and collect in case of disasters.
    - It is crucial to equip these shelters with proper toilet facilities and reserve resources like torches, grocery etc. to make it equipped enough for people to live there for a few days in case the need arises.
    - These shelters or spaces should also be at an elevated and accessible part of the community such that they are not flooded and can accommodate people during floods. They should also be equipped to address particular needs of persons with disabilities, children, pregnant women, etc. and any local discrimination based on caste or gender should strongly be addressed in ensuring safe access for the most marginalised.

- The unpredictability of extreme weather events and their effects are rendering existing models of response and resilience inadequate. Hence, a focus on innovations in climate and disaster response needs to be integrated thoroughly.
    - Identifying and promoting community based local innovations and innovators that contribute to climate change adaptation and flood resilience. This bottom-up approach creates an enabling environment for resilience instead of being dependent solely on government response. An example of this is the Beattheheat championship held by SEEDS in East Delhi during the heatwave season in 2022. The participants, who were mostly children, were asked to share their ideas on low-cost reduction measures for their homes. One of the champions, came up with the idea of insulating the water tank so that the water does not get heated. She came up with the idea after seeing polystyrene ice boxes which are used to store cold drinks in local stores.
    - Involving children and youth in decoding climate science to build awareness and interest is of paramount importance to tackle climate change effects which will pronounce themselves in the future.
    - Innovations could include setting up climate weather labs across schools for fostering weather watchers from an early age who will be at the forefront of demanding climate justice.

5.5 Climate Budgeting

- Climate change budgeting is a 'government-led process of identification, measurement, and monitoring of climate-relevant public expenditures.'[37] It is a continuation of fiscal policies targeted at groups or welfare interventions, such as pro-poor budgets, or gender-budgets, and budgets for development goals. In the

[37] https://openknowledge.worldbank.org/bitstream/handle/10986/35174/Main-Report.pdf?sequence=1&isAllowed=y

same light, climate change budgeting involves demarcating a section of the state or country's budget for climate-change related actions.

- Seven Lessons for ministries working on Climate Budgeting by World Bank include:[38]
    - Incorporate climate change into longer-term budget frameworks to allow for planning and adjustment of spending across programs.
    - Send an early and clear signal of the importance of climate action through the budget process, preferably before actual budget development.
    - Use interagency committees to help mainstream new policy initiatives such as climate change into the plans of line agencies and to allocate resources in balance with other priorities.
    - Require more comprehensive reporting at the sub-national level and among state-owned enterprises.
    - Identify and monitor all off-budget expenditures.
    - Identify all externally funded initiatives and establish uniform reporting practices to give a complete picture of climate-related expenditures. Ministries of finance and planning agencies must track and report on these expenditures and reflect them in budget documentation.
    - Respond strategically and effectively to the requirements of external donor funds.

- There are three essential design elements to climate budget tagging methodologies: definition of climate-relevant expenditure; definition of appropriate coverage; and estimation of climate-relevant spending. What qualifies as a climate-relevant activity can include direct plans introduced by the government, such as expenditure on improving drainage systems, or expenditure that generally helps improve climate resilience, such as subsidizing water harvesting and solar panels in households.

- It is crucial for the Tamil Nadu government to identify which sectors are most crucial for investment in the state. While other states like Bihar have focused on renewable energy generation in their climate budget,[39] the scope of Tamil Nadu's climate action is broader: focusing on sustainable technologies like renewable energy is as important as tackling possible climate impacts in the state, and in Chennai.

- Within cities and communities, it is important to identify those who would be worst affected and address policies directly towards them. A study of climate-related budgets in four states of India found that policies and budget targeted towards

[38] https://openknowledge.worldbank.org/bitstream/handle/10986/21036/933830WP0Boc380e0Budgeting00PUBLIC0.pdf?sequence=1&isAllowed=y
[39] https://www.cbgaindia.org/wp-content/uploads/2022/03/Bihars-Policy-and-Budgetary-Priorities-for-Transitioning-towards-Green-Economic-Recovery.pdf

women was completely lacking, whereas the National Action Plan on Climate Change acknowledges that climate impacts will be severe on poor women.[40]

- Many climate change impacts disproportionately impact women: structural transformation of the Indian economy has shifted men out of agriculture while women are still employed in it. As climate change impacts agricultural produce, women will be disproportionately affected.
- Similarly, lack of equal access to household resources and information sources reduces women's ability to be resilient towards climate disasters.
- Consequently, it is important to demarcate a part of the overall state climate budget for gender-budgeting within climate action.

- Identifying the most vulnerable sector and allocating funds for climate change adaptation and long-term mitigation measures
  - Odisha uses two metrics to identify key policies and programs in its climate budget: Climate Change Relevance Share which refers to how relevant improvements in a sector or program are for climate change resilience, and Climate Change Sensitivity Share which refers to the sensitivity of a particular sector or program to being adversely affected by climate change.[41]
  - As an example, agriculture is both very relevant to climate action, and hugely sensitive to the effects of climate change. On the other hand, transportation is not very sensitive to climate change effects, but a hugely relevant factor when it comes to tackling climate change. Similarly, while fishing is very sensitive to climate impacts, changes in fishing practices might not help fight climate change significantly.
  - Addressing policies and programs through such a framework will help identify key sectors and programs which should be prioritized for climate budgeting. Using a combination of sensitivity and relevance helps identify the most crucial sectors that score high on both metrics.
  - This process needs to be carried out for every program, every department, and every sector to identify the key areas which should be targeted through climate budgeting, depending on the overall impact interventions in these areas would have.

5.6 Further studies

This study is rather a beginning to look in detail into the different facets of climate change impacts. Here we outline a few such studies and projects that can be carried out based on the findings:

1. *Journalist handbook for Climate change reporting*: As seen from the media review, the reportage of climate change is not adequate within the media. Even the reports which do address climate change, majority of them focus on the failures on what has

[40] https://www.cbgaindia.org/wp-content/uploads/2017/03/Climate-Change-Adaptation-and-Gender-Budgeting-Policy-Brief.pdf
[41] https://finance.odisha.gov.in/sites/default/files/2022-07/Climate%20Budget.pdf

not been done. While this is important, it is also equally important to look at the science, causes and inform the public about the phenomena as such. For that, the first step would be to sensitise journalists on how to report on climate change and use it as a lens for reporting extreme weather events. Developing a journalist handbook on Climate Change reporting would aid better reportage of climate change impacts and would also better inform the public.

2. *Hazard and vulnerability studies for Chennai* – The current study looks at only the impacts of climate change on flooding and inundation. But as mentioned in section 3, vulnerability of Chennai extends to hazards like heat, drought sea level rise, cyclones etc. Detailed hazard and vulnerability studies for Chennai, especially for extreme heat, would be instrumental in long term climate change adaptation pathways for the cities. The studies shall also look at the sectors that are most vulnerable to each hazard and this could further aid in the climate budgeting for the city. This could also be done to other issues like pests, which are also seen increasing in the recent times.
3. *Landscape study on automatic weather stations and weather labs*: Conducting a landscape study of the existing automatic weather stations in the city and the good practices from across world can be done. This would further aid in an effective implementation of the NDMA guidelines establishing 100 AWS in the city. The study can also look into the potential of setting up weather labs in the schools across the city and how they could be an integral part in the early warning communication network.
4. *Climate hazards and burden of disease*: Conducting a detailed study on the diseases and other health related issues faced by different groups of people would aid in enhancing the capacity of the health sector of the state. This would involve looking at the health issues during different climate hazards like floods, heatwaves etc, mortality, root cause analysis, most vulnerable areas and population, gaps in the health infrastructure and the measures taken to tackle the issues. The study can also look at the short and long-term economic burden these diseases can bring upon the vulnerable population.
5. *Mapping the stormwater the city*: Drainage lines getting clogged due to waste dumping was one of the major reasons cited by the survey respondents for flooding in their surroundings. Mapping the drains, STPs and the other waste management infrastructure, wetlands, estuaries, groves etc in the city would help in understanding the gaps in the required stormwater infrastructure for the city.

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Annexures

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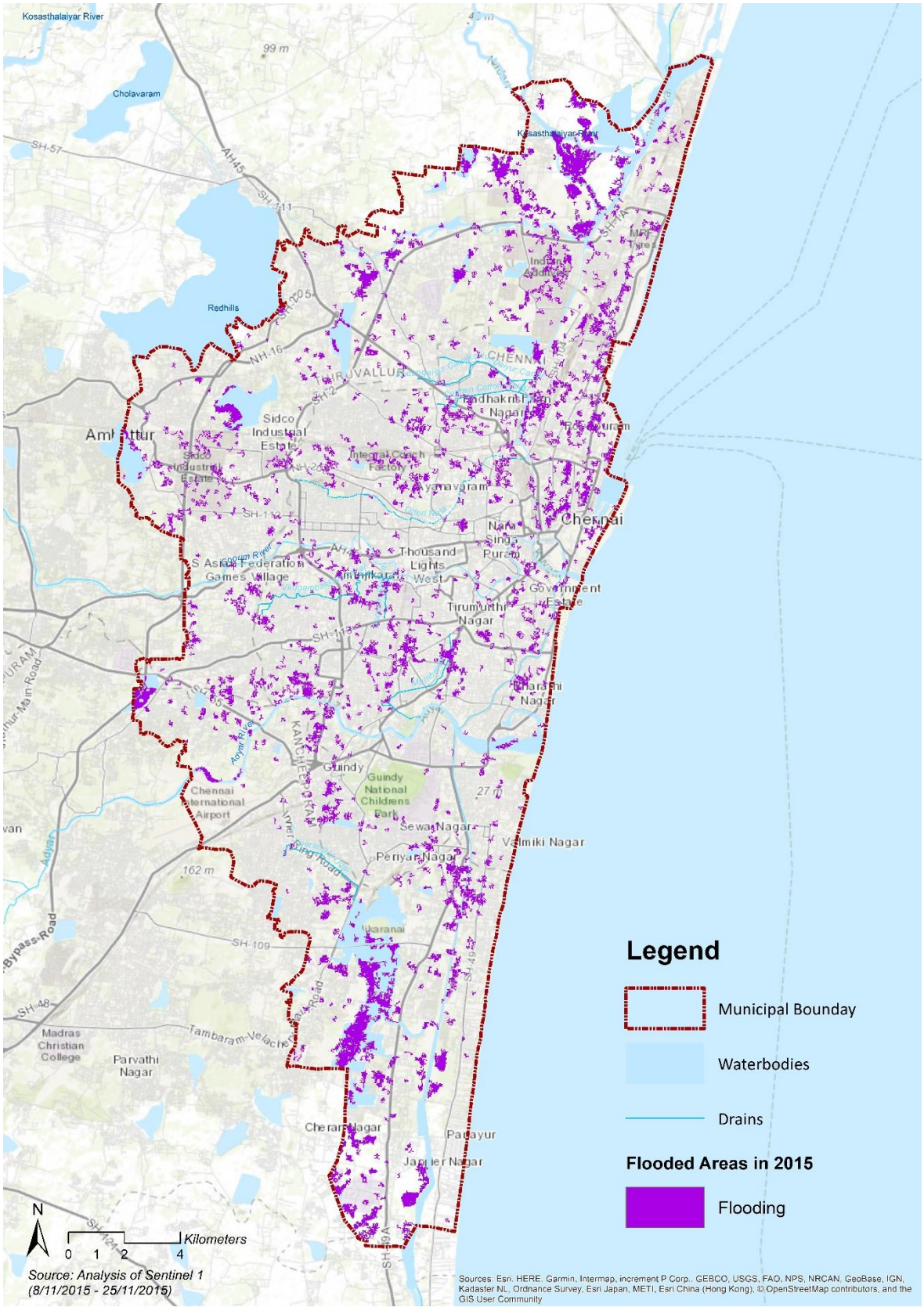
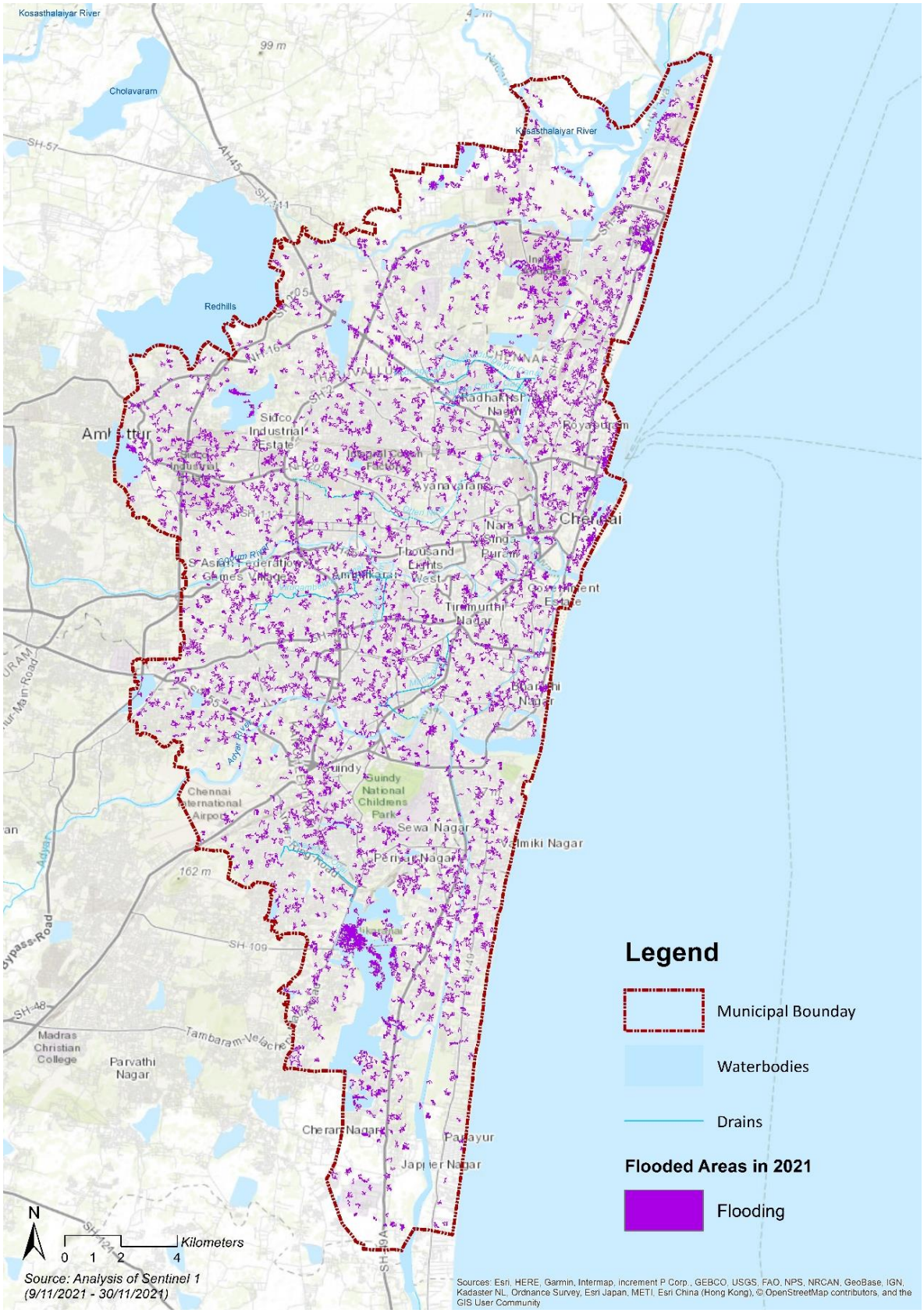
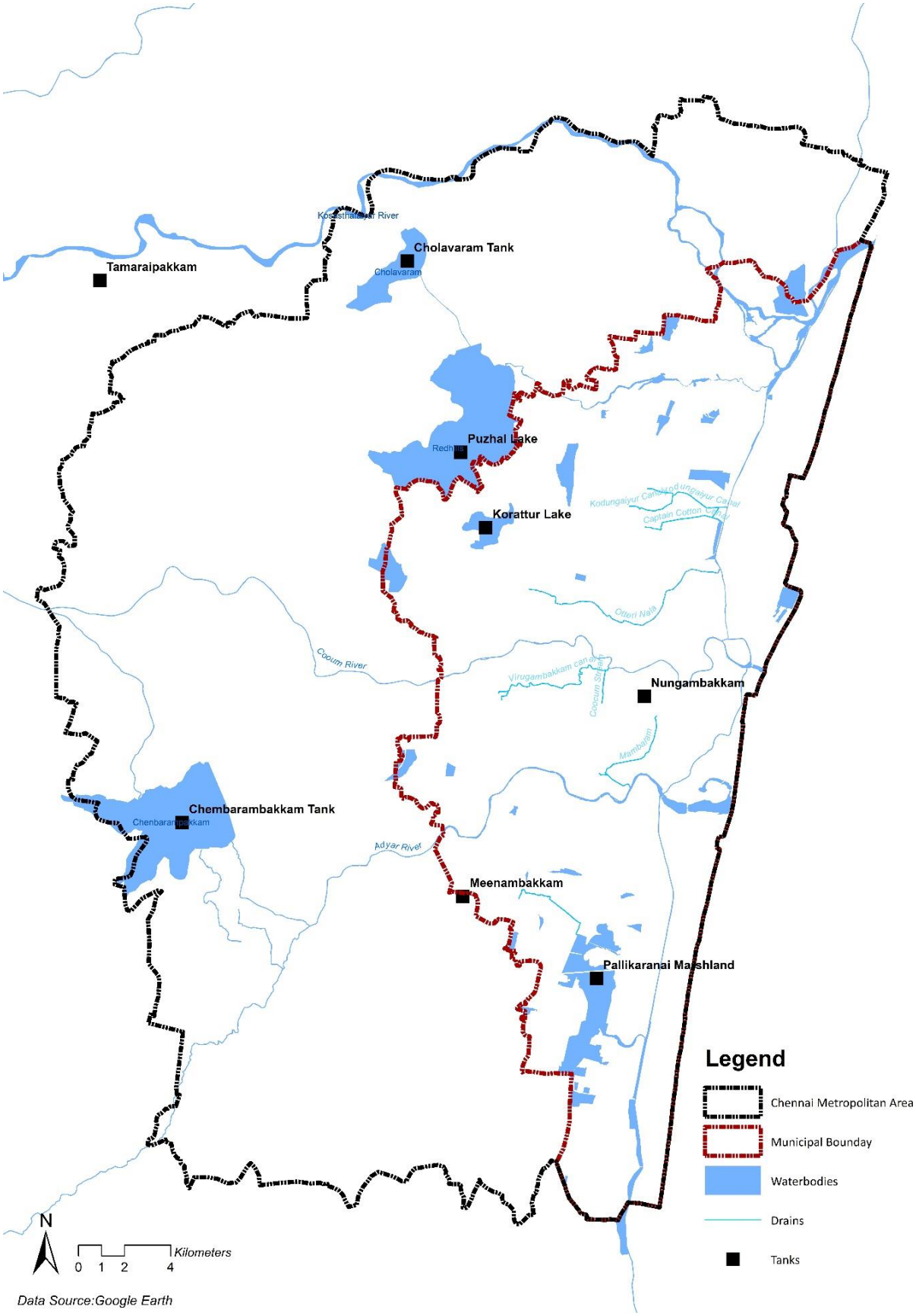


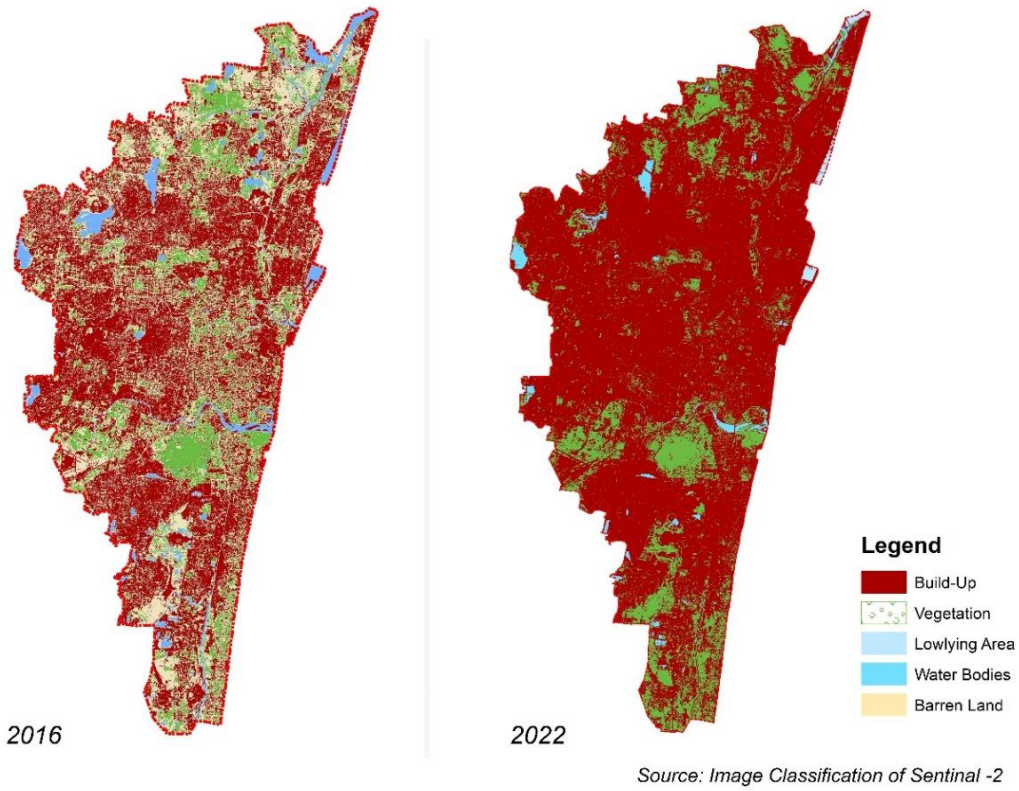
Map 1: Flooded areas in 2015



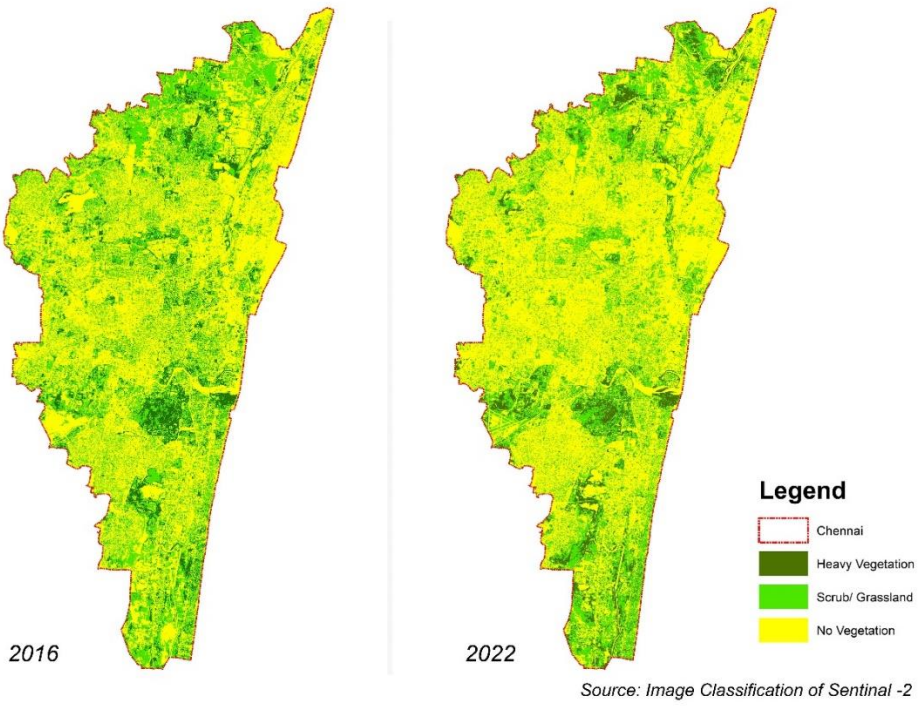
Map 2: Flooded areas in 2021



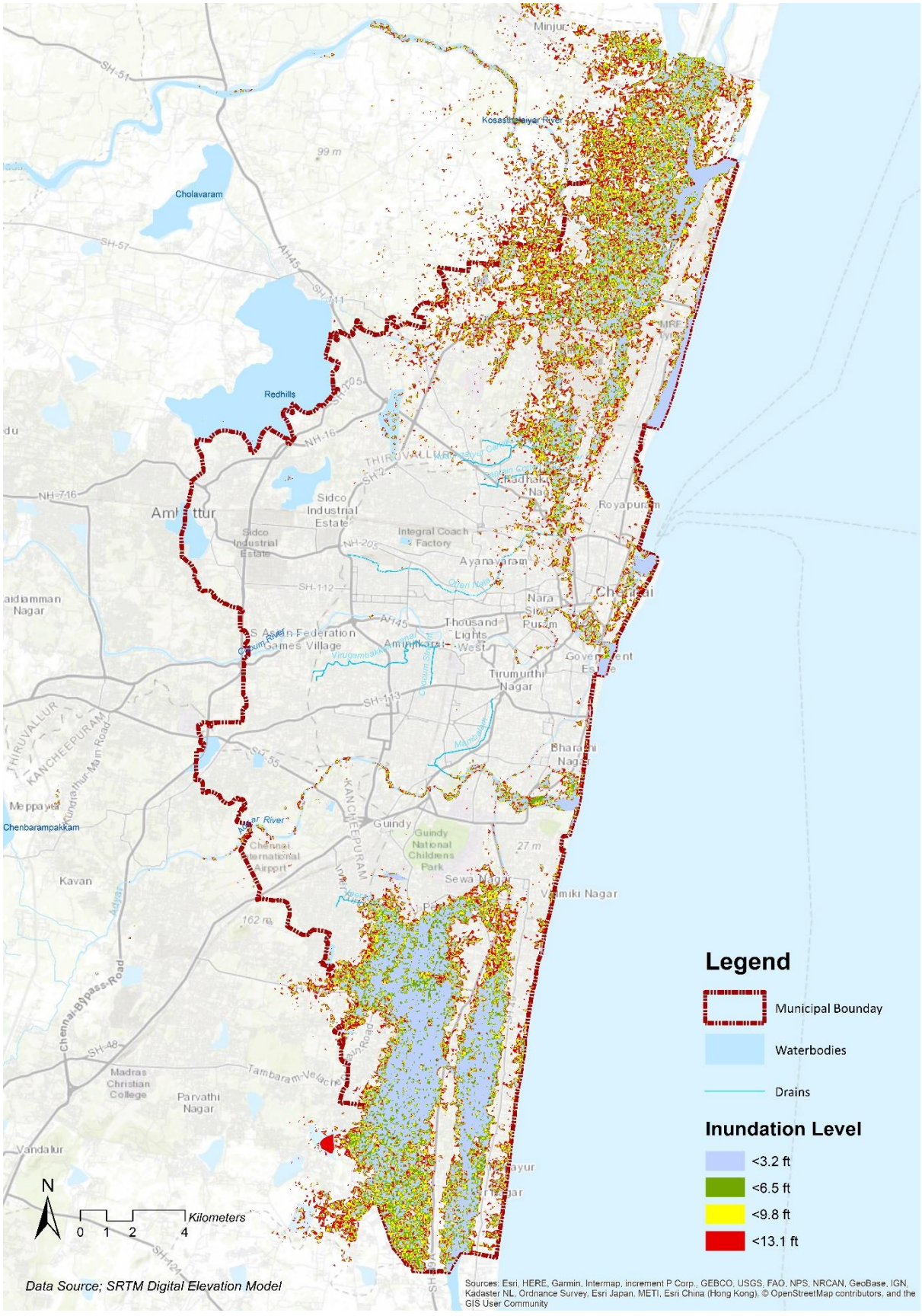
Map 3: Water Channels and Tanks of Chennai



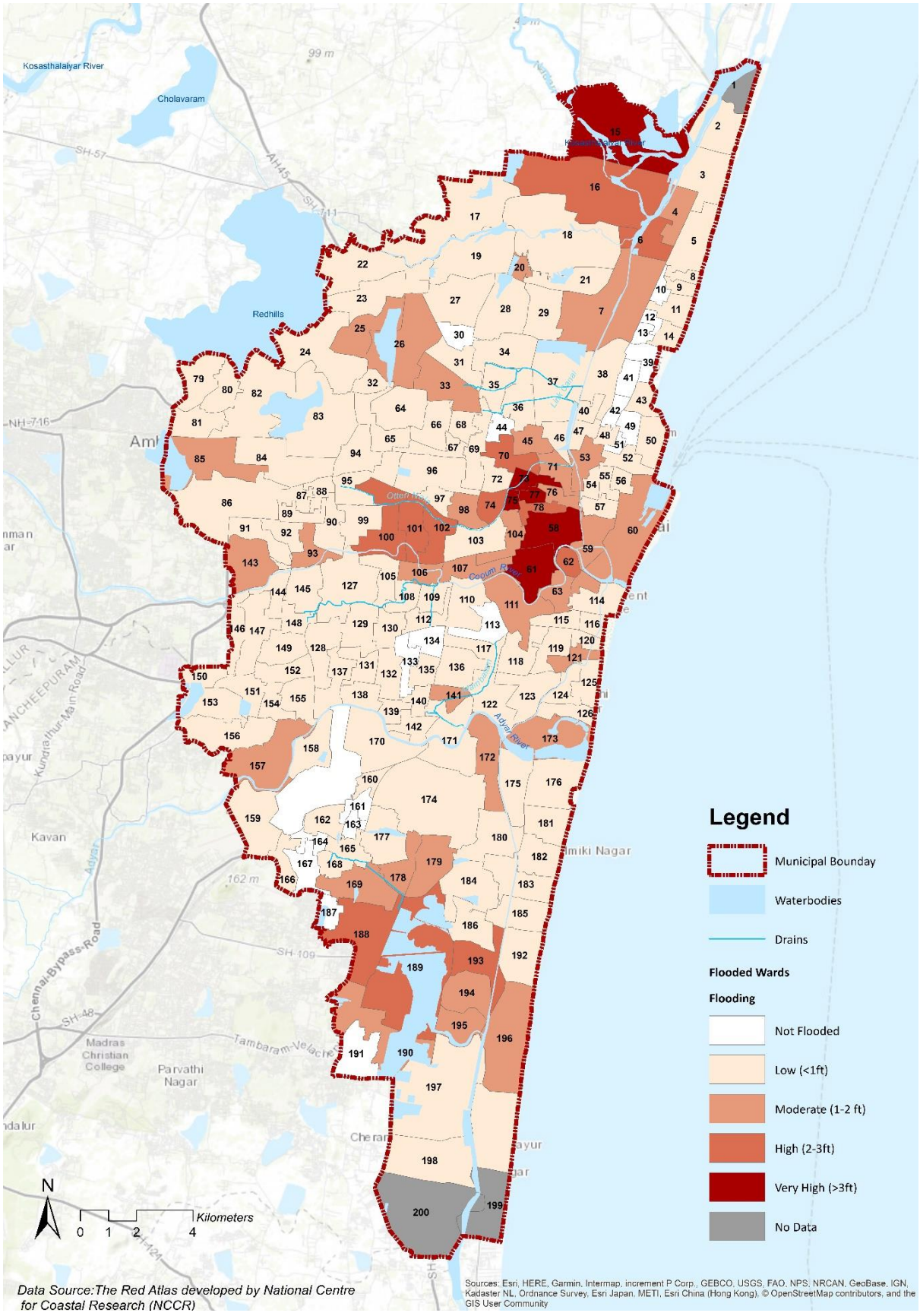
Map 4: Chennai Land Use and Land Cover (2016 and 2022)



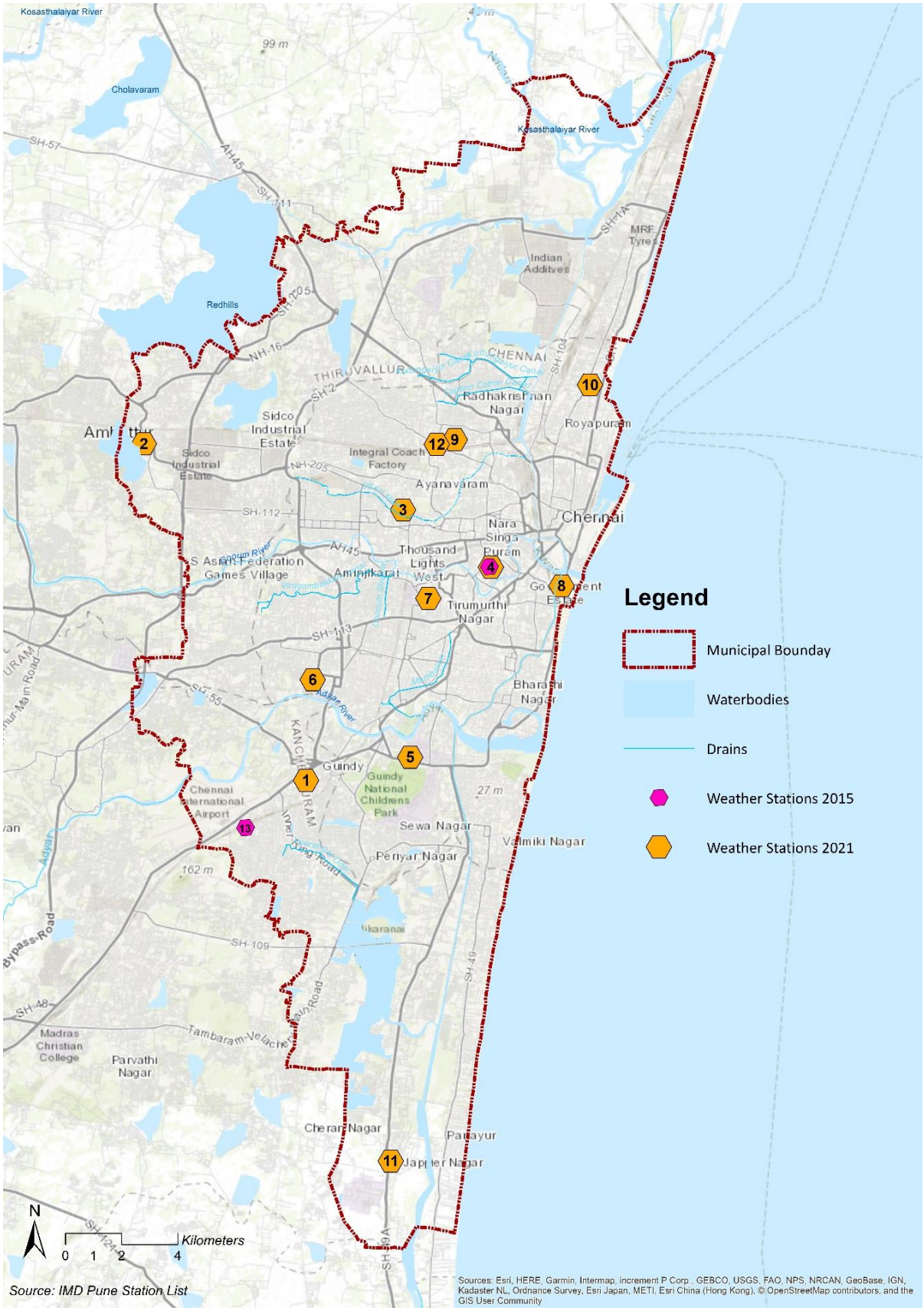
Map 5: Vegetation Index for Chennai (2016 and 2022)



Map 6: Chennai Inundation Risk by Area



Map 7: Flooding Level in Wards (2015)



Map 8: List of weather stations in Chennai (2015 and 2021)

Annexure II: Focus group discussion questionnaire

(FUQ: Follow up question, PQ: Probing question)

I. What was your experience during the floods in November 2021?
    1. PQ: Was your street flooded and waterlogged?
        - FUQ: How deep was the waterlogging?
        - FUQ: How long did it remain waterlogged?
        - FUQ: Was there a drainage network? Why do you think it failed to clear the water?
        - FUQ: Did the water finally recede on its own or did the government do some interventions to clear it?
        - FUQ: What was the impact of the waterlogging on people living on that street? Was anyone hurt due to it?
    2. PQ: Was your house submerged during the floods?
        - FUQ: How deep was the water, and how long did it remain?
        - FUQ: Did the water cause damage to any electronics, documents, or other belongings like the bed?
        - FUQ: Why did the water come into your house? How did it finally recede?
    3. PQ: Can you compare the experience of the 2021 flood to that of the 2015 floods in Chennai?
        - FUQ: Was the 2021 flood managed better by the government?
        - PQ: Which rains were more severe, and when did you face more loss and damage to property or assets?
        - FUQ: What were the impacts on your livelihood and earnings in 2015 and 2021? When was the impact worse?

II. Did you receive any aid during or after the floods from the government or anyone else like NGOs or volunteers?
    1. PQ: Who was it that assisted you? Was it a government official, disaster management teams, NGO workers, or other volunteers?
    2. PQ: What kind of help did you get? Did it help you manage the effects of the flooding and survive the crisis?
    3. FUQ: Is there anything you wish the government managed better? Something that would make heavy monsoons less disastrous and more manageable?

III. Did you know before the floods that heavy and potentially flood-causing rainfall was about to happen?
    1. PQ: How early did you know that heavy rains were coming?
    2. PQ: What source did you get your information from?

- FUQ: Have you heard of the weather watchers of Chennai? Do you rely on them for your updates?
- FUQ: Did you get any governmental updates, sirens, or alarms warning you of heavy rains and flooding?

3. PQ: Are you aware of any 'early warning systems' in or around your community that will inform you of the threat of any heavy rains? Are there any alarm systems to warn of such a scenario?
4. PQ: How did early warning systems perform compared to the 2015 floods? Did you have more time to prepare for the flooding this time?
    - FUQ: What source did you rely on for weather information in 2015? Has the source you rely on changed?
    - FUQ: What sources do you currently rely on for weather updates?
    - FUQ: How useful do you find information about weather updates? What kind of information do you think is most helpful for you?

IV. Are there any storm shelters, relief shelters, or rain shelters around you where you can go for support, relief, and protection during a disaster?

1. PQ: How far is the nearest such shelter from your house?
2. FUQ: Have you gone to any such shelter in 2015 or 2021 for protection from flooding or to get food?
3. FUQ: Do you think the number of relief shelters is adequate, or do you think the government needs to build more such shelters in your community?

V. Has your life and livelihood recovered after the floods in 2021? Have you been able to go back to life as it was before the floods, or has there been a permanent change?

1. FUQ: How long did it take for you to get back to work, repair the damage to your home and assets, after the flooding?
2. PQ: Was your health or the health of any household members affected by the flood? How long did it take for them to recover from their ailments?
3. PQ: Are there children in your households who are studying in school or university? How does the flooding affect their education? Do they have to skip school for some days?
4. PQ: Are you able to get groceries when heavy rains and flooding arrive? Where do you get them from usually? Are the local grocery shops and chemists open?

VI. What do you think needs to be done to reduce the severity of flooding in your area?

1. PQ: What are the factors that make your area vulnerable to flooding?
    - FUQ: What can be done to mitigate these factors? Are they things that can be changed with government intervention?
2. PQ: Where do you think the government's disaster management needs to improve?
    - FUQ: Is there any aspect of disaster management that has improved between 2015 and 2021?

- FUQ: Were you able to get access to rain shelters, food, and other relief materials more easily in 2021 compared to 2015?

3. PQ: Do you think NGOs are important for disaster relief and management?

VII. Do you think weather patterns and rainfall in Chennai have become more extreme or unpredictable over the past few years?

1. FUQ: Why do you think this is happening?

VIII. Have you heard of climate change? What do you think it means?

1. FUQ: Do you think climate change has anything to do with the changing weather pattern of Chennai?
2. FUQ: What other effects do you think climate change is having on our lives?

Annexure III: Ground survey

Data collection themes

Table 1 Ground survey themes and questions

Theme	Reasoning	Questions
Building characteristics	To understand properties of the building in order to assess their vulnerabilities to disasters	• Number of floors • Size of house • Roof material and type • Building materials • Access to electricity, water and sanitation
Experience of 2015 and 2021 floods	To understand the impacts and people's experiences in the two and how they view the preparedness measures	• Early warning sources • Level of flooding and duration of water logging • Structural and non structural damages • Health impacts • Disruption of services •
Disaster vulnerability and resource access	To understand the vulnerabilities and flood experiences in general	• Reasons for waterlogging • Access to safe shelters • Access to early warning • Factors in the neighbourhood that increases the risk • Factors in the neighbourhood that reduces the risk • Impact on livelihood, education and access to essentials • Relief and aid received
Climate change impacts	To assess the understanding among the communities on climate change impacts	• Perception on change in rainfall and other weather events • Perception of climate change and sources of hearing about climate change

Survey data results

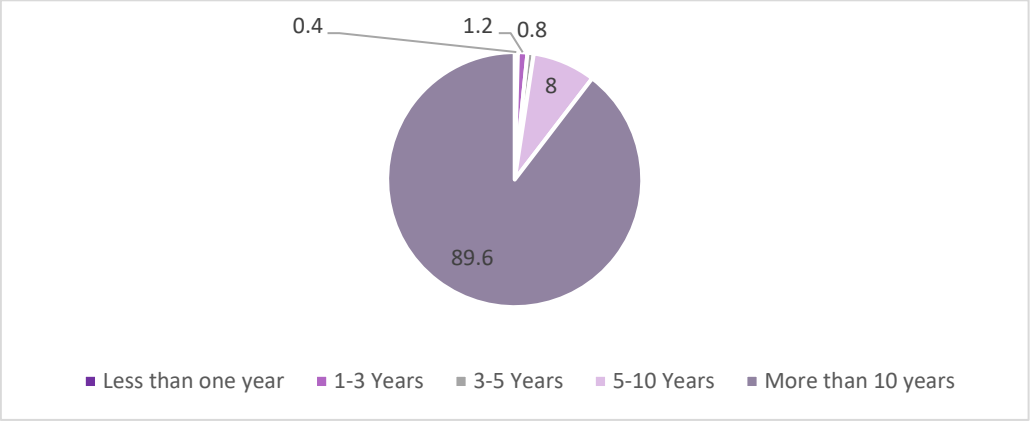


Figure 1: Duration of Current Residence

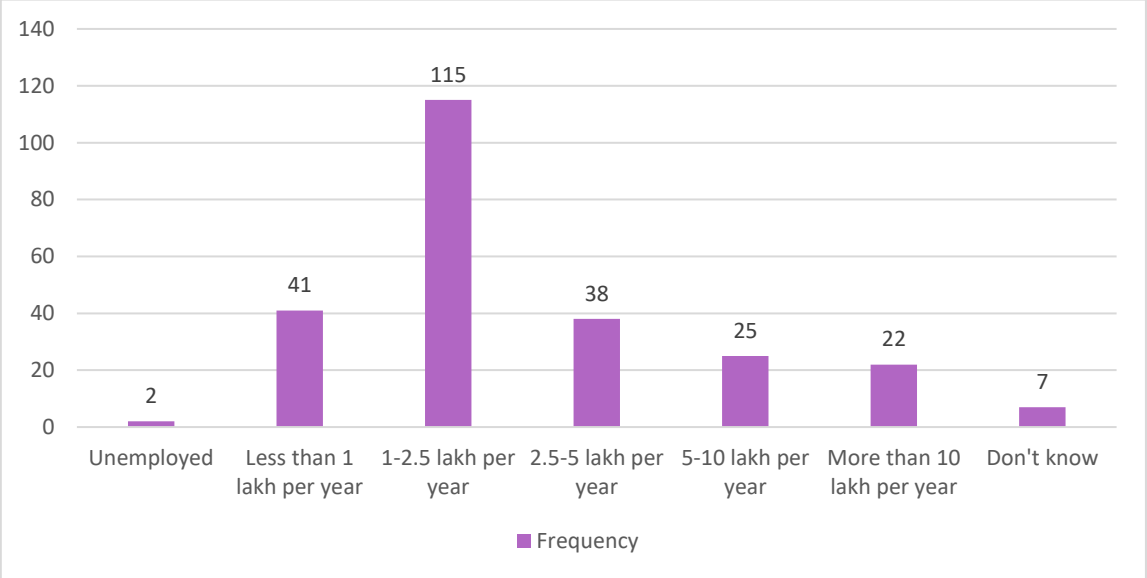


Figure 2: Household Income

**Key: Don't Know - those who doesn't wish to reveal their household's income.*

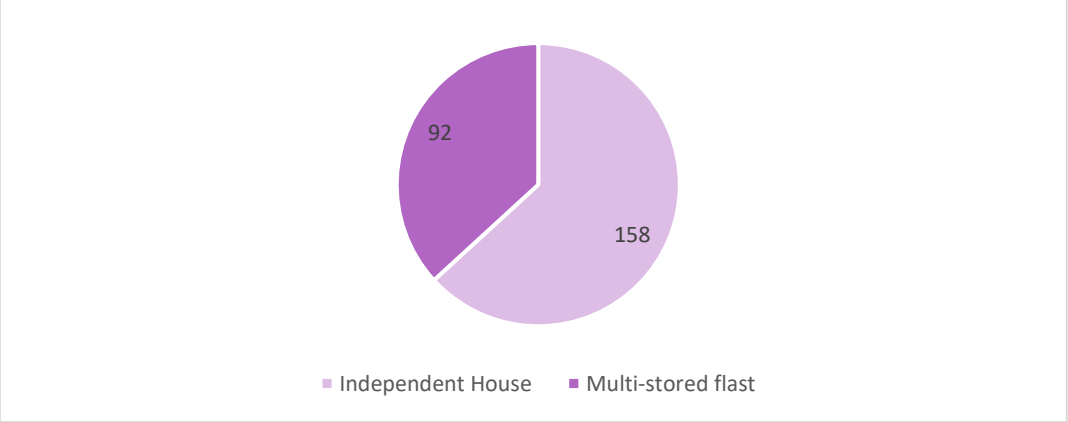


Figure 3: Type of House

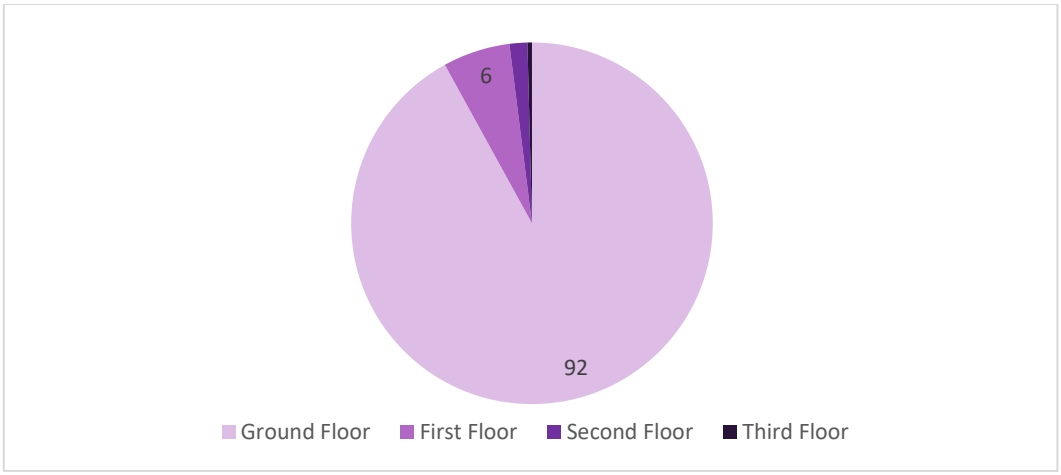


Figure 4: Level of Floor of House

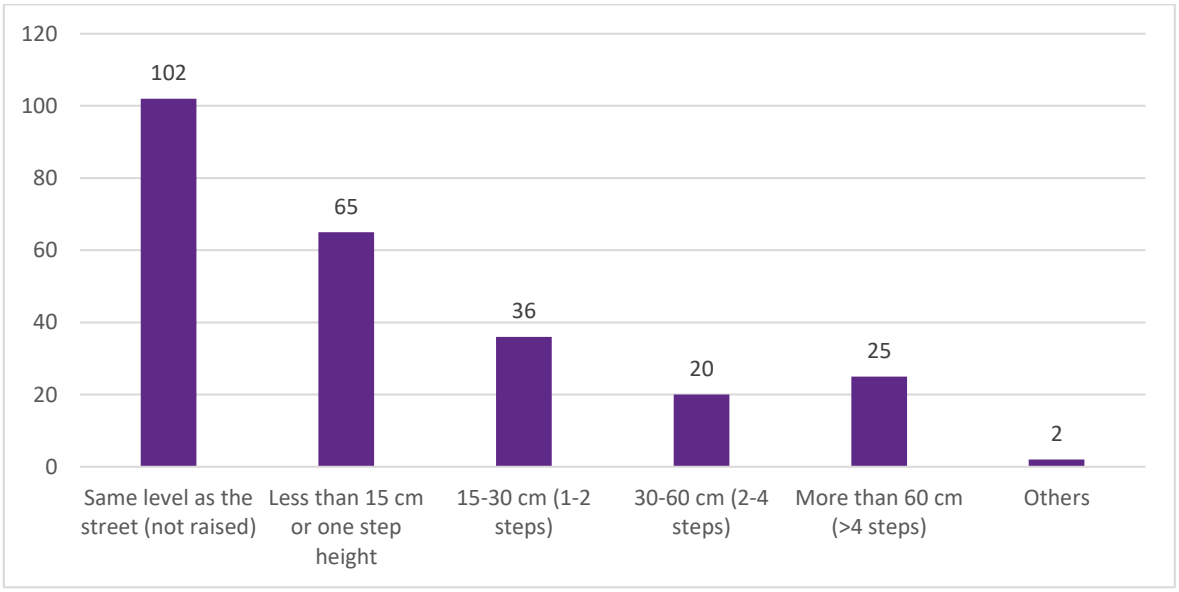


Figure 5: Height of Plinth

Does the house have a Piped Water Connection?

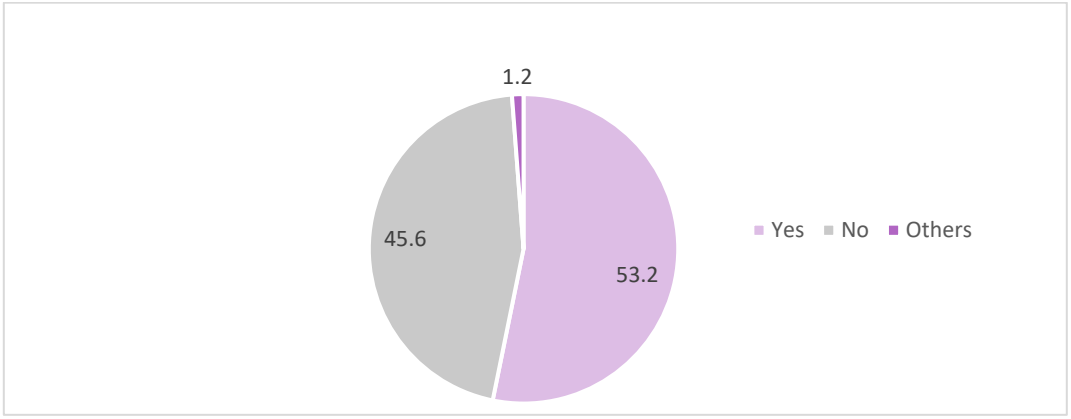


Figure 6: Piped Water Connection

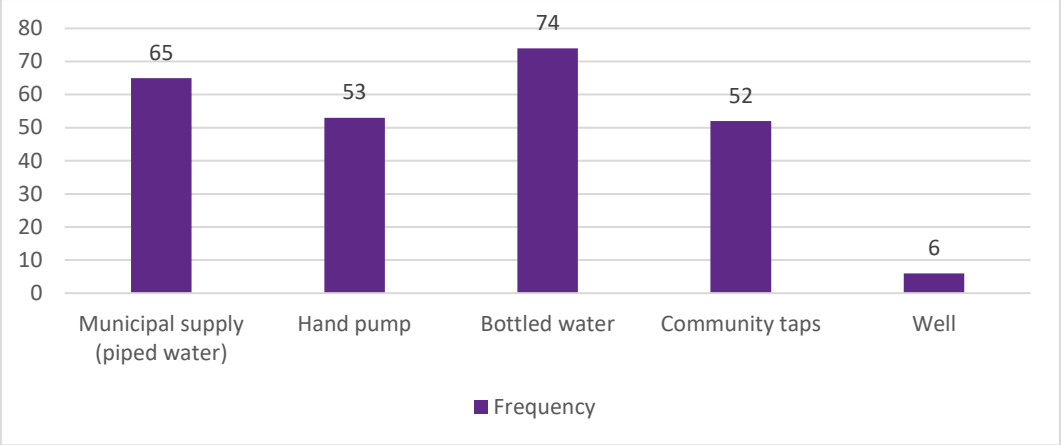


Figure 7: Source of Drinking Water

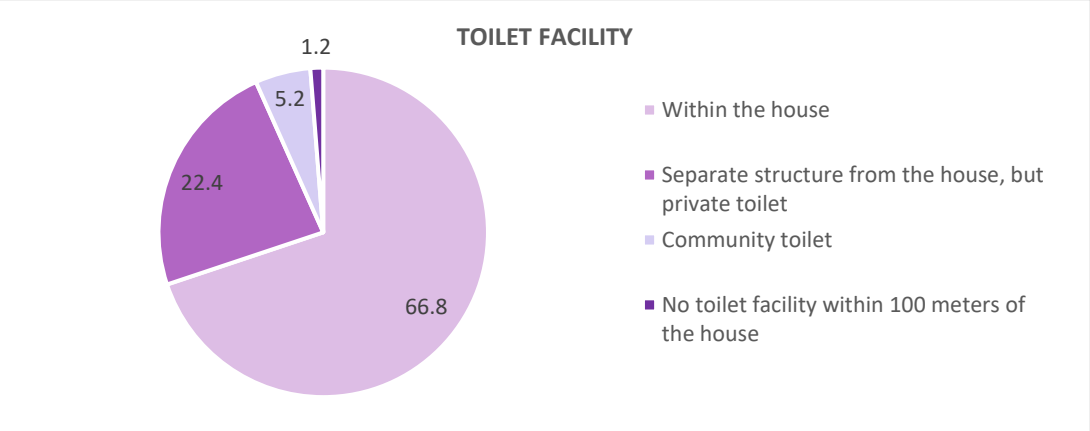


Figure 8: Toilet Facilities

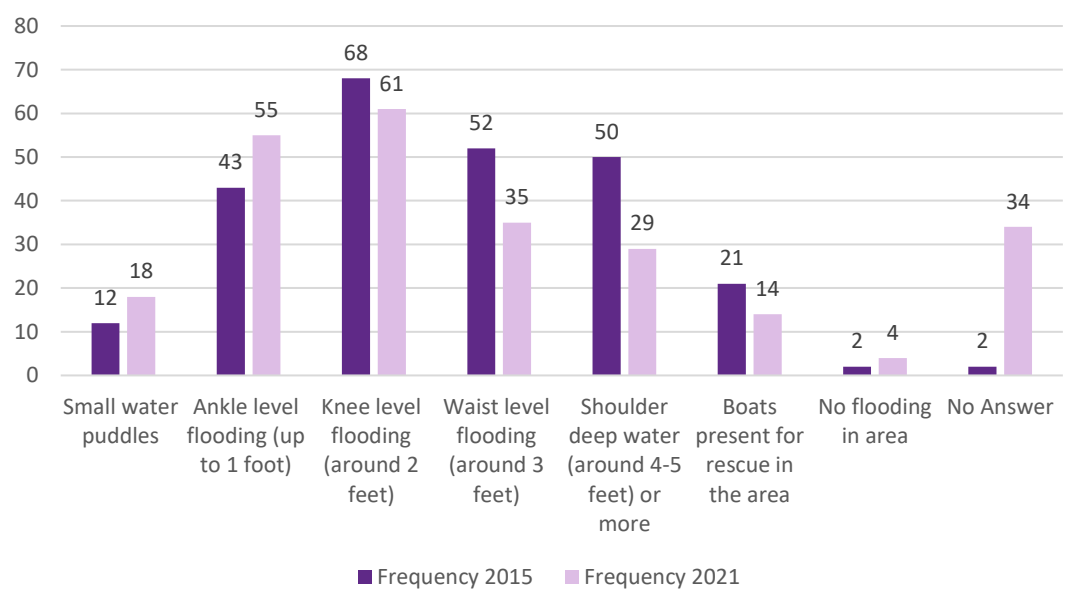


Figure 9: Level of Flooding in the Area

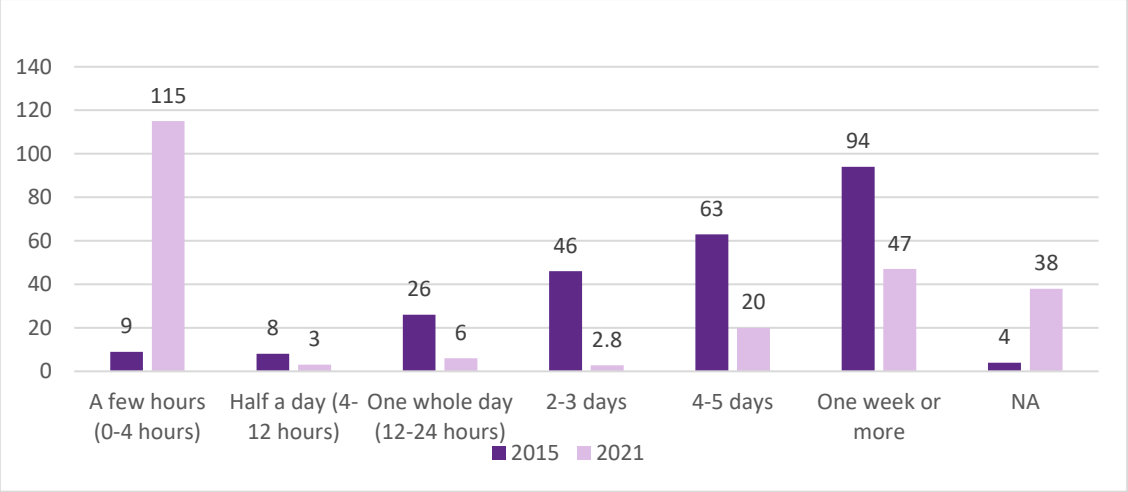


Figure 10: Duration of Water Stagnated in the Area

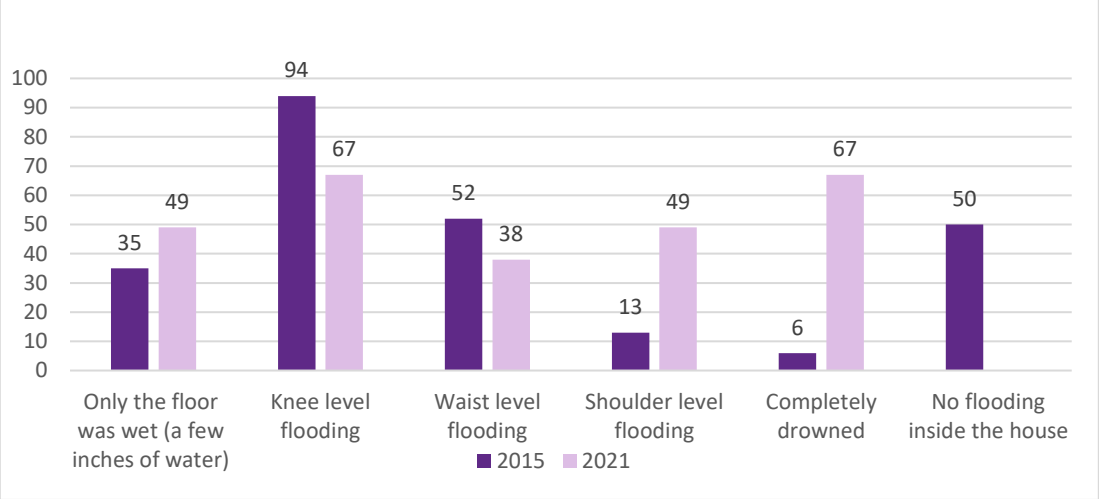


Figure 11: Level of Water Inside the House

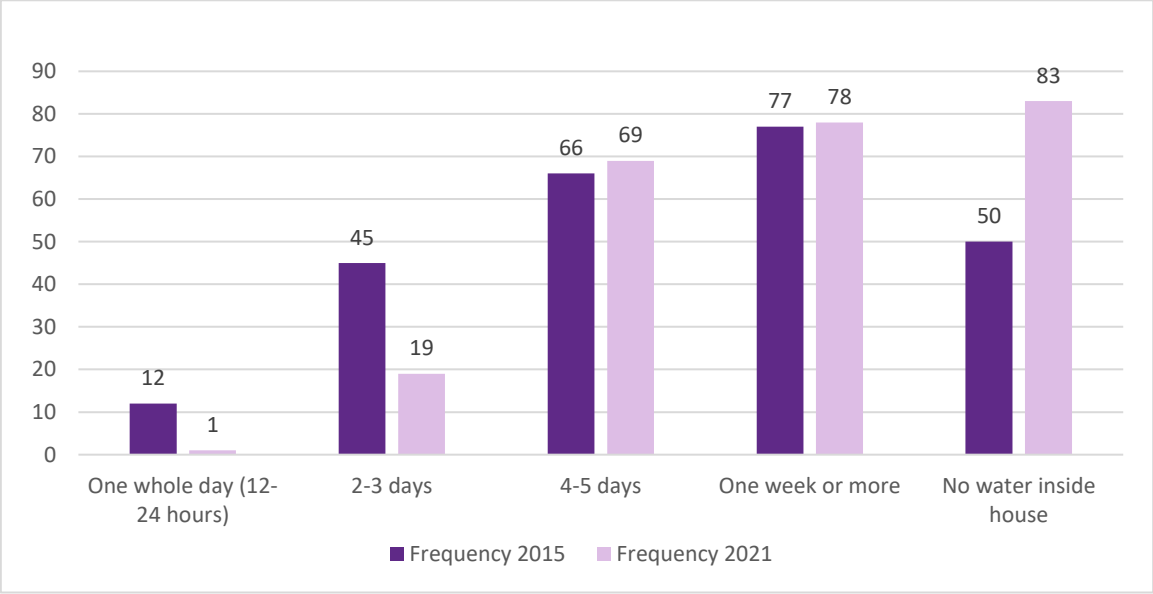


Figure 12: Duration of Water Stagnation in the House

Is your Household Members' Health Significantly Affected by the Flooding?

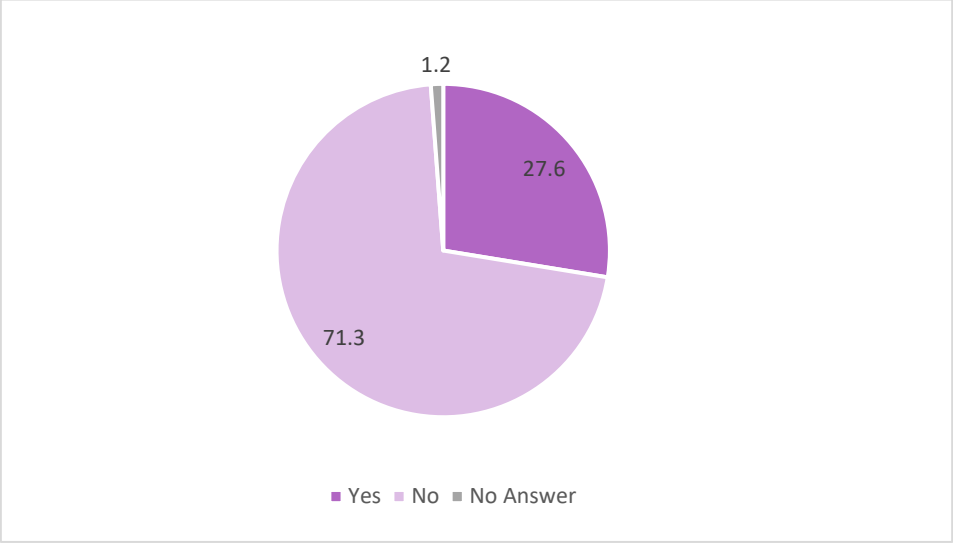


Figure 13: Household Members Health Significantly Affected by the Flooding

Was Your Access to Any of the Following Services Disrupted?

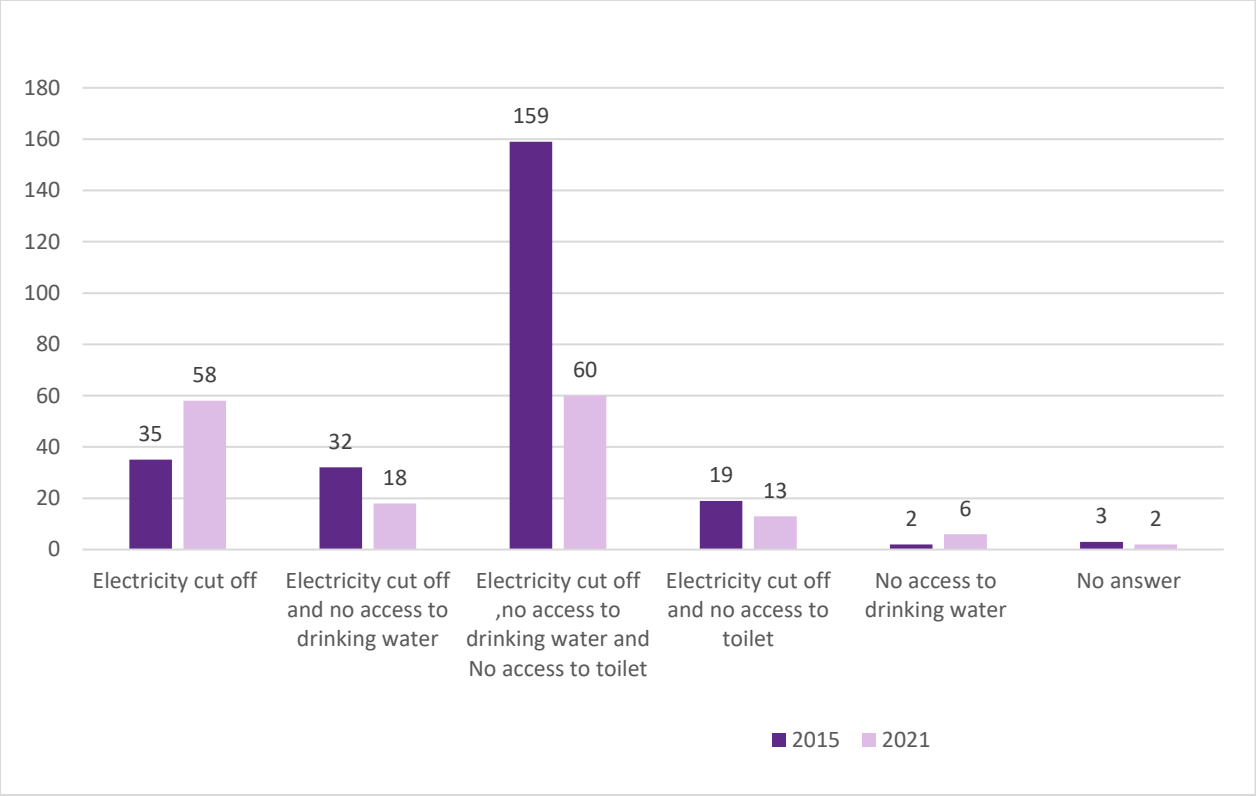


Figure 14: Services Disrupted during floods

How long did it take for the services to resume after disruption?

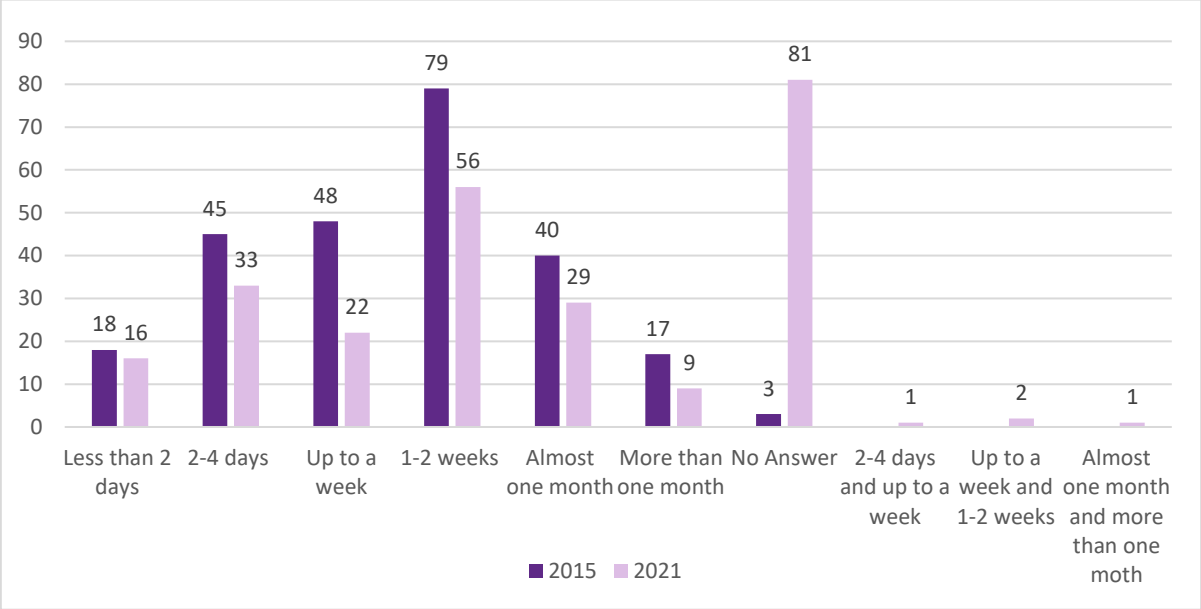


Figure 15: Duration of services resuming after disruption

Do You Know of Any Safe Shelters you can Access During Disasters?

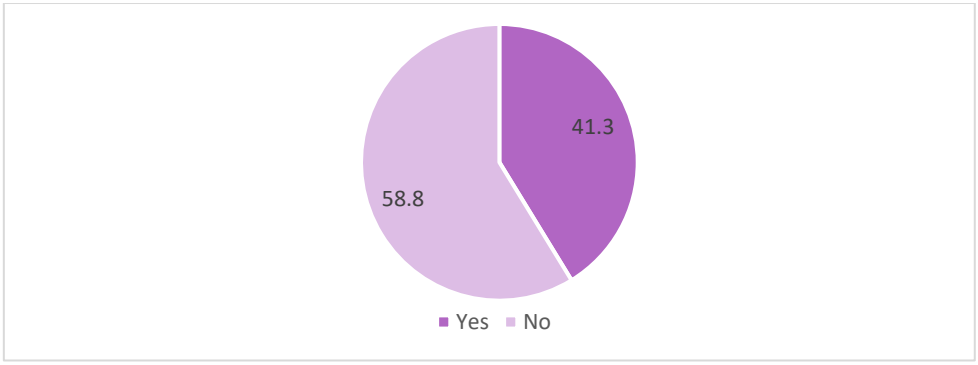


Figure 16: Awareness of any Safe Shelters accessibility during Disasters

How Far is the Nearest Shelter you can Access?

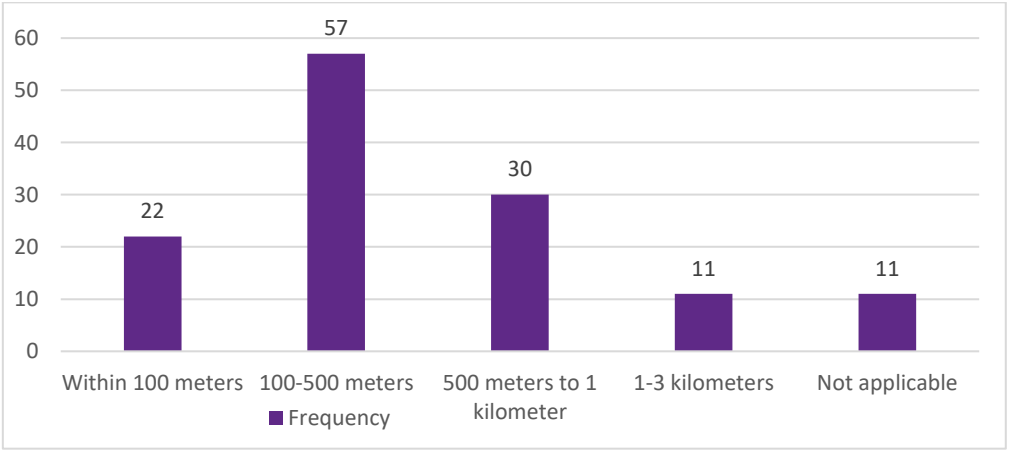


Figure 17: Distance from nearest accessible Safe Shelter

Are you able to access Groceries, Medicines, and other Essentials during flooding or periods of heavy rainfall? How do you access them?

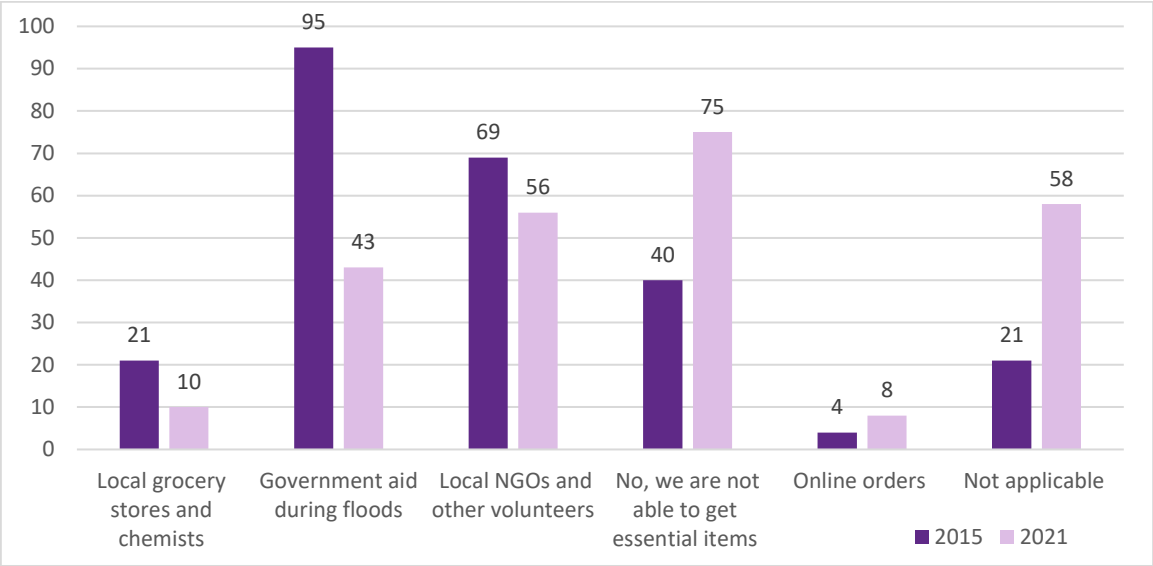


Figure 18: Access to Groceries, Medicines, and other Essentials during flooding or periods of heavy rainfall

Nature of Relief or Aid Received

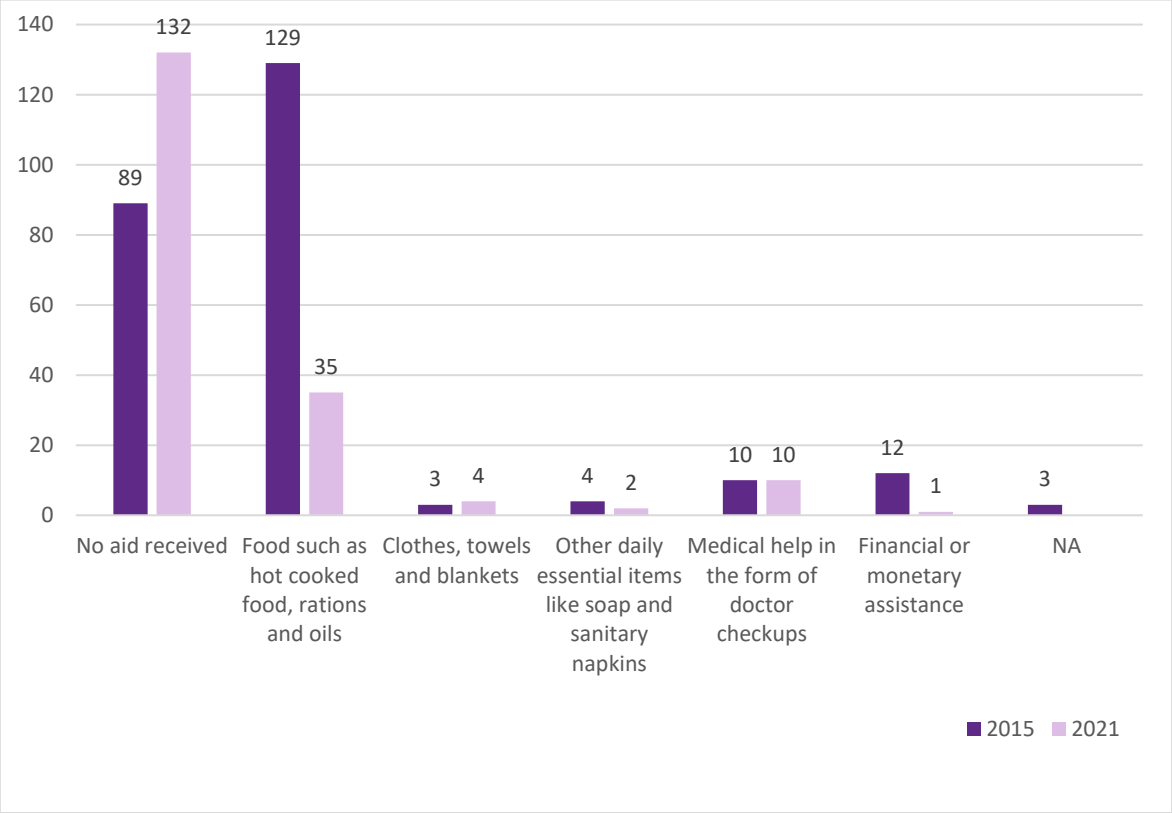


Figure 19: Nature of Relief or Aid Received

Before the First Floods, when did you know that Heavy Rainfall was going to Occur?

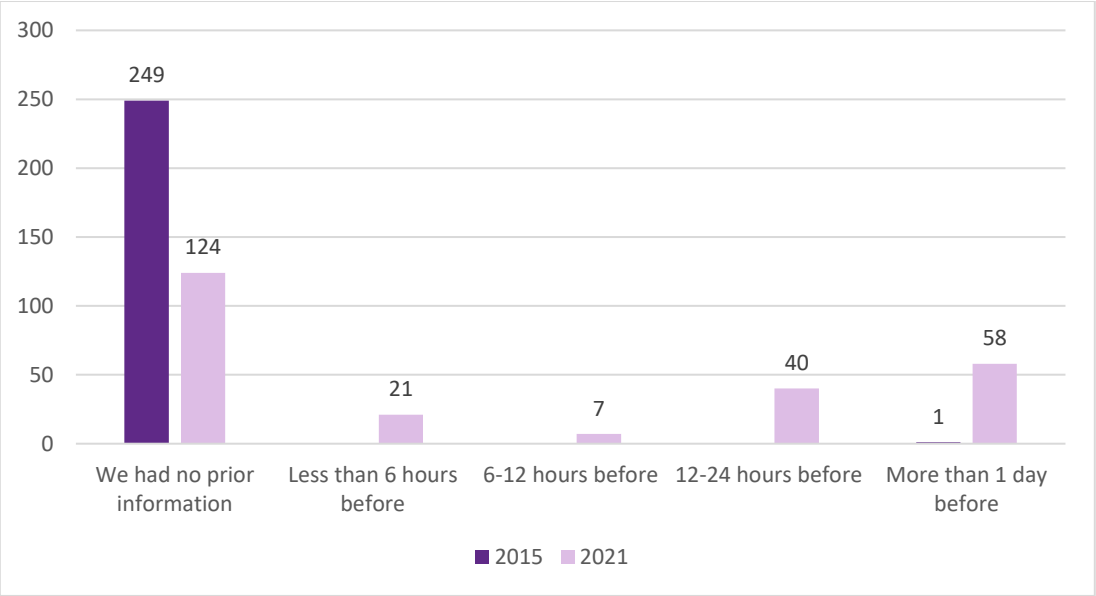


Figure 20: Before the First Floods, when did you know that Heavy Rainfall was going to Occur

What are the sources you rely on to get information about the weather?

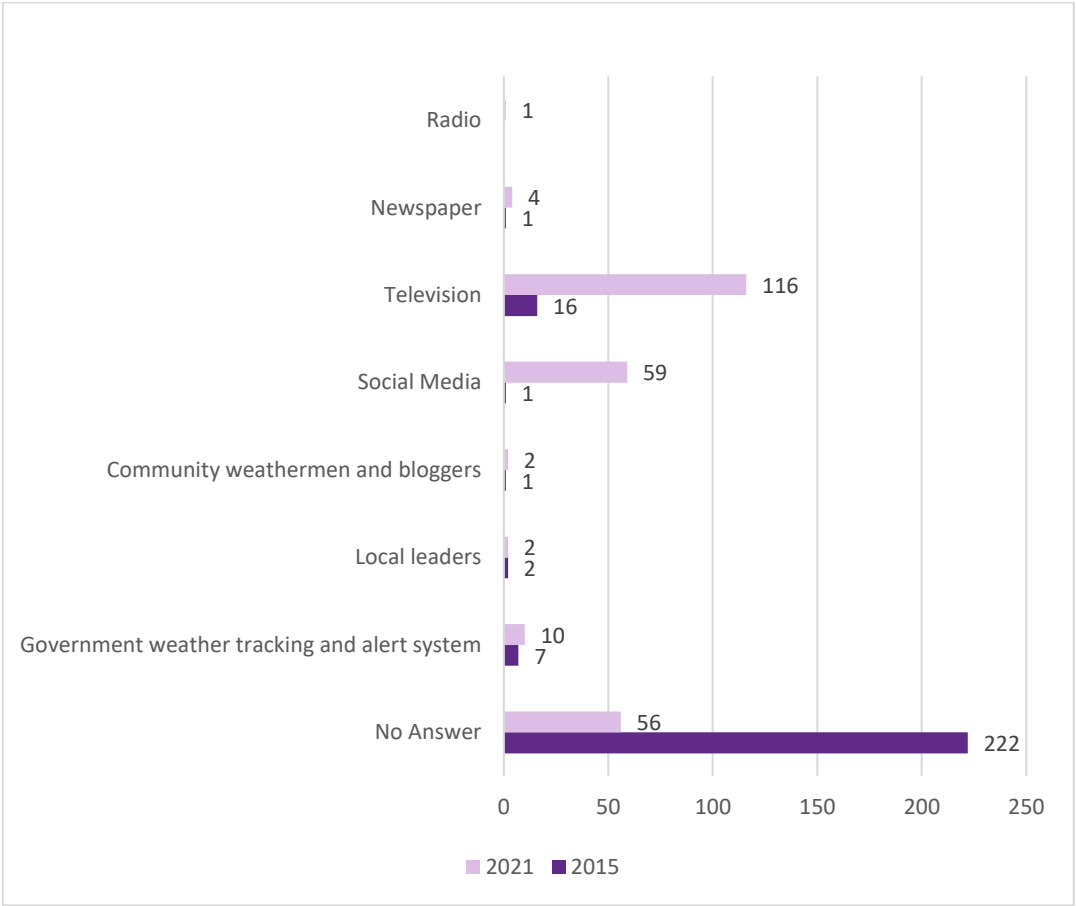


Figure 21: Sources of information about the Weather

Do you have Access to any Early Warning Systems, or sources from which you can learn about potential flooding events?

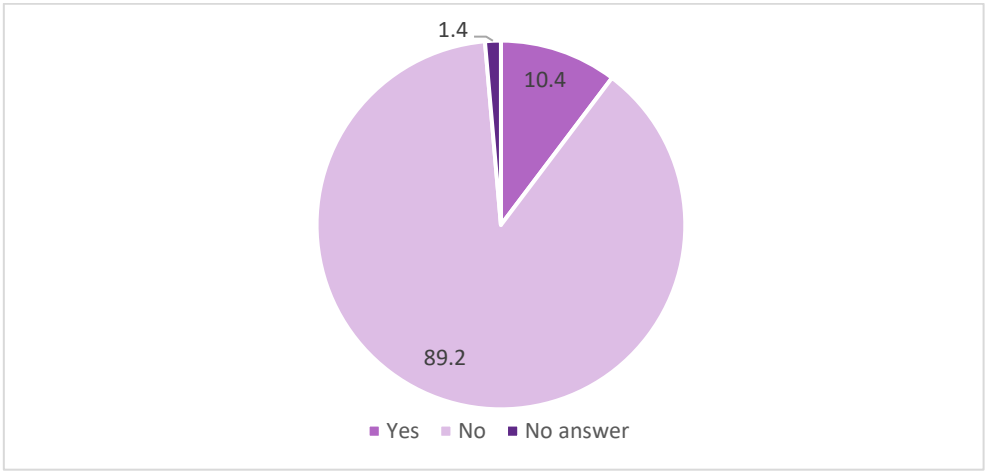


Figure 22: Access to any Early Warning Systems, or sources from which you can learn about potential flooding events

Sources of Early Warning Systems

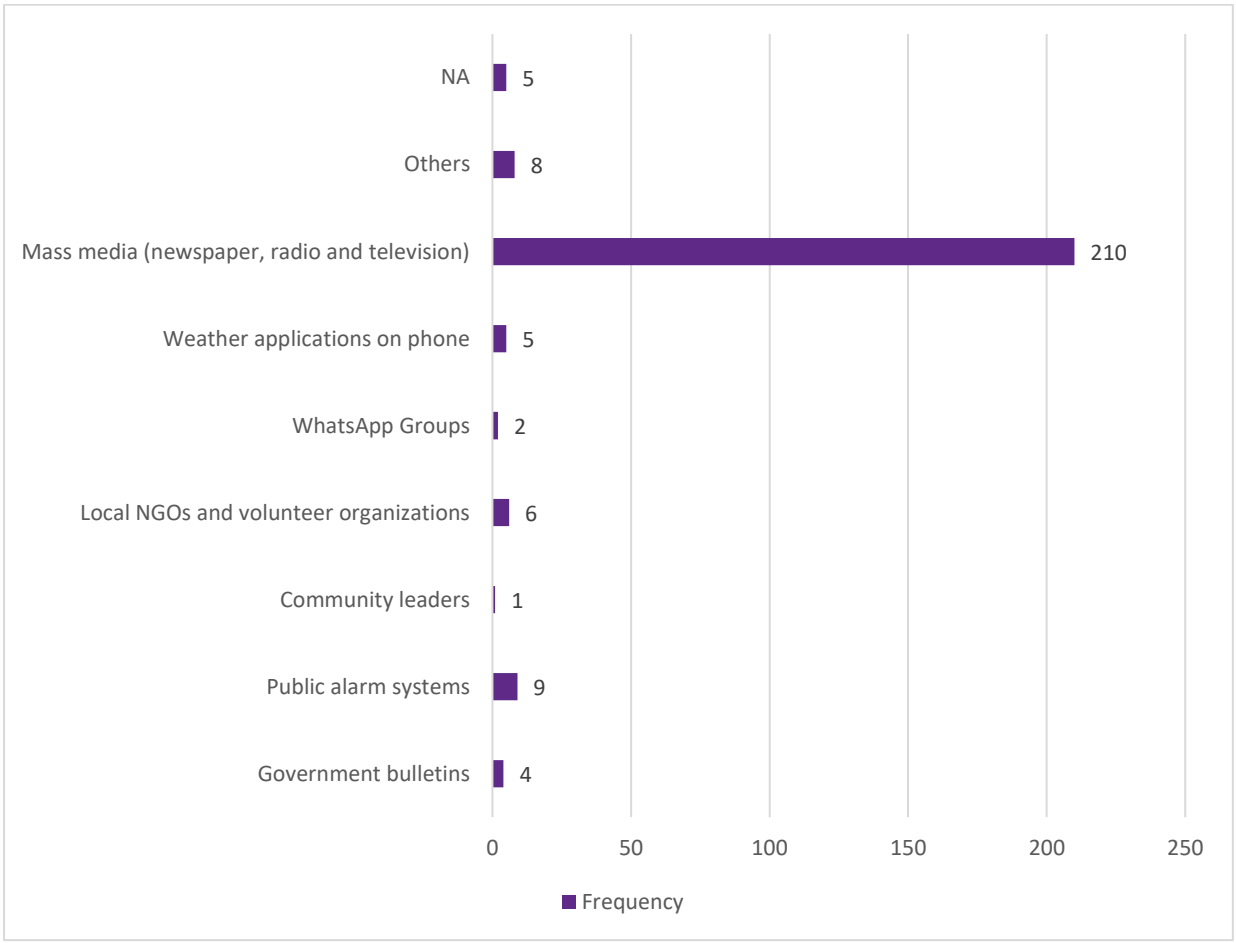


Figure 23: Sources of Early Warning Systems

Sources of Receiving Alerts

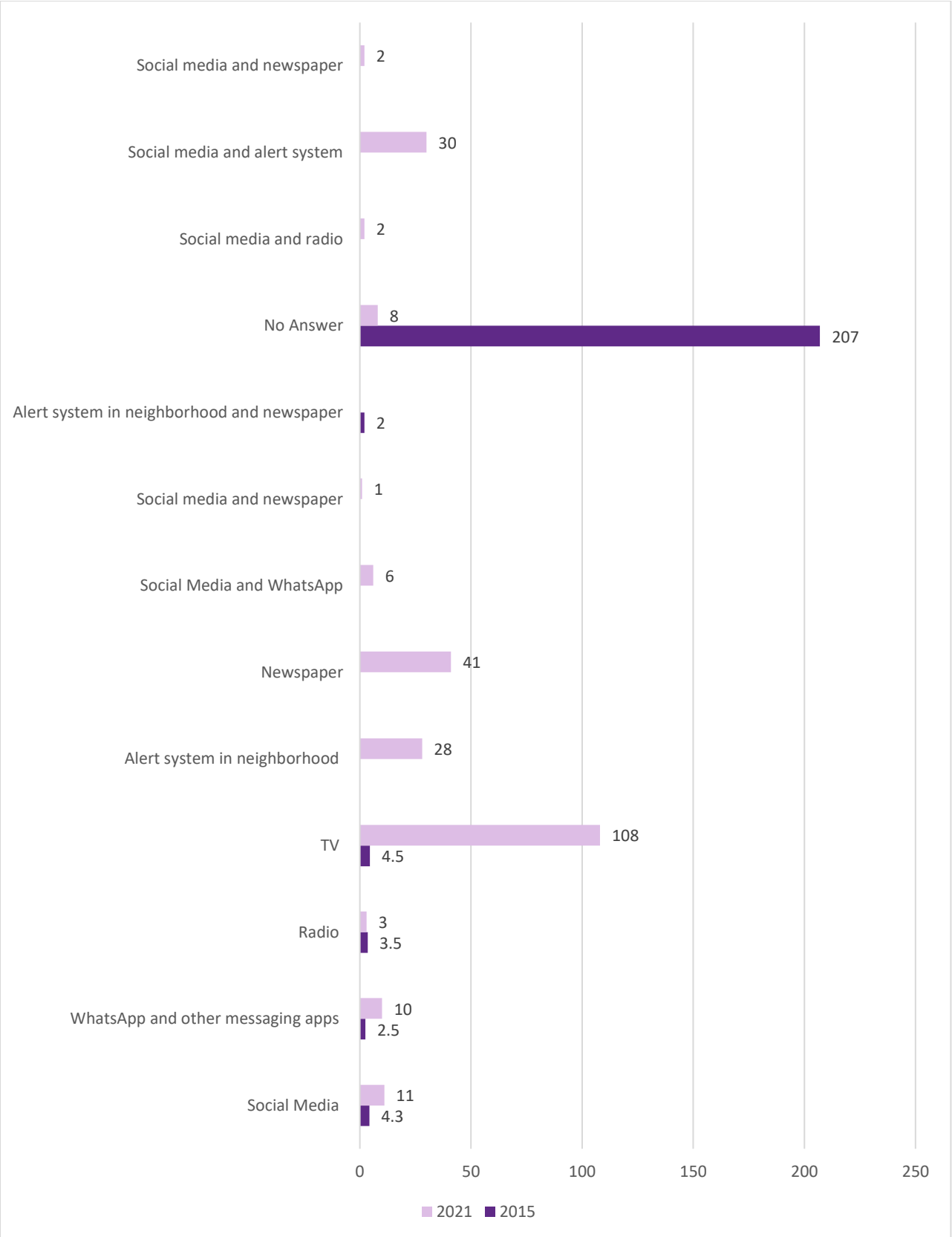


Figure 24: Sources of Receiving Alerts

How much time do you Need to Prepare for Heavy Rains after getting Information from these Weather Information Sources?

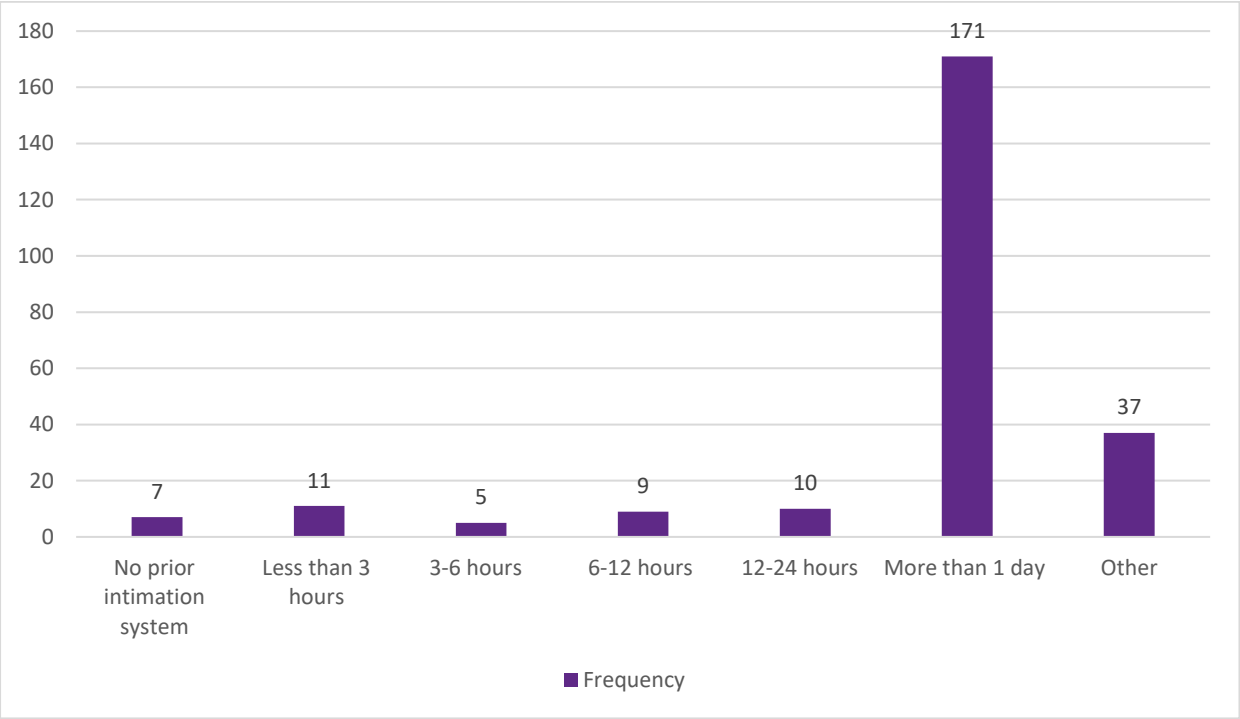


Figure 25: Time needed to prepare for heavy rains

Major Factors that Increase Water Logging in Houses

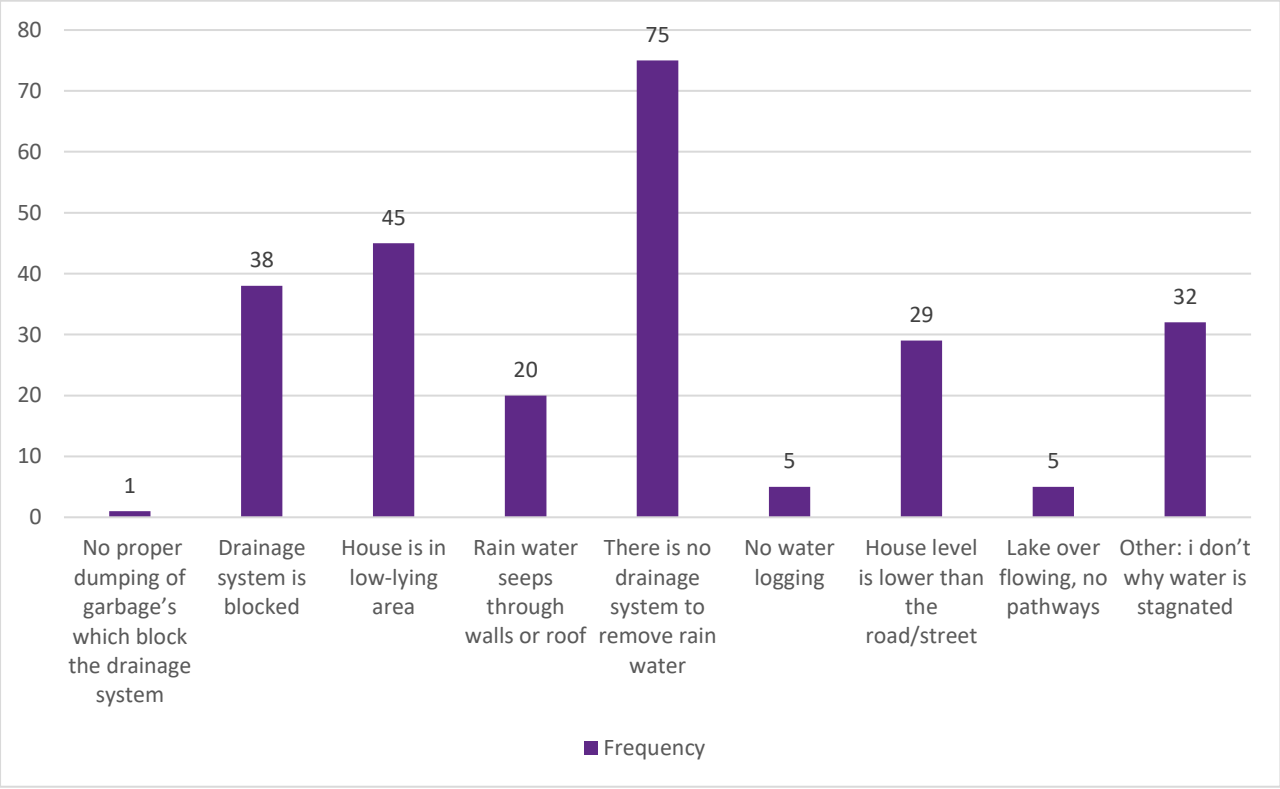


Figure 26: Major Factors that Increase Water Logging in Houses

Do you think Rainfall is Becoming More Intense or the Patterns of Rainfall have Changed over the past few years?

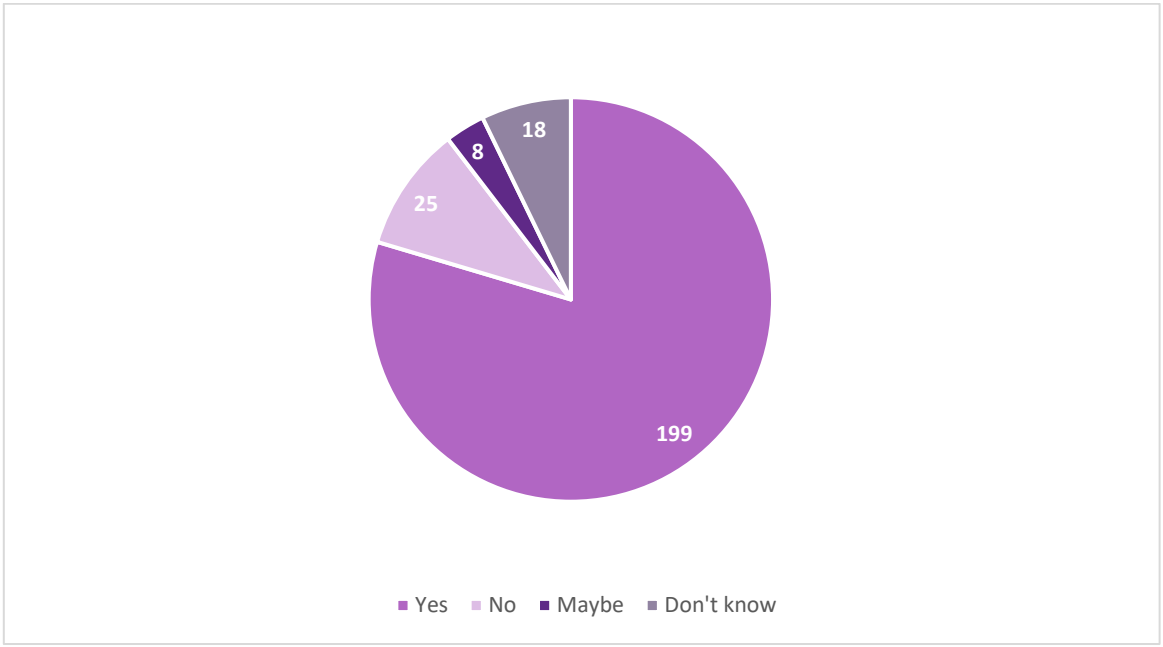


Figure 27: Changed rainfall Pattern over the past few years

Had you heard of Climate Change before the Survey? Are you aware of what it is supposed to mean?

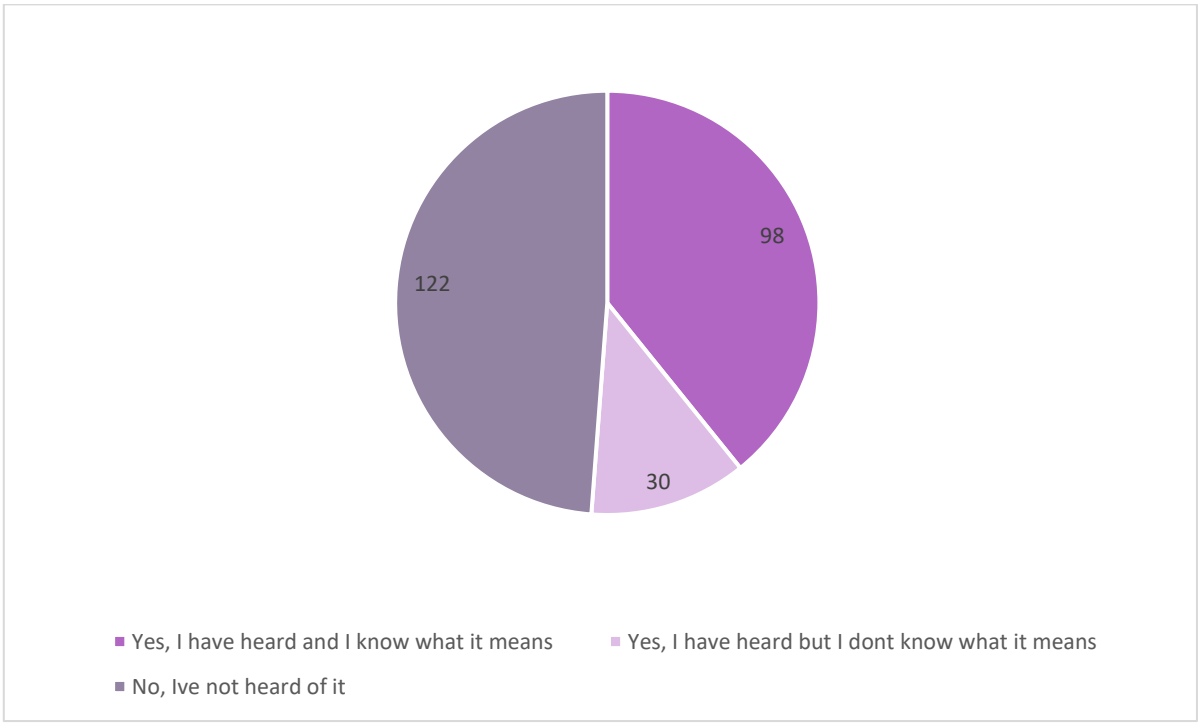


Figure 28: Awareness about Climate Change

Do you think Climate Change had anything to do with, or is the reason behind, Heavier Rainfall in Chennai?

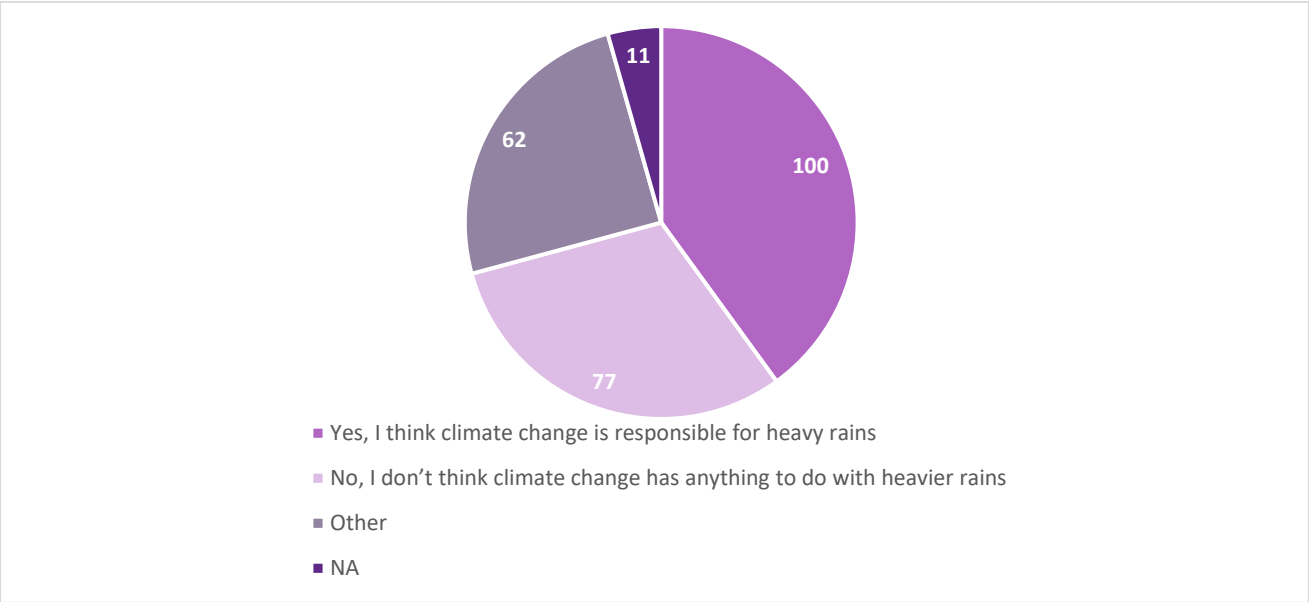


Figure 29: People opinion on climate change as a reason behind, heavier Rainfall in Chennai

Data stratification

In this section, we break down some of the key results by different characteristics such as social groups, income levels, and area to see how the results vary across groups.

Stratification by Social Groups

1. **Mobile Phone Access across Social Groups**

Table 2: Mobile Phone Access across Social Groups

Social Group	Mobile phones (% of Group)							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Upper Caste (General)	4	0	44	36	16	0	0	100
Scheduled Caste (SC)	4.7	22.1	29.1	20.9	15.1	4.7	3.5	100
Backward Class (BC)	0	8.9	41.8	15.2	24.1	3.8	6.3	100
Scheduled Tribes (ST)	0	0	0	0	100	0	0	100
Most Backward Class (MBC)	0	10.3	43.6	20.5	15.4	5.1	5.1	100
Others	0	30	20	0	40	10	0	100

2. Internet Access across Social Groups

Table 3: Internet Access across Social Groups

Social Group	Mobile phones with Internet Connectivity (% of Group)							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Upper Caste (General)	4	8	48	28	12	0	0	100
Scheduled Caste (SC)	25.6	24.4	29.1	9.3	7	2.3	2.3	100
Backward Class (BC)	6.3	24.1	31.6	17.7	15.2	1.3	3.8	100
Scheduled Tribes (ST)	0	0	0	0	100	0	0	100
Most Backward Class (MBC)	2.6	25.6	41	12.8	10.3	7.7	0	100
Others	20	10	30	0	30	10	0	100

3. House Sizes across Social Groups

Table 4: House Sizes across Social Groups

Social Group	Size of House (% of Group)			
	Less than 25 square metres	**25-100 square metres**	**More than 100 square metres**	**Total**
Upper Caste (General)	8	12	80	100
Scheduled Caste (SC)	45.3	40.7	14	100
Backward Class (BC)	12.7	44.3	43	100
Scheduled Tribes (ST)	0	100	0	100
Most Backward Class (MBC)	35.9	41	23.1	100
Others	30	10	60	100

4. Flooding Incidence in 2015 across Social Groups

Table 5: Flooding Incidence in 2015 across Social Groups

Social Group	What was the level of water inside your house in 2015? (% of Group)						
	Only the floor was wet (a few inches of water)	**Knee level flooding**	**Waist level flooding**	**Shoulder level flooding**	**Completely drowned**	**No flooding inside the house**	**Total**

Upper Caste (General)	4	52	12	4	0	28	100
Scheduled Caste (SC)	23.3	29.1	25.6	7	0	15.1	100
Backward Class (BC)	7.6	38	20.3	5.1	1.3	27.8	100
Scheduled Tribes (ST)	0	0	0	0	0	100	100
Most Backward Class (MBC)	10.3	43.6	25.6	0	10.3	10.3	100
Others	30	30	10	20	0	10	100

5. Flooding Incidence in 2021 across Social Groups

Table 6: Flooding Incidence in 2021 across Social Groups

Social Group	What was the level of water inside your house in 2021? (% of Group)						
	Only the floor was wet (a few inches of water)	**Knee level flooding**	**Waist level flooding**	**Shoulder level flooding**	**Completely drowned**	**No flooding inside the house**	**Total**
Upper Caste (General)	20	20	16	0	8	36	100
Scheduled Caste (SC)	14	36	17.4	10.5	1.2	20.9	100
Backward Class (BC)	16.5	27.8	10.1	1.3	0	44.3	100
Scheduled Tribes (ST)	0	0	100	0	0	0	100
Most Backward Class (MBC)	38.5	12.8	12.8	0	0	35.9	100
Others	10	30	20	0	0	40	100

6. Water Stagnation Duration in 2015 across Social Groups

Table 7: Water Stagnation Duration in 2015 across Social Groups

Social Group	What was the duration of water stagnation in 2015? (% of Group)					
	One whole day (12-24 hours)	**2-3 days**	**4-5 days**	**One week or more**	**No water inside house**	**Total**
Upper Caste (General)	0	20	16	36	28	100
Scheduled Caste (SC)	4.7	12.8	27.9	33.7	20.9	100
Backward Class (BC)	5.1	22.8	27.8	26.6	17.7	100
Scheduled Tribes (ST)	0	0	100	0	0	100
Most Backward Class (MBC)	5.1	15.4	30.8	30.8	17.9	100
Others	20	40	10	30	0	100

7. Water Stagnation Duration in 2021 across Social Groups

Table 8: Water Stagnation Duration in 2021 across Social Gro

Social Group	What was the duration of water stagnation in 2021? (% of Group)					
	One whole day (12-24 hours)	**2-3 days**	**4-5 days**	**One week or more**	**No water inside house**	**Total**
Upper Caste (General)	16	28	16	0	40	100
Scheduled Caste (SC)	14	14	16.3	9.3	46.5	100
Backward Class (BC)	24.1	11.4	21.5	16.5	26.6	100
Scheduled Tribes (ST)	0	0	0	0	100	100
Most Backward Class (MBC)	28.2	12.8	25.6	10.3	23.1	100
Others	40	30	30	0	0	100

8. Livelihood Impacts due to Floods across Social Groups

Table 9: Livelihood Impacts due to Floods across Social Groups

Social Group	Livelihood Impacted by Floods (% of Group)		
	Yes	**No**	**Total**
Upper Caste (General)	84	16	100
Scheduled Caste (SC)	96.5	3.5	100
Backward Class (BC)	92.4	7.6	100
Scheduled Tribes (ST)	100	0	100
Most Backward Class (MBC)	89.7	10.3	100
Others	80	20	100

Stratification by Annual Income

Livelihood Impacts due to Floods across Annual Income Groups

Table 10: Livelihood Impacts due to Floods across Annual Income Groups

Annual Income	Livelihood Impacted by Floods (% of Group)		
	Yes	**No**	**Total**
Less than 1 lakhs	100	0	100
1 - 2.5 lakhs	93.9	6.1	100
2.5 - 5 Lakhs	84.2	15.8	100
5 - 10 lakhs	96	4	100
More than 10 lakhs	90.9	9.1	100
Unemployed	50	50	100

Stratification by Area

1. Flooding Incidence in 2015 across Vulnerable Areas

Table 11: Flooding Incidence in 2015 across Vulnerable Areas

Area	What was the level of water inside your house in 2015? (% of Group)						
	Only the floor was wet (a few inches of water)	Knee level flooding	Waist level flooding	Shoulder level flooding	Completely drowned	No flooding inside the house	Total
Puliyanthope	16	4	36	20	0	24	100

Madipakkam	0	100	0	0	0	0	100
Perumbakkam	28	12	12	12	0	36	100
Semmenchery	0	0	100	0	0	0	100
T Nagar	8	40	4	0	20	28	100
Ashok Nagar	4	88	4	0	0	4	100
Pattalam	4	24	20	12	4	36	100
KM Garden	80	20	0	0	0	0	100
Manali	0	68	32	0	0	0	100
Kolathur	0	8	12	8	0	72	100

2. Flooding Incidence in 2021 across Vulnerable Areas

Table 12: Flooding Incidence in 2021 across Vulnerable Areas

Area	What was the level of water inside your house in 2021? (% of Group)						
	Only the floor was wet (a few inches of water)	Knee level flooding	Waist level flooding	Shoulder level flooding	Completely drowned	No flooding inside the house	Total
Puliyanthope	8	60	0	0	0	32	100
Madipakkam	16	20	8	0	8	48	100
Perumbakkam	16	16	8	0	0	60	100
Semmenchary	0	24	36	0	0	40	100
T Nagar	56	0	8	0	0	36	100
Ashok Nagar	20	28	16	0	0	36	100
Pattalam	4	16	20	40	0	20	100
KM Garden	16	36	44	0	0	4	100
Manali	48	12	8	0	4	28	100
Kolathur	12	56	4	0	0	28	100

3. Duration of Water Stagnation in 2015 across Vulnerable Areas

Table 13: Duration of Water Stagnation in 2015 across Vulnerable Areas

Area	What was the duration of water stagnation in 2015? (% of Group)

	One whole day (12-24 hours)	2-3 days	4-5 days	One week or more	No water inside house	Total
Puliyanthope	4	28	24	28	16	100
Madipakkam	0	12	32	36	20	100
Perumbakkam	0	16	52	24	8	100
Semmenchary	0	16	28	36	20	100
T Nagar	16	24	16	24	20	100
Ashok Nagar	12	44	20	20	4	100
Pattalam	4	12	16	40	28	100
KM Garden	8	20	36	24	12	100
Manali	12	8	24	32	24	100
Kolathur	0	0	16	44	40	100

4. Duration of Water Stagnation in 2021 across Vulnerable Areas

Table 14: Duration of Water Stagnation in 2021 across Vulnerable Areas

Area	What was the duration of water stagnation in 2021? (% of Group)					
	One whole day (12-24 hours)	2-3 days	4-5 days	One week or more	No water inside house	Total
Puliyanthope	12	8	64	12	4	100
Madipakkam	28	48	8	0	16	100
Perumbakkam	12	20	40	28	0	100
Semmenchary	0	0	12	0	88	100
T Nagar	52	4	20	24	0	100
Ashok Nagar	64	24	8	4	0	100
Pattalam	12	20	8	8	52	100
KM Garden	20	32	24	24	0	100
Manali	0	0	12	0	88	100
Kolathur	4	0	8	4	84	100

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