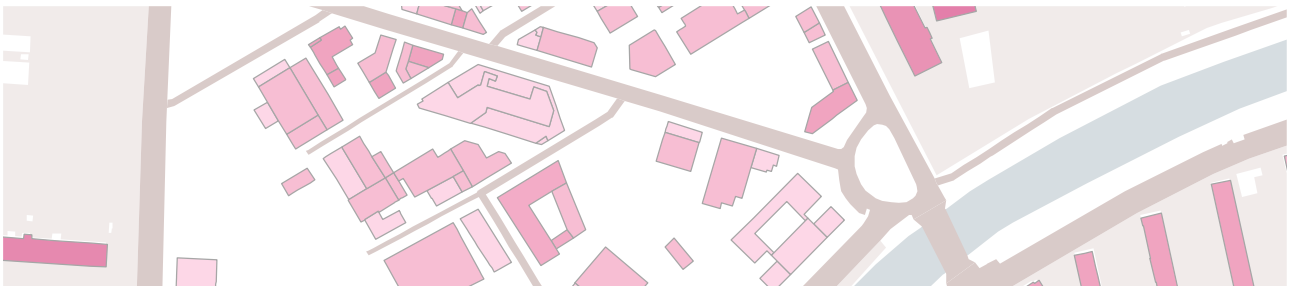
URBAN FLOOD RESILIENCE
TURIN



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URBAN FLOOD RESILIENCE

General Overview and Comparative Analysis.

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Warm gratitude to the people who participate in the interview.

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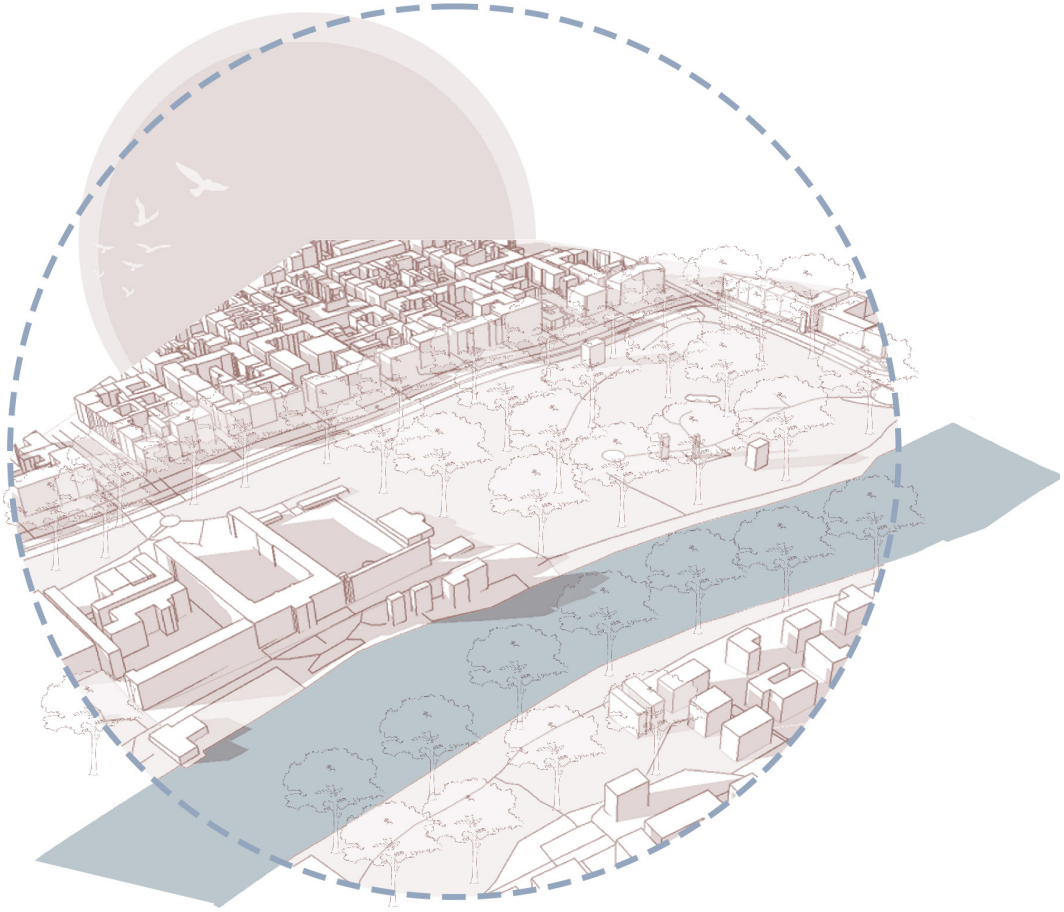

ABSTRACT

Urban flooding is one the most destructive natural and man-made disasters which is causing a significant amount of fatality and financial loss. Over the globe, cities are confronting complex and questionable challenges, including urbanization, heavy rainfall, landslides, climate change, heatwaves, dangers to water supply, and increased flood risk. Among all these causes, the most proven reason is rapid urbanization and the thesis will address all the issues related to urban flooding. Nevertheless, urban flooding is treated as the cause of heavy rainfall without considering the watershed as an interrelated system connected with the development of its domain.

The conventional flood control approach needs constant monitoring, persistent corrective measures, and intervention after learning from past events. To achieve a level where even the city will get flood still it will able to run off the excess water itself. This system requires progressively expensive investment to build or retrofit the structure which is competent to quarter the runoff water collected from urbanized areas. However, these systems are unable to prevent a city from high flood destruction globally. Therefore, there's an ought to alter storm water management procedures and start following the risk management approach, which contemplates the cost analysis.

Additionally, considering all these factors need to focus on the major issue that is urbanization, uncontrolled growth of the urban sector, and climate change. To tackle the growing threats of urban flooding, for cities, it is a necessity to mitigate the integrated Urban Flood Risk Management to achieve urban flood resilience in an uncertain future. The thesis research helps to understand the problem and the source with the help of case studies from many cities. It also focuses on the urban policies developed by developed and developing countries to overcome the risk of urban flooding. This thesis report looks into all the aspects which contribute to urban floodings such as urbanization, climate change, land use land cover, expanding built-up area, encroachment, run-off retention, permeable and non-permeable surface, and structural and non-structural urban flood resilience policies.

Keywords: Urban Flooding, Urbanization, Flood control, Climate Change, Urban Flood Resilience, Flood Risk management .

METHODOLOGY

The research that has been carried out for the thesis is based on the methodology of scientific research, with the help of articles and books for which the references are mentioned in the bibliography. The case studies that have been mentioned in the thesis are justifying the theoretical data. For the thesis, a set of interviews was conducted by the Author in order to acknowledge the experience of the residents, which are mentioned in the annex.

This thesis consists of 5 chapters starting with the synopsis explaining the purpose of the thesis and the reason to choose the topic, to justify the reason there is a case study. Chapter 1 explains the source and types of flood threat and urban flood resilience. Chapter 2 explains how urban flooding is a global affair? To justify this there are two cases studies from two different continents. Chapter 3 explains the counties which are trying to achieve Urban Flood Resilience in the form of case studies. Chapter 4 consists of the brief of How piedmont in Italy is suffering from urban flooding. Furthermore, it focuses on the study area Turin Italy. In the end, chapter 5 explains the Urban Flood Risk management Policies by Italian authorities. The thesis is concluded with the data provided and achieved during the research.

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Flooded street in Hoboken, New Jersey, USA.

SOURCE:https://www.bloomberg.com/news/articles/2018-12-12/u-s-urban-flooding-study-it-s-bad-and-getting-worse

A SYNOPSIS FOR THE THESIS.

BACKGROUND OF THESIS.

Urban flooding is a significant and rapidly growing threat for developed or developing countries. More than the topographical conditions, rapid urbanization, and climate changes have become the major cause. The disturbance and destruction caused by urban flooding are beyond any data to record. Now, it is time to take necessary actions by the authorities, government, policymakers, and stakeholders. This thesis describes the old and new approaches, designs, and policies developed in different cities and countries.

Furthermore, the key role of the synopsis is to under the reason to choose this topic for the thesis. As a Citizen of India, which is a developing country, the author has experience as well as studying about other states in India that have been facing the same urban flood issue. It has been affecting my life while commuting, however for rest the of the citizen it is worse, who lives in urban areas but under temporary settlements.

This synopsis includes topics which:

- Describes the reason to choose this topic.
- A case study on Indian city to explain the condition of urban flooding in India.
- Describe impacts of urban floods worldwide.
- Discuss the increasing issue of urban flooding.
- Discuss the condition, source, and measures taken by India to tackle urban flooding.
- Describe a reason to go with this topic and the aim to achieve goals at the end.

This thesis includes the case studies of the cities that have been dealing with urban flooding, international studies to understand how to tackle urban flooding, and to explain the growing issue of the urban flood around the world. Additionally, it explains the situation of the current city I am living in is Turin, Italy. To explain the process or method of urban flooding and urban flood resilience, this thesis contains graphical representation, tabular representation, and architecture maps. The graphical representation and tabular representation have been used to explain the government policies developed to resist and mitigate the urban flood risk. The architecture maps describe the location of the city and the major rivers within the city. The map has been developed by ArcMap GIS software with the data allocated in the ESRI, which is an international platform of GIS and geodatabase management applications.

Moreover, this chapter summarizes that the world has to acknowledge the rapidly growing risk of Urban Flooding take action to overcome the threat; for policymakers to recognize, the time has come to use the concept of adoption, resistance, and mitigation. To recognize the fact that urban flooding brings more challenges over time, majorly causing fatality loss and financial loss all over the world. Hence, this thesis has described the Urban Flood Risk management Policies and the path on which all the countries following this, are the policies helping those counties to tackle the issue or the policies that need to upgrade for better performance and outcomes.

Aim to choose Urban Flooding.

This section describes the reason to follow urban flood as a thesis topic and questions about the problems arising due to urban flooding. Furthermore, this part focuses on the aim reason, majorly because of the author's native country. India is one of the rapidly developing countries in the world. At present, India has 28 states and 9 union territories.[1] As per the Census of India provided by the Ministry of Home Affairs, Government of India and the last 2011 census report shows Indian population is 377million.[2] There are many states such as Delhi, Uttar Pradesh in the north, Assam in the East, Maharashtra in the west, Bihar in the Center, and Tamil Nadu in the South that has been facing urban flooding issue for over three decades now. Moreover, it is the author's personal experience of living in the capital city of Delhi. Moreover, the condition of urban flooding and government policies has been explained in chapter 2.4 briefly. Although, it is possible to figure out the key reasons for the flood in India. The reasons are almost the same in every state in India. The challenges of urban flooding are not easy to tackle due to the densely urbanized cities and old sewage systems. Moreover, the cases of flooding have been noted more during June to September because the monsoon clouds come from the South-West and from October to December because of the North-East monsoon clouds.[3]

The reason for flooding is a natural cause also, because India is surrounded by ocean from West to East, so most of the times flooding occurred due to the cyclones in the ocean. Additionally, urbanization plays an important role in urban flooding. The amalgamation of urban growth, urbanization, and heavy rainfall has increased the risk of flooding in urban areas. The permeable area has been reused in all the cities in India due to densely constructed settlements, especially in urban areas. This is one of the reasons for surface water that it can not run off and cause a flood. Overpopulation and mass movement of people from rural to urban areas in search of a better opportunity has caused encroachment, unplanned or unauthorized settlements, removal of water bodies, removal of permeable surface, hence reducing the groundwater discharge. In addition to the above, overloaded urban areas are still using the old drainage system, a result of which the capacity of sewers to run off the excess surface water has reduced or has been completely ineffective. The condition of the drainage system is extremely bad and contains garbage which is affecting the whole city's drainage connection. Because of urban development, and construction, the width of drainages has been reduced which is not sufficient to full fill its purpose. This is not only because of the residents or encroachment, another reason is the lack of planning and strict laws from local or state authorities.[4]

Furthermore, there are many incidents that have occurred of urban flooding and heavy rainfall, although one is the most disastrous occurred in Mumbai city in July 2005. During this time, Mumbai's climate recorded almost 944mm of rainfall in a day. In resultant of heavy rainfall, the

1 States Uts - Know India: National Portal of India (no date). Available at: https://knowindia.india.gov.in/states-uts/

2 Population, total - India | Data (no date). Available at:https://data.worldbank.org/indicator/SP.POP.TOTL?end=2020&locations=IN&start=1960&view=chart

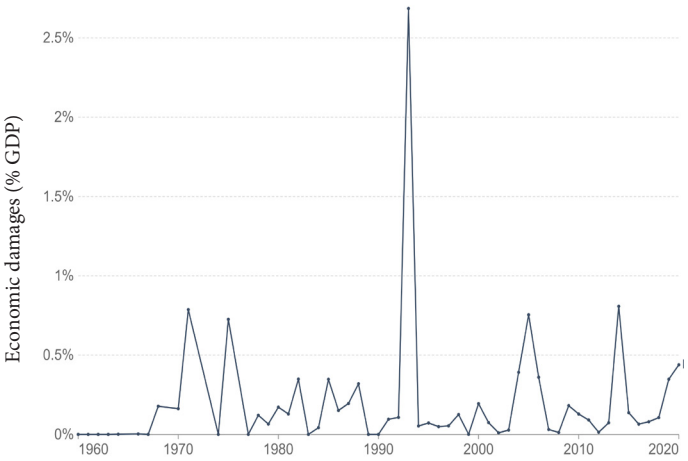
3 Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.

4 Ibid.

city was filled with rainwater and drainage water causing a blackout in the city. Over and above that, the percent of fatality and financial loss has caused due to flooding is a lot. The data of financial loss of annual GDP and deaths has been explained in the form of graphs in Figures 1 and 2.

Figure 1 describes the average economical loss from the year 1960 to 2020 as more than half the percentage of the annual GDP of India, and the highest happened between the years 1990 and 2000 that was 2.69%.[5] These graphs help to acknowledge the effects of flooding that can cause an immense amount of economic loss for a state or a country. This data is concerned with 28 states and 9 union territories in India.[6] Although it raises some points, for instance, the state or central government restoring the damages by taxes of citizens, even so, they can distribute a percentage to the local authorities to develop a policy which is inclusive of all and works on the updated concept of adaptation, performance, and mitigation.

Figure 1: Chart for financial loss due to flooding in India



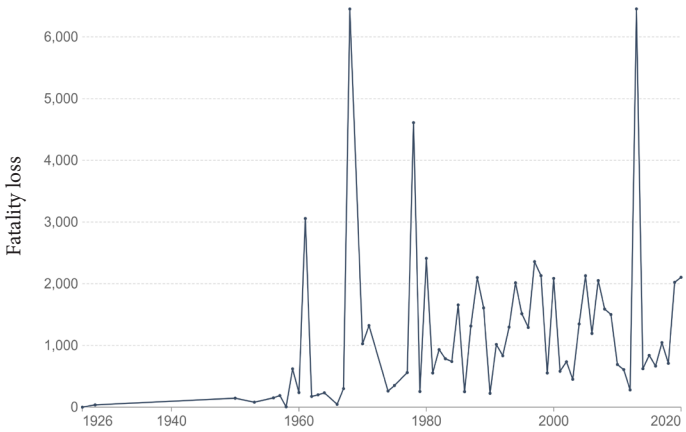
Source: EM-DAT: TheOFDA/CRED International Disaster Database, Available at: https://ourworldindata.org/natural-disasters

5 Natural Disasters - Our World in Data (no date), Our World in Data based on raw disaster data published by EM-DAT, CRED / UCLouvain, Brussels, Belgium. Available at: https://ourworldindata.org/natural-disasters

6 States Uts - Know India: National Portal of India (no date). Available at: https://knowindia.india.gov.in/states-uts/

On the other hand, Figure 2 explains the fatality loss between the years 1926 to 2020. The highest data was recorded in 1968 with 6452 deaths and the latest in 2016 with 6453 deaths in a year all over India. The main shock for the government was during Mumbai 2005 heavy rain floods, hundreds of people were reported missing and many were dead.[7] Moreover, the resident of every city has suffered more in these urban floods, on average between 40 -60 million people has been affected by a flood.[8] Due to this almost 3 million-4 million people lost their houses, and then the government put them in a settlement that is as densely populated as newly developed temporary settlements.[9] In conclusion of these graphs, this data helps to understand the impact of nature flooding as well as urban flooding caused by urbanization, old policies of Urban Flood Risk management.

Figure 2: Fatality loss due to flood in India.



Source: EM-DAT: TheOFDA/CRED International Disaster Database, Available at: https://ourworldindata.org/natural-disasters

7 Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.

8 Natural Disasters - Our World in Data (no date), Our World in Data based on raw disaster data published by EM-DAT, CRED / UCLouvain, Brussels, Belgium. Available at: https://ourworldindata.org/natural-disasters

9 Ibid.

Further on, this topic explains the problem that arises while taking the measure of flood resilience and the issue that the government has to tackle. To deal with urban flooding the National Disaster Management Authority (NDMA) of India organized a committee, which is registered in the organization of National Guidelines on Urban Flood Disaster Management.[10] Considering the topography, vast scale, and different climate or weather conditions in India, the authority developed the Risk management strategies and policies differently for each city. The topography and the climate differ from plain land to hilly, downstream, coastal areas to densely forest areas. However, the policy is different from rural to urban settlements. Usually, in many rural areas, there is no proper drainage system, whereas urban areas are using the old drainage system.

Moreover, by only developing or increasing the capacity of urban drainage, this problem is not supposed to solve. The authorities should make strong laws against encroachment, against invalid temporary settlements at the bank of rivers, fine the industries which are dumping discharge in the rives. Although, authorities have organized a committee within the National Disaster Management Plan to tackle the threat of Urban Flooding and develop policies related to resilience.[11] The measures taken by the committee are the use of structural measures, for example, retrofitting, restoring, developing the areas, and following the laws of hazard resistance structure.[12]

10 Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.

11 Ibid.

12 Ibid.

Following are the organization that currently is working to develop measures and policies for Urban Flood resilience:

- National Disaster Management Authority (NDMA)
- Central Public Health and Environmental Engineering Organization (CPHEEO).
- State Municipalities.

Difficulties arise while taking measures for urban flood resilience.

The first and foremost reason is the purpose of the Municipality of each city is to consider and take care of the city's sewerage, storm-water drainage, and water supply. Moreover, the difficulty in this is the constant expansion of a city and its population. For instance, Delhi is not a full state, it is a Union Territory and the Capital of India. Hence, the matter of Municipality is tricky in Delhi because the Municipality comes under the jurisdiction of the central government and doesn't control by the state government. Due to Delhi and Delhi NCR expansion, every year many people, migrate from rural areas and other states in search of better opportunities this puts the burden on the city, its sewerage system, and city municipality. To deal with this issue Delhi municipality has broken down into parts to handle all the regions in the city such as; the East Delhi Municipal Corporation, the Delhi Municipal Corporation, and the South Delhi Municipal Corporation.[13]

Additionally, another state in Southern India which is Hyderabad has also set up another municipality to tackle the issue. Hyderabad has developed

13Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.

Greater Hyderabad Municipal Corporation to handle the area of about 778 km square, whereas the old Hyderabad Municipal Corporation used to look after an area of about 172 km square.[14]

The second reason is the waste in the sewerage blocks the whole system. Due to the displacement of land, blockage occurred because of landslides, waste disposal from the house, temporary settlements, and factories reducing the capacity of drainage and reducing the flow. However, to deal with this problem in the city, National Disaster Management Authority (NDMA) has developed a draft for all city municipal corporations, that before the monsoon season cities shall clean the sewage network. Although, the local authorities and disputes between Central and State governments usually neglect the draft.[15]

The third reason many cities have underdeveloped drainage is that due to the rapid urbanization, the settlements are in an unplanned manner. Hence, the residents dump their waste into the rivers and the open sewers. In addition, most of the planned and approved residential buildings have underground septic tanks. Although it doesn't consider the safest way, usually it has the ability to contaminate the groundwater and soil. Also during heavy rainfall, mostly the water in the septic tank mixes with the rainwater or storm-water and causes disease. According to the health care records, from July to September diseases like dengue and malaria starts to spread due to the mixing of water.[16]

The fourth reason is the unplanned land use distribution. Most of the cities in India are old, and the land use is also old and dense. In many coastal cities, permanent residential settlements have been developed near the coastal line, and the same issue in a hilly region, the house is planned near the natural flow path of the rivers. For instance, consider Delhi it was never planned for residential zones only the land use for the central Civic zone was planned before the partition of India by British Architect Edwin Lutyens.

The fifth reason is the lack of planning and data of drainage design system. Also, the municipalities lack a basic program to store data and develop maps. For instance, a curve map of big cities is not easily available or ready to read which is known as Intensity-duration frequency come sunder in the India Meteorological Department.[17] This curve helps to detect the intercity, duration, and occurrence of rainfall.

Furthermore, many reasons like this are coming in between to tackle the threat of urban floods. However, now to understand this a case study has been done on the Indian most financial city Mumbai. The purpose of the study is to understand the planning and capacity of the sewers and drainage system. Also, how urbanization is affecting the drainage capacity and land use of the city. The purpose is to find the key problem and a solution which is inclusive of all.

14 Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.
15 Ibid
16 Ibid

17 Gupta, K. (2020) 'Challenges in developing urban flood resilience in India', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190211. doi:10.1098/rsta.2019.0211.

Case Study of Mumbai, India dealing with Urban Flooding

This topic describes the condition of Indian major cities which are suffering from the threat of urban flooding and trying to improve the Urban Flood Risk Management program. Well, flooding is a natural disaster, although due to man-made activities it has been enhanced immensely. Also, only urbanization and poor planning are not the only cause. Even climate plays an important part in urban flooding. The high amount of precipitation, climate change, and change in land use causes a high risk of flooding. This is explained in Chapter 4 in detail.

One the other reason to choose Mumbai as a topic of case study is that author's childhood was spent in Mumbai, even at that time there was an issue of water-logging during monsoon season. Even now in news, it appears every year that Mumbai has shut down due to a waterlogged monsoon storm. This gives the idea that over the years thongs have not been changed that much, as part of the Navi Mumbai area which is designed and built while considering the factors of urban flooding. This case study focuses on the area of the Poisar River that connects to the Arabian Sea. The catchment area of the Posiar River is almost 20.19 km square, and the research studies the catchment capacity of the area around the Poisar river.[18] This addresses the issue of preamble surface and non-permeable surface in the city and the importance of soil permeability in the city.

Although the mass movement to urban areas has disturbed the land cover. Where Mumbai already has a disturbing landmass, it has made out of 7 small islands combined with each other at the bay of the Arabian sea. This as result has widened or shortened the drainage system due to the change in the land use and land cover. However, the issue of this is more in coastal cities due to the discharge rate of water and backwater issues.[19] The hydrological maps are useful to study the land use and land cover, in this case, study the main role has played by the maps, which helps to understand the topography and hydrography of the area. It also helps to study surface runoff which is a key model to understand urban flooding because the main reason is that storm-water, rainwater, floodwater do not get a space to run off.

The research area of case study:

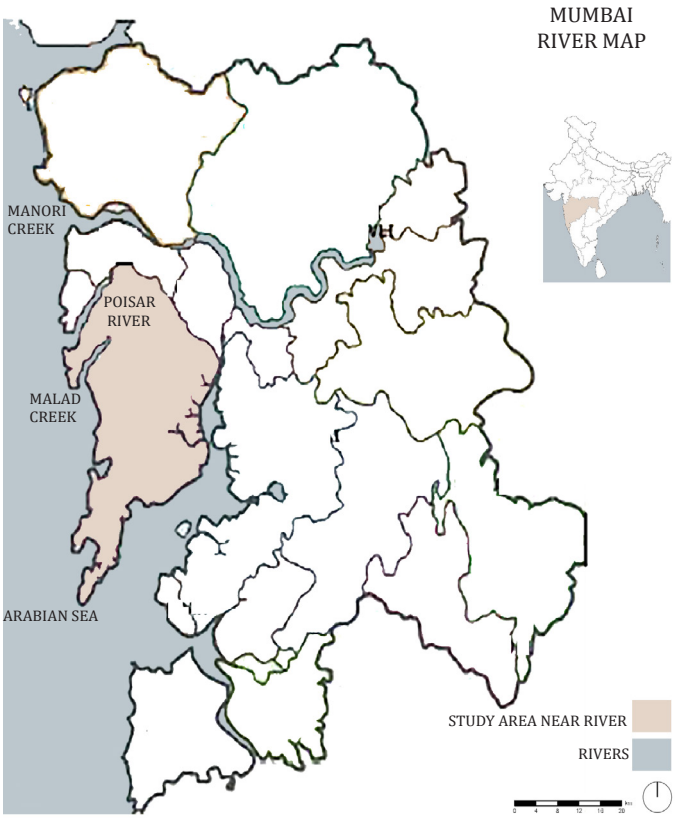
The Poisar river is located in the western coastal suburbs of Mumbai, Maharashtra, India. The catchment area around the river has an elevation of 8 meters above sea level.[20] The Poisar River is coming from a hilly location of Mumbai, Sanjay Gandhi National Park, and joining the Malad Creek into the Arabian Sea. The location has shown in Figure 3 and 4 with the catchment area. The river has a length of 8 km where the middle and lower areas are fully progressed, and it is connected with five tributaries (flowing from the river to small lakes).[21]

18 Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

19 Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

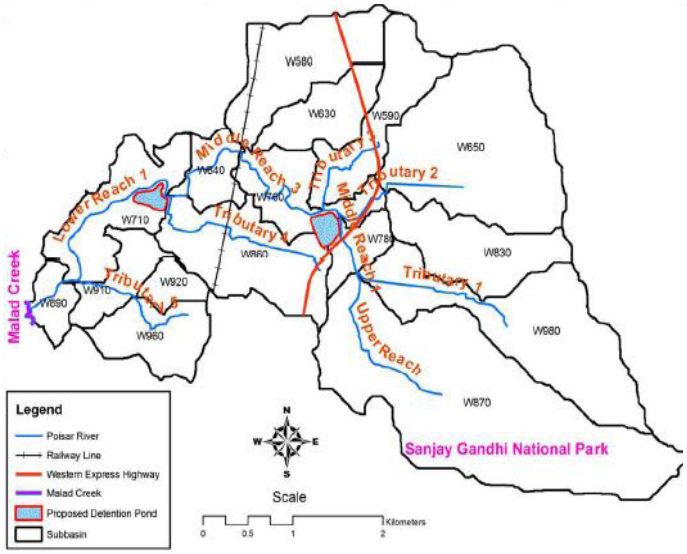
20 Ibid.
21 Ibid

Figure 3: Location of research area the Poisar River in Mumbai, India.



Source: The Author.

Figure 4: Location of catchment for the Poisar River.



Source: Location map of the Poisar River, Mumbai Muincipal Corporation. Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

Moreover, a railway track crosses the river, and the nearby development mostly blocks the discharge system. According to the Mumbai Municipal Cooperation rainfall data from the year, 1901 to 1969 and 1966 to 2009 the research was carried out which explains the total catchment area of the Poisar River is 20.9 km square, also it contains 6 more sub-catchment zones. [22] For the case study, researchers have developed a chart to explain the process of getting the details about catchment zones in order to study the run-off water area.

The methodology to understand the land cover and land use is as follows:[23]

Firstly, use actual surveyed data of Shuttle Radar Topography Mission and amend it with digital elevation model (DEM). Later upload the data in Geo hydrological modeling software to process the data, which helps to find the catchment area. After this, rainfall data is uploaded into the system of different periods and generated a database for further research.

After raster, the data, a land-use and land cover map develop, which again goes to the Geo hydrological modeling software and generates a flood hydrograph of the study area. This second methodology stage assists in developing the Flood hazard Modeling.

Later on, the last part of the methodology generates a soil map topography map to study the preamble and non-permeable surface, which

22 Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

23 Ibid

helps to detect the specific area with hard and soft surfaces. Furthermore, after using all 3 maps of land use, land cover, hydrography map, and soil maps it will develop a detention pond area to study. later on, it prepares a Flood hazard modeling system.

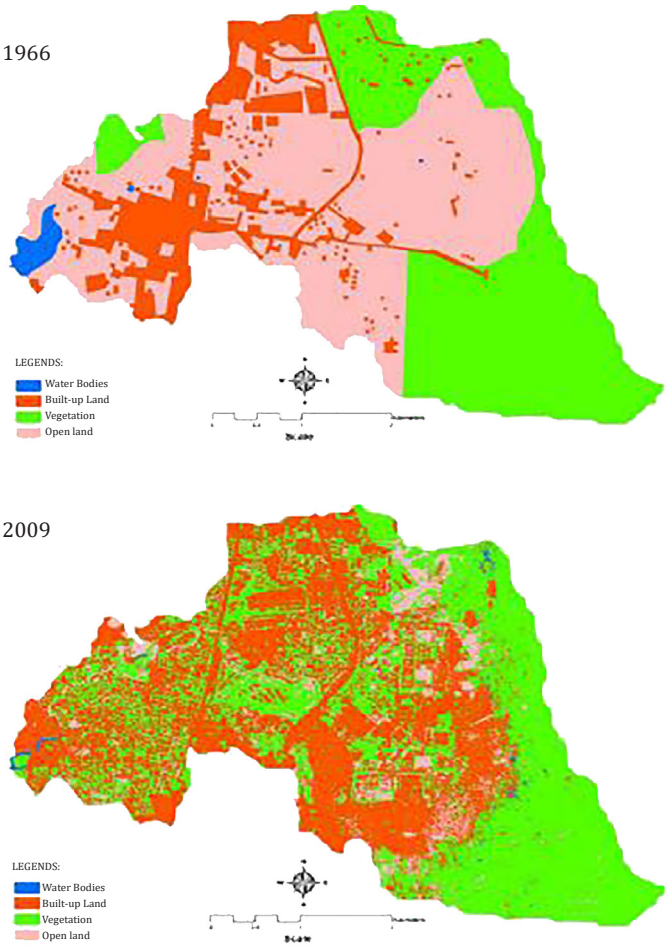
As a resultant of the methodology, it will develop a process to compare the change in land use and land in different periods helps to acknowledge the effects of hydrotherapy of land use and land cover, the impact of land use and land cover on detention ponds, and hazard area. Further on case study explains the outcome of the methodology in brief.

The outcome of the research and process is explained in the methodology.

The first outcome of the methodology is to have data to compare the two different land use and land cover at contrasting times. The case study research between the years 1966 to 2009, in resultant of which reached found the considerable change in land use and land cover. The results show the reduction of open spaces and permeable surfaces into densely populated spaces as well as the increase in the built-up areas. As shown in the figure 5 it describes that during this particular period the built up area has changed from 16.64 to 44.08%, from 43.09 to 7.38% open spaces has reduced and most importantly, from 5.6 to 2.73% found for the reduction of water bodies with reference to the total catchment area of 20.9 km square.[24]

24 Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

Figure 5: Research area Land Use Map for 1966 and 2009.



Source: Location map of the Poisar River, Mumbai Muincipal Corporation. Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

In addition to the above, this result is all based on the rapid urbanization and encroachment near the river which reduces the open spaces and water bodies.

The second outcome describes the flood impact on land use and land cover. It gives a clear vision of the reduction in flood peaks due to the impact of the detention pond. The data has collected between the same period as the first between 1966 to 2009. The case study research explains the results, that the peak discharge (It can be

defined as in a given condition it is the maximum rate of flow.) has increased in the basin of the river. One minor peak discharge has the capacity to alter the condition of land use. However, the main reason for the change of peak discharge is Mumbai is surrounded by sea, which causes the high saturation.

Table 1: Change in Land Use and Land Cover During 1966 to 2005.

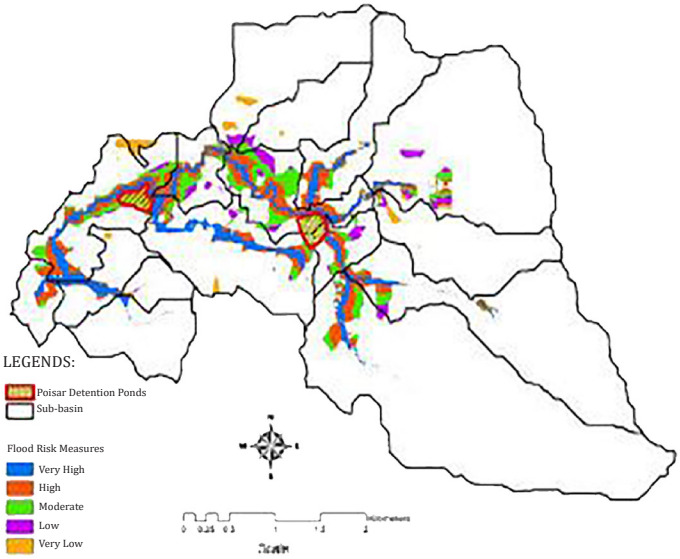
Land Use	Land Use and Land Cover 1966		Land Use and Land Cover 2009	
	Area (km square)	% according to total catchment area	Area (km square)	% according to total catchment area
Built-up land	3.36	16.64	8.9	44.08
Vegetation	7	34.67	9.25	45.81
Open Land	8.7	43.09	1.49	7.38
Water Bodies	1.13	5.6	0.55	2.73

Source: Land use and Land Cover at Poisar River.
Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

The third outcome focuses on the difference that occurred in land use and land cover and its impact on flood threats. Moreover, the flood maps assist to understand the change in land use as well. The case study research data has shown the results, that high flood risk area has been enhanced from 1966 to 2009 by 0.068 to 0.833 km square. [25] Furthermore, in the last step of methodology, that outcome generated a flood map that indicated the high-risk zones to low-risk zones which are shown in figure 6.

At last, the presence of detention ponds can reduce the peak discharge and flood intensity which has proven to be a vital factor because it has reduced the risk of urban flooding in the study area.

Figure 6: Flood Risk Map of the Poisar River.



Source: Flood Risk Map of the Poisar River.
Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

Outcome of the case study.

The final results described by the data and maps show that urbanization has put a lot of impact on the condition of urban flooding. The main reason behind the sudden rise in the peak discharge is urban settlements in open space, overtaking all the green areas and water bodies. Moreover, the open areas and green spaces near the river basin were used to use as a retention zone, however now it has been used as a dumping area. Also, the land or built-up area in Mumbai is less due to specific reasons that it is made by combing seven islands together, with a very porous soil foundation. Although, in the research data of land use and land cover has been proven that from

25 Zope, P.E., Eldho, T.I. and Jothiprakash, V. (2017) 'Hydrological impacts of land use–land cover change and detention basins on urban flood hazard: a case study of Poisar River basin, Mumbai, India', Natural Hazards, 87(3), pp. 1267–1283. doi:10.1007/s11069-017-2816-4. Available at: http://link.springer.com/10.1007/s11069-017-2816-4

1966 till 2009 the built-up area has increased. Besides, the flood map generated by methodology can be used to develop measures for urban flood risk management and find a way to resist and mitigate in the land use map.

In addition to the above, with the help of the method and software mentioned in the case study, authorities can have the chance to discover about the particular area, land use, built-up space, open space, and most importantly highly flood-prone area. However, possibilities are available for authorities it depends on the central and state government with the help of the national organization, these concepts can be developed and achieve an urban flood risk-free Mumbai.

Moreover, rapid urbanization has been growing for over two decades, and Mumbai is the center of financial and film state in India. The movement of a huge amount of population comes from other parts of India to work, to find a better lifestyle, and to find a better opportunity. However, unless the government starts developing rural areas and giving people work where they are staying, urbanization would not stop. Besides, the Mumbai Municipal Cooperation has passed a metro project which is crossing the 800 acres of Aarey forest which is highly important to the wildlife and ecosystem.[26] Later environmental organizations and students protest that the Chief Minister of the state has changed the decision. These incidents show that the power can overtake anything unless the National Organization takes some action.

In the end, this case study gives a better understanding of Urban Flood Management Risk and ways to overcome urban flooding.

The next topic consists of summarizes the rapidly growing cases of urban flooding globally and the risk growing with it. Also explains the reason for growing threats. Moreover, it addresses the basic principles of policies that can help with urban flooding. Later in chapters 1 and 2, these topics have been described in detail.

26 800 Acres Of Mumbai's Aarey Declared Forest, Metro Car Shed To Be Shifted (no date) NDTV.com. Available at: https://www.ndtv.com/mumbai-news/controversial-metro-carshed-to-be-shifted-from-mumbai-aarey-2308421

Comprehensive the rapidly increasing Risk of Urban Flooding.

This section describes the increase in threats due to urban flooding all over the world. Later in Chapter 1 and Chapter 2, it has explained in detail. In this section, there will be a summarized overview of how the world's rich countries are unable to deal with the growing risk of urban flooding. Over the two decades, the cases of flooding have been increased immensely. The incidents recorded of flood distance have been increased over the years. However, urban flooding can not be explained without mentioning the growth in urbanization as well as it is important to consider the rural areas. Although, the is a difference between the properties and the functions in rural and urban spaces. This sections discuss the threats that are growing with urban flooding and a summary of solutions for the urban flood risk management policies.

Over a course of time, the disastrous event of flooding has become more frequent and highly intense. All the continents are affected by flooding. Most of all the countries are trying to deal with urban flooding, hence it becomes a global affair, which is later explained in detail in chapter 2. The major countries which are affected by urban flooding are India, Pakistan, America, South Africa, Japan, Sri Lanka, Germany, Italy, Australia, and many more.[27] The events of flooding, cloud bust, heavy rainfall have become constant every year. This is not just causing the economic loss, more than this it caused the loss of lives and homes.

Although, more than rural areas, urban areas have been found to be more affected by the flooding, since the built-up area expands in urban areas and reduces the green and open spaces that have proven to make the flooding more severe (as explained previously in the case study of Mumbai). However, few countries such as Netherlands and Japan have managed to reduce the effects and frequency of flooding, and the losses come along it, by simply developing the more accurate Urban Flood Risk Management policies, which are later discussed in detail in chapter -3. Their policies involve non-structural and structural concepts. In the present situation, the research and case studies explain that the Urban areas are in the need of accurate policies to tackle the flooding. Since urbanization has not stopped, even in the coming time many more people might migrate which can cause more loss after a have rainfall or flood.[28] Additionally, the countries define urban areas and urban settlements in dissimilar forms, which makes it hard for the organization to define the flooding in the same way. Most of the time, the data are not explained and separated properly among urban and rural areas. Although, there is a fewer similarity between urban flooding and rural flooding than the difference. In the rural areas, the settlements are usually not permanent, although open space is usually available. On the other hand, most of the settlements are permanent in urban areas and with lesser availability of open and green spaces, most spaces are densely populated. Hence the flooding affects them differently, on one hand, it affects the majority of low-income settlements whereas, in urban areas, it causes

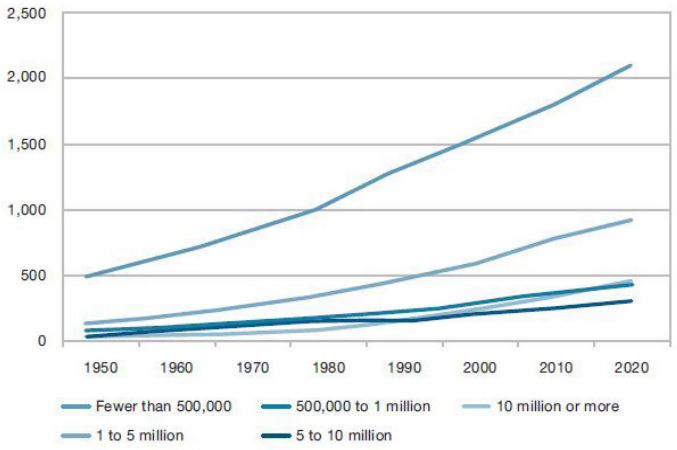
27 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

28 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

more damage and economical loss.[29]

At present, urbanization has become an attribute for all the countries to explain the geographical and socio-demographic form of urban flooding. According to the data, it has been recorded that in 2008 half of the world's population was living in urban areas where half of that belonged to the middle class and low-income groups. Besides, this assumption will increase by 60% in 2030 approximately.[30] As a consequence, urban flooding has been found to be more disastrous, threatening, and highly expensive to manage the cost afterward. This has explained by the graph in figure 7, which clearly describes the rise in population till 2020. Hence, side by side authorities has to develop a plan to tackle the rise in urban growth and also upgrade the urban flood risk management policies.

Figure 7: A chart showing the results of population growth in urban areas around the world.



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2008 Revision and World Urbanization Prospects: The 2009 Revision.
Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2.

Moreover, the case studies and research have been explained that unplanned built-up areas are the main cause to reduce the function of land use and land cover. (That has been explained previously and in upcoming chapters as well.) Due to this, a city has to expand its ground area to a quarter high percentage of the population that is migrating from rural to urban areas. In most of the underdeveloped and developing countries, it is common to see temporary dense settlements without any authorization and land use planning. These accommodations or temporary houses are there without any basic amenities, these settlements are known as slums. Furthermore, the world's largest slums are in South Africa, Kenya, India, Pakistan, and Mexico with almost a population of 5.7 million people.[31] These slums can be discovered under the flyover in a city, near the coastal line, near lakes or rivers. These are the factors that should take into consideration while making police.

Although, before that, if the government tries to control this mass movement as mentioned in figure 7, later it would be easy for developing countries especially to tackle the threats of rising urban flooding. The local authorities, government, policymakers, and stakeholders need to acknowledge that urbanization has caused overcrowding, encroachment of sidewalks, coastal areas, affecting and putting pressure on the old drainage system, reducing the porous surface. All of these reasons were mentioned in the Case study of Mumbai as well. Mumbai has one world's largest Slum as mentioned above which is known as Dharavi.

29 Ibid
30 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

31 The World's Largest Slums: Dharavi, Kibera, Khayelitsha & Neza (2017) Habitat for Humanity GB. Available at: https://www.habitatforhumanity.org.uk/blog/2017/12/the-worlds-largest-slums-dharavi-kibera-khayelitsha-neza/

Climate Change is another reason for the rise of Urban Flooding globally.

This section focuses on climate change as a reason for the rise of urban flooding all over the world which is later explained in chapter 1. This section addresses the cause of climate change on flooding in brief. For over a course of time, the impact of climate change has become noticeable in the form of extreme drought, heavy rainfall, disastrous flood, and movement of meteorologies causing landslides. However, in case of flooding, the melting of ice, increase in earth's temperature, and global warming is causing climate change which eventually causes flooding near coastal region due to a rise in sea level. In addition, the excess amount of carbon dioxide also leads toward a higher amount of precipitation resultant of which causes heavy rainfall. This has been described in detail in chapter-4.

Furthermore, as per the data given by the Intergovernmental Panel on Climate Change (IPCC) describes these kinds uttermost climate condition is constant for global warming.[32] Nonetheless, not all climate events are responsible for extreme weather changes added by IPCC. Where it mentioned like climate change is the main attribute for the rise of urban flooding, yet it is not an important attribute. Whereas urbanization is still the main reason for the worse urban flood results. Although climate change arises many other factors related to weather, even after that IPCC report mentioned not all the highly disastrous events are not all because of climate change, usually, it plays a small part in it.

The factors that are less related to climate change has more impression on the growing cases of urban flooding than the actual climate changes. Although at some point it triggers it, due to the rise of CO2 which raise the precipitation level. To deal with the urban flood not just in present also in the future a foresight approach needs to be developed which can withstand the minor change in climate and the limitation of urbanization.

Usually, a methodology has been prepared to measure the Co2 emission which is a cause for climate change. The more disastrous flood events can be measured by Average Recurrence Interval (ARI), only with the proper data of CO2.[33] In the end, this section has described in detail in chapter 1, where the factors are also explained.

Moving onward to the next topic, which describes the factors for the policy of urban flood risk management. However, an integrated approach toward urban flood risk management could be hard to achieve due to the lack of sources, technology, and funds provided to the local authorities majorly in developing countries.

It includes the role of policymakers and stakeholders, that can lead the issue on the path where they can develop the solution. In order to do that, the policies should include all and up-gradation of the old structure. The execution of the policies includes the residents, lower-income groups of people, people living near coastal ranges, bringing up resistance and mitigation plans in the traditional policies of urban flood risk management.

32 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

33 Schreider, S.Y., Smith, D.I. and Jakeman, A.J. (no date) 'CLIMATE CHANGE IMPACTS ON URBAN FLOODING', p. 26.

Fundamental of an integrated approach for Urban Flooding.

To properly understand the fundamentals, it is necessary to acknowledge hazard type and the cause because it will provide a better vision to tackle the rising threat of urban flooding. However, it seems as the threat comes with urban flooding, and the pattern has been changing over time. The models and data are still being used, when the land use, land cover, and built-up areas have changed in many cities. For this, the data has been mentioned in the Mumbai case study.

Moreover, to keep the account about the type of flooding in urban areas, assist with the planning and design in the system and policies. Whether the flood type is fresh floods, rainfall flood, river flood, and ground water flood, it is always helpful to acknowledge this, and the combination of this information, an effective integrated system can be developed.[34] However, flooding should be seen as a weather event or a flood event, where the occurrence can be easily predictable. Although it has still been seen as a weather event, in most cases it is still hard to detect the occurrence probability of the flood. Due to this, the occurrence of floods is usually anticipated by historical data of a selected area. Mainly, the widely used system to study and anticipate the occurrence of the flood is the flood hazard map. These maps play a vital role to develop and upgrade the policies. Though, the discussion needs to add the rapidly growing urbanization without it a hazard map has the possibility to failed to perform.

Undoubtedly urbanization is and will be the constant cause for urban flooding, which is also shown in the case of the Mumbai case study. Undoubtedly urbanization is and will be the constant cause for urban flooding, which is also shown in the case of the Mumbai case study. Nonetheless, it has the capability to flood the area and enhance the flood risk in a particular area. Additionally, unless a master plan is prepared by the authority which includes the space for future expansion and built-up area, to talk with unplanned urban growth would be hard.

Besides all, there is unreliability while planning for urban flood risk because not just the urbanization has to be considered even climate in some cases plays its role to worsen the conditions. This is one of the reasons for not being able to anticipate the flooding because insufficient data of climate change can not develop proper data to follow to generate flood hazard maps. This can be another challenge on social and ecological factors. The loss and the profit can be defined by using economical factors, nonetheless, the decisions are usually not based on economical factors solely. After the flooding authorities calculate the total loss which not just only considers housing a public area, even a loss of biodiversity is also included in the economical factors.

Nevertheless, it is not possible to achieve resilience completely even with the precision of climate data, flood maps.[35] Only it can be achieved to some extent, over-resilience for the future can not be possible with so much change in urban settlements. Although, with the help of mitigation inversion on policies flooding even and threats can be reduced.

34 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

35 Ibid

The proposition can assist in achieving urban flood resilience with an integrated approach in urban flood risk management.

The first fundamental explains, to figure out the source of the flooding, its type which is explained in chapter 1, and the possibility of flooding. Along with identifying the area which is highly flooded prone zones which can be an advantage for the policymakers. The foreseeing can assist to plan obstruction for flood, however, if it is planned in less or non-flood prone zone it might worsen the situation than solving it.

The second fundamental describes the change that is going to be constant in the future. Which states that urbanization is not going to stop, it might slow down with the efforts of government however, the changes are constant. However, it wouldn't be completely possible to anticipate the flood occurrence and the damages caused by it, due to the reason that the main reason of urban flooding is happening by humans and urban settlements.[36]

The third fundamental explains that at present times, it has become a necessity for the authorities to incorporate the integrated urban flood risk management plan for future master plans. To have the latest data of land use and land cover maps, because of the exceed in built-up areas would help to pre-plan the land use for future expansion.

The fourth fundamental describes that the traditional way of making policies does not work in the present day scenario as well as for the future. In order to achieve this, policies need to integrate the structural and nonstructural approaches to tackle urban flooding. Both the procedure can assist in case of failure of one during flooding.

The fifth fundamental explains extreme technical and structural design can also help in achieving the integration of urban flooding for the future, this has been explained in chapter 3 in detail. These structural solutions can be thoroughly successful in order to reduce or stop urban flooding. However, it is not easy for most developing countries, since this type of approach requires funds from the government.

The sixth fundamental discuss the advantage of having an integrated urban flood risk management plan is the connection with all other authorities, plans, and data. For instance, Urban planning, urban design, climate change, master plan, green space , open space planning and management.

The seventh fundamental explains the inclusivity is a key to success to achieve urban resilience by an integrated approach. The involvement of stakeholders and residents has the tendency to reduce the threat.

The eighth fundamental describes the transmission and connection assist residents, authorities, and stakeholders to do not forget about the past incidents of flooding. It has seen the floods with less intensity which doesn't affect drastically can be forgotten by everyone easily, this is elaborated in chapter 4 by using the example of Turin city.

36 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

The ninth fundamental explains that even with the use of mechanical, technological, and structural policies it is not certain to completely overcome the events of flooding. In this case, usually, nonstructural integrated design helps. However, even their progress is not predictable.[37]

The last fundamental describes as much as it is important to plan for reducing the effects of urban flooding; it is also important to plan for its recovery after the occurrence of flooding in case of failure of planning and system. To achieve this, the policy makes need to have a recovery plan which can assist to rebuild the destroyed area.

These fundamentals are useful in order to commence with the planning of urban flood resilience.

OUTCOME OF THE SYNOPSIS:

The outcome of the synopsis is to understand the purpose of the thesis topic and reason to understand Why urban flooding is a matter of concern. This topic needs attention to develop policies and improve them by intervention and mitigation. A case of Mumbai describes the condition of urban flooding and the effect of policies approached by policymakers. It explains how urbanization is affecting a city which is made by combing 7 islands together and surrounded by a river. Also, the measures are taken by the state authorities and national organizations. However, the outcome of the case study explains the change in the area of retention basin into to dumping zone, due to rapid urbanization it changes the land cover of the area as well. Moreover, an overview of the integrated approach has proven to be the solution for urban flooding to some extent.

37 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

CHAPTER 1

COMPREHENSIVE THE FLOOD THREAT

1.1 INTRODUCTION

This chapter addresses the fundamentals of flooding. It is a natural disaster. Although, human-made mistakes are making it worse. This section explains the issues mentioned in the synopsis such as growing urbanization and climate change.

Key topics addressed in this section are as follows:

- A brief of natural disaster flooding.
- Describe the source of natural and urban flooding.
- Describes the classification of flooding.
- Explains to evaluate the growing urban flood threat.
- Understanding the impact of flooding on the city as well as the resident level.
- Describes the role of rapid urbanization in urban flooding.
- Explain the relation of climate with urban flooding and the impact of climate change.
- Describe a brief of urban flood resilience.
- A difference between the traditional approach and the resilient approach for urban flooding.

This chapter focuses to understand the flood hazard and looking into the change and growth of flooding from old times to the present day. Moreover, urban flooding is not just the floods that occurred in cities and overflows the rivers. Rather it happened due to the lack of space for runoff excessive water, low capacity of old sewage system, and lack of permeable surface.[38]

Additionally, even less amount of rainfall can cause blockage of the drainage system and flooded the streets of cities. Also, urban flooding can be described in many ways such as flooding in terms of heavy rainfall, flooding due to non-permeable space, flooding in terms of old sewage stem with less capacity, flooding due to rapid urbanization, and poor infrastructure.

Although, often research discuss the financial loss and fatality loss, however, it is also necessary to enlighten the loss of an individual and a community. Urban flooding affects the city on small scale also, by blocking the traffic, reducing the frequency of public transport, blocking the supply chain, closing institutional buildings, and many more.[39] Furthermore, most of the low-income groups are living in the flood prone areas. Or should say this, in search of good living standards and job opportunity people are moving from rural to urban area. Due to low income, these migrated populations were unable to afford a house in developed settlements, hence ended by staying in temporary settlements by the river or under the bridge. Hence, it is obvious that urban flooding is a major threat for a large population of low-income and middle-class groups. All the authorities and police makes are aware of this problem, anyhow, the policies aren't going to stop the growth of urbanization.

As continue in this chapter with the brief of flooding as a natural and man-made disaster.

38 Anna and Weber, 2019, January 15, (no date) What Is Urban Flooding?, NRDC. Available at: https://www.nrdc.org/experts/anna-weber/what-urban-flooding.

39 Ibid

Flooding is the most occurring and destructive natural disaster affecting urban and rural areas, causing more causalities and final loss all over the world. Flooding is one of the natural disasters which causes the most social and economic loss. Globally these floods have caused loss of life, billions of property damage, affected a number of the world's population, and cause financial loss of major metropolitan cities. Sometimes even small floods that happen during brief downpours or high tides are capable of causing an amount of damage to the social and financial cost. [40]
Floods can be categories into three parts:

- Fluvial floods (river floods).
- Pluvial floods (flash floods and surface water).
- Coastal floods (storm surge and coastal tidal flooding).

For this reason, the worldwide challenge of the twenty-first century is Urban Flooding with climate change, future flood risk, old infrastructure, and urbanization. In addition to this, the cities are complex space that allows interaction and intervention between people, the environment, and infrastructure. In this settlement, water plays a vital role as central to numerous of these intuitive; whereas impacts the urban climate and biodiversity.[41] However, increases in urbanization are taking over the green spaces and builds on floodplains: these affairs are emerging the term **Urban Flooding.**

These days, due to the migration of people from rural to urban areas, it has become a home for more than half of the world's population. The development of commerce and the accessibility of jobs drew people to these early settlements, which accelerated industrialization in the mid-19th century.

This rapid migration is causing the development of more cities at an extraordinary rate. Urbanization is altering land use which affects the surface, urban micro-climate and influences urban flood processes. [42] When natural landscapes have been modified for urban development, it disturbs the drainage system because the natural landscape helps the flow slowly gather through little hollows and channels into local streams. However, this has been replaced by an evaluated landscape where boulevards carry surface water flow and are a vital part of the drainage system.[43]

As per disaster management, it is essential to understand the types and causes of flooding and the risk before an event takes place, to allow for mitigation and preparation for damage reduction. It requires knowledge of the causes and types of flooding to manage the flood risk, which is essential for planning measures and solutions which can avoid or restrain harm from particular sorts of floods. This is also necessary to take measures and develop policies for the urban flood threat.

40 National Academies of Sciences, E. et al. (2019) Introduction, Framing the Challenge of Urban Flooding in the United States. National Academies Press (US). Available at: https://www.ncbi.nlm.nih.gov/books/NBK541185/

41 Dawson, D.A., Vercruysse, K. and Wright, N. (2020) 'A spatial framework to explore needs and opportunities for interoperable urban flood management', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190205. doi:10.1098/rsta.2019.0205.

42 Du, Juan, Linlin Cheng, Qiang Zhang, Yumeng Yang, and Wei Xu. 2019. "Different Flooding Behaviors Due to Varied Urbanization Levels within River Basin: A Case Study from the Xiang River Basin, China." International Journal of Disaster Risk Science 10 (1): 89–102. https://doi.org/10.1007/s13753-018-0195-4.

43 Committee on Urban Flooding in the United States. 2019. Introduction. Framing the Challenge of Urban Flooding in the United States. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK541185/.

Similarly vital is the information of where and how frequently surge occasions are likely to happen. Usually, this is a process in understanding the need for flood risk management. Additionally, it is also necessary to map the flood paths and damages in data which helps to generate a risk map. That could help to develop a system that is suitable for flood risk reduction such as, forecasting: and early warning systems.[44]

1.2 Classification and Source of Flooding.

Floods can form due to meteorological extremes that can define as repetition of weather: the same climate will occur day after day, and extreme hydrological events (EHEs), such as extreme precipitation and temperature. In addition to the above, unplanned urban growth, development on floodplains, encroachment in land use and embankments: and breach of a dam is also the reason to form floods.

Worldwide, in many cities migration from rural to urban cities has increased and developed their small settlements which are highly exposed to flooding and due to poor defense mechanism can make these settlements are vulnerable to flood. Encroachment of land is common in cities of developing countries, which raises the risk of flooding every year: urban development that reduces the permeability of soils increases surface runoff, and poor drainage systems affecting the excess water flow.

Floods can categorize into river floods, pluvial floods, groundwater floods, coastal floods, or failure of artificial water systems, such as dams. Furthermore, according to the rate of the flow of floods, it is usually expressed as flash floods, urban floods, semi-permanent floods, and slow rise floods.

The classification of floods is illustrated in table 2. The table explains the causes of each type of flooding concerning natural and man-made actions. The first issue mentioned in the table is **urban floods** since it is a recently growing threat around the globe. As mentioned above and in the previous chapter, it is a major concern for developed and developing countries at present time. The urban environment is used as the equal natural pressure as the natural environment, although the densely urban settlements make it worse. On the other hand, **fluvial floods** (river floods) can occur due to the less capacity of artificial and natural channels such as sewers and lakes to run off the excess water from the city.[45] The excess amount of water just overflows the banks of rivers and low floodplains. The river floods can occur due to the constant and heavy rainfall and melting of the snow. Same as this, **overland floods** also occur due to the heavy rainfall land melting of snow. Although, the non-permeable surface makes it worse because the excess water can not be absorbed by the surface. On the contrary, **coastal floods** are caused by ocean and seawater. In some cases, a combination of wind and hurricanes can exaggerate coastal flooding. At last, **flash floods** can be occurred due to reservoirs and dams. Heavy rainfall can increase the water level in that situation dams overflow.

44 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2.

45 Ibid

Table 2 : Classification of flooding.

Categories of Flooding	Natural Cause	Man-made Cause	On-set Time	Duration
Urban flood	Fluvial Coastal Flash Pluvial Groundwater	Saturation of drainage and sewage capacity Lack of permeability due to increased concretization Faulty drainage system and lack of management	Varies depending on the cause	From few hours to days
Pluvial and overland flood	Convective thunderstorms, severe rainfall, breakage of ice jam, glacial lake burst, earthquakes resulting in landslides	Land used changes, urbanization. Increase in surface runoff	Varies	Varies depending upon prior conditions
Coastal (Tsunami, storm surge)	Earthquakes Submarine volcanic eruptions Subsidence, Coastal erosion	Development of coastal zones Destruction of coastal natural flora (e.g., mangrove)	Varies but usually fairly rapid	Usually a short time however sometimes takes a long time to recede
Groundwater	High water table level combined with heavy rainfall Embedded effect	Development in low-lying areas; interference with natural aquifers	Usually slow	Longer duration
Flash flood	Can be caused by river, pluvial or coastal systems; convective thunderstorms; GLOFs	Catastrophic failure of water retaining structures Inadequate drainage infrastructure	Rapid	Usually short often just a few hours
Semi-permanent flooding	Sea level rise, land subsidence	Drainage overload, failure of systems, inappropriate urban development, Poor groundwater management	Usually slow	Long duration or permanent

Source: Types of Flooding.
Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

1.3 Flood Threat Evaluation.

Most of the time, the flood has a possibility to occur during a specific time, area, and intensity. In order to know about the occurrence of floods, data has been collected and recorded by using a flood hazards map, which is known as real-time records or hazard assessments. Before this, it is necessary to understand the nature of flooding, for that few points need to contemplate:

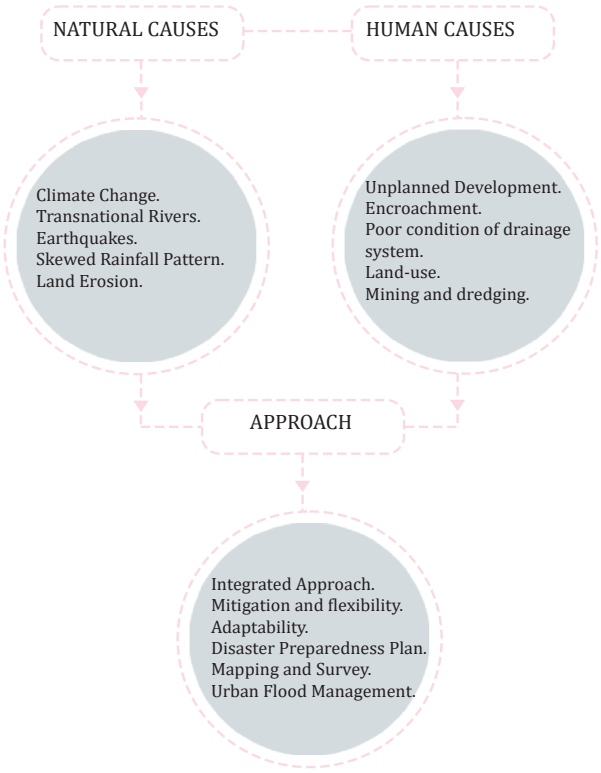
- The anticipation of flood to occur.
- The magnitude and intensity of the flood occur.
- The anticipated time of another future occurrence.

There are many modes or tools available to record these data such as flood hazard maps and GIS systems. Mapping floods is vital to plan for the areas and allow to have development. The hazard maps are created in a way that allows to read and understand for a technical and non-technical person. Whereas the GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. Also, an analytic tool that uses the data and values, to generate a detailed plan to handle the flood crisis and to minimize damage.

1.4 Flood Impact comprehension.

Throughout history, this has shown that flooding is one of the natural hazards which destroyed human settlements, the economy, and prosperity. There are many natural and man-made sources of flooding, such as heavy rainfall, snow-melt, glacial melt, ground infiltration, overflow of the reservoir, and dams.

Figure 8: Factors responsible for urban flooding.[46]



Source: The Author.

Figure 8 illustrates the factors that can be responsible for urban flooding. The classification has divided between natural and human causes. In natural causes, one of the principal reasons is **climate change**, which can alter the pattern of rainfall. This topic is further explained in chapter 1.6. Another reason mentioned is **transnational rivers**, which means the rivers which cross more than one border. The problem that arises from transnational rivers is they come under different local and regional municipalities. Hence, sometimes due to politics, lack of communication and combination can make it hard for the policymakers to tackle the threat of urban flooding. Since the rapid growth of urbanization has increased the built-up area and changed the

46 Flood Management In India (no date) Drishti IAS. Available at: https://www.drishtiias.com/daily-updates/daily-news-editorials/flood-management-in-india.

land use land cover for the same. This is further explained in chapter 4. Moreover, heavy rainfall brings the threat of **landslides** with it in hilly regions. This causes the flood with mud and debris, damage more financial loss, and make it hard to clean after the flooding.

On the other hand, first and foremost, **unplanned development** is the human factor responsible for urban flooding. With **urbanization**, a high percentage of people migrated from rural to urban areas. With already overloaded urban areas having no space to accommodate more, hence they started to develop their own unplanned and temporary accommodations. This raises another issue of **encroachment**, which means spaces are occupied by residents without authorization. Another factor is the old and low-maintenance **sewerage system**. Most of the cities are still using the old drainage system (explained in chapters 2 and 4). However, it can work only after regular proper maintenance. Even though the capacity of the old drainage system is not supposed to cater present population. On top of that, change in **land use** and land cover is a key problem in almost every city. There are some other environmental factors also. Such as **mining and digging** are affecting the natural environment, biodiversity and enhancing the amount of **soil erosion**. These factors assist in understanding the growing threat of urban flooding as well as its causes. Policymakers use all the information to take serious measures to tackle urban flooding.
Ultimately the result of errors made by the human can be catastrophic. However, the main concern is to understand flooding in urban environments that is challenging by rapid urbanization and urban development.

1.5 Urban Difficulties.

Over time the urban centers have developed and changed drastically, especially the economic factors that vary from a simple shop to small markets in towns to complex, into large metropolitan regions connected to a local, regional, national, and worldwide market. Moreover, the increase in urbanization and its result has shown an impact on Urban Population. Due to this, cities have to expand their parameters which spread the built-up area outwards. Hence diminishes the effect of urban resilience to flooding. Urbanization is accountable for an immense amount of greenhouse gases emission, environmental damage, and high capital cost in urban areas.

In addition to this, rapid urbanization is attracting stakeholders and infrastructure developers to invest in an urban city. However, this is growing the issues of social inequalities, high economic differences, environmental degradation, faulty regulations by authorities and government. For instance, in many countries, infrastructure developers are investing in housing projects due to which trees have been cut down, taking land from farmers, and creating a concrete forest that is expensive for more than half of the population. Hence, the high price is increasing the class difference in society which makes living conditions inhabitable.

Nonetheless, if cities have developed in such a manner from the primary level, which uses the integrated approaches for climate change, develop, and mitigate the Flood Risk Management System, and promote sustainable development. Rapid urbanization is generating an opportunity

to design and build cities that incorporate urban flood risk management. Hence, in developing countries and growing cities, it is necessary to deal with old urban settlements: and urban expansion to enhance urban flood resilience in times of climate change.

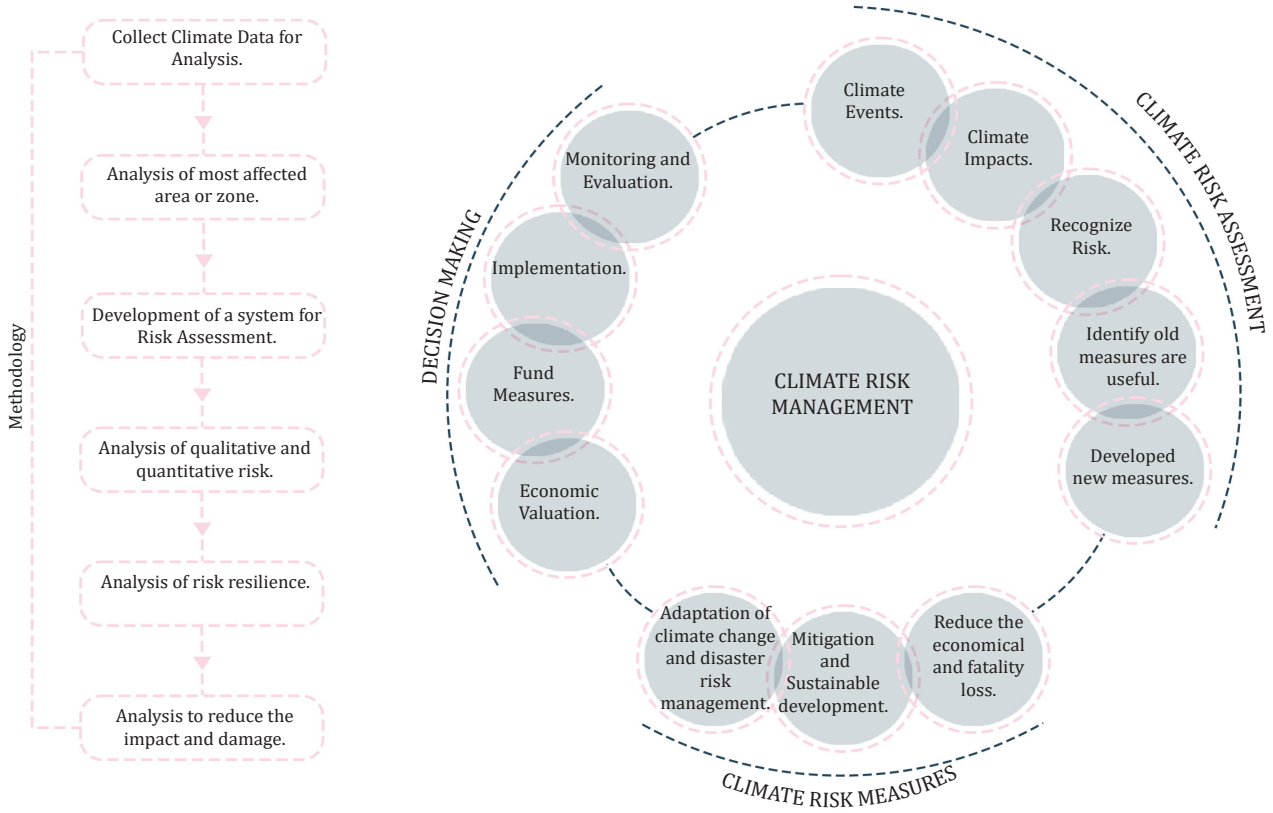
1.6 Correlation of Climate Change with Urban Flooding.

For the last two decades, the effects of climate changes can be seen by the rise and fall in temperature, heavy rainfall in some cities, flooding events, and an increase in drought events. The severe conditions of climate change events occur in both rural and urban areas.

The threat of flooding is rising due to the uttermost precipitation that makes decision-making tough for climate adaptation.[47] Additionally, planning adaption has become priorities for authorities and government. Adaptation planning is a complex system to achieve a cost-effective design that can resist flooding in urban areas.

Over and above that, the system requires integrated assessment for climate, flood damage cost, financial loss, involvement of stakeholders, and communication with decisions makes. Figure 9, is explaining the methodology that can be used for Climate Risk Management and the factors to be considered for its assessment. Although, with climate change, it is hard to predict future changes that make it strenuous to mitigate and design any system.

Figure 9: Framework of Climate Risk Management.



Source: The Author.

'Climate Risk Assessment & Management – Adaptation Community' (no date). Available at: https://www.adaptationcommunity.net/climate-risk-assessment-management/

47 Integrated climate change risk assessment: A practical application for urban flooding during extreme precipitation | Elsevier Enhanced Reader (no date). doi:10.1016/j.cliser.2017.06.012. Availabe at : https://www.sciencedirect.com/science/article/pii/S2405880717300250

1.6.1 Case Study: Impact of Climate Change on urban flooding in Vietnam.

This case study focuses on the fundamental of climate change which is affecting urban flooding. To understand how climate change and climate variability have a direct impact on flooding.
Further on, it is shown that the occurrence of flood events has become more frequent. One of the reasons has mentioned the extreme precipitation due to climate change. However, one factor is global warming which is enhancing the global water cycle as a result, of which extreme event of flooding has been sen with high magnitude around the world.[48] Climate change is making it hard to anticipate the weather, rainfall, and storm rainfall more efficiently. Climate change also influences the change in sea level, tides, and large-scale runoff changes, which can cause coastal flood incidents.[49]

Study Area

This case study focuses on a city in Vietnam called Can Tho city. The one side of this country is surrounded by the ocean. The reason to choose to study Vietnam is from last decade In Asia, Vietnam is one of the most affected and exposed to natural disasters. The sea level In Vietnam is rose from 1mm to 3mm from 1993 to 2008.[50] Figure 10 illustrates the river map of Vietnam showing in dark the location of Can Tho city with the Song Hau river.

Figure 10: Vietnam River map showing Can Tho city.

Source: The Author.

This city is located on the south bank of the Hau River and the population of the city is almost 1.2 million.[51] This city is at a distance of 84 km from the bank of a large river. Also, the city's elevation is low almost 60-80 cm above mean sea level, which makes this city vulnerable to urban flooding.[52] However, the rapid growth in urban development and urban population enhances the poor condition of living and infrastructure. These are also causing the risk of urban flooding.

48 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

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On October 5, 2009, the city was hit by heavy rainfall that collaged the city. According to the report, climate change caused the change in sea level and runoff increase which has caused most of the severe flooding. The flooding in 2009 was considered a first-level hazard. Figure 11 illustrates the street filled with water completely.

Figure 11: Flooding on October 5, 2009 in Can Tho city.

Source: Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

According to the data, the flooding is overtaking the area in the city from 30% to 50% up till now.[53] The rainfall was lasted for one hour and caused severe damage in the city. Moreover, various flooding events have been occurred due to the higher river tides and upstream flow. Besides, contusion in flood-prone areas or unplanned land use is one the reason to increase the risk in the city.

Furthermore, the topography of Can Tho city plays an important role because the city is just 1 to 1.5 meters above sea level. Many places in the city have lower than 1-meter topography.[54] According to the Vietnamese norms, the average rainfall in the city per year is around 1640 mm. Although, it has been recorded that, with change in rainfall pattern they have recorded 50 to 100 mm in a day.[55] However, the city's drainage system can't store excess water due to rainfall in a day. Also, the residents are not aware of the policies which make the situation worse.[56] People throw garbage into the drainage, canals, and rivers. The encroachment has been found to be a growing issue in the city. The inner city has been recorded notable growth from that decade. Nevertheless, the growth has not in a planned manner. Into the bargain, Can Tho's municipal authority developed a storm sewer network for central Ninh Kieu District. Nonetheless, it has been recorded that the capacity of this storm's network is insufficient. Figure 12 illustrates the Can Tho city administrative area and shows the province of the committee. As per the research conducted by the construction consultant company under the supervision of the Ministry of Construction, the length of the current drainage system in Can Tho city is almost 23500 meters and 7000 meters.[57]Also, several natural drainages are present in the city which connects into canals. In spite of that, most of the drainage has less capacity according to the present urban growth and some are collapsed.

53 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

54 IBID
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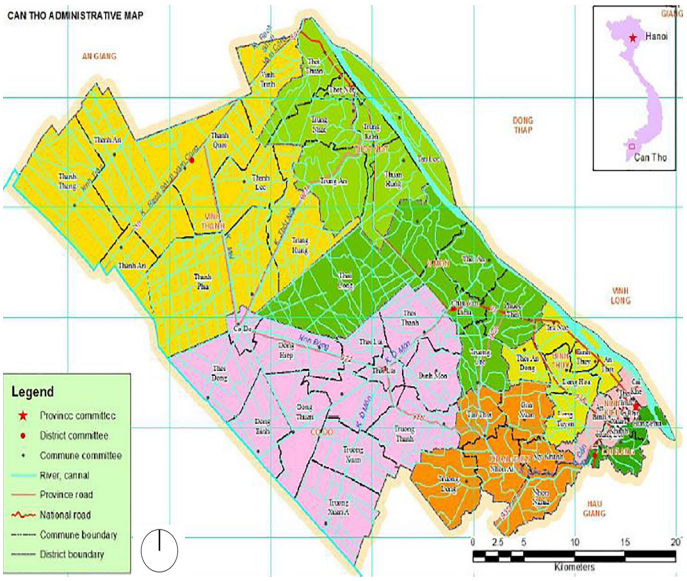
57 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

Figure 12: Administrative area in Can Tho city.



Source: Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

1.6.1.1 Methodology to understand the action of climate change on Can Tho city.

It has been predicted that the city might experience a rise in the cases of flooding in upcoming years, due to the location which is more flood-prone.[58] The urban water cycle is mostly affected by changes in land use and hydrological factors. Furthermore, the methodology includes the study of three major stages to understand the issue of rising sea levels and the impact of climate change. The stages comprise **urban growth, urban flood,** and **atmospheric research.** This is to recognize the effect of local and global climate change.[59] The methodology involves the development of a model of each stage, to discover the data scientifically.

The digital platform used to develop the model for each stage is **Dinamica EGO (Environment for Geo-processing Objects).** Later the output of Dinamica EGO was used as in Pathirana another digital platform to get atmospheric data.[60] Furthermore, to generate the urban growth data the digital platform developed data with the help of historical urban patterns and compare it with the new urban pattern. In the process, the application considers the land use maps. In addition, for atmospheric data, the platform used is the Weather Research and Forecasting[61] which analyzes the atmospheric system and involves the density of pollutants, wind, precipitation, and cloud formation. The application needs the base information for this, such as the land use map and topography of the city. At last, for urban flood data, the urban drainage model is used as a tool, which needs the information of storm sewers and the capacity of drainage. For the research, two historical land-use maps are used in the Dinamica EGO application from 1989 and 2005.[62] Where, for the Weather Research and Forecasting, a land-use map is used along with an atmospheric map to generate data for local rainfall and the changes that occur in a micro-climate concerning land use.

Framework for climate change.

Vietnam has developed several frameworks for climate change at national, regional, or smaller scales like other countries around the world. To develop the framework the Vietnamese government assigns the agency which gives a more efficient and effective result.

58 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

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62 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

The agencies involved are the Ministry of Natural Resources and Environment (MONRE) and the National Target Program to Respond to Climate change (NTP). These agencies assist in creating scenarios for climate change majorly the change in sea level.[63] According to the research conducted by the Ministry of Natural Resources and Environment (MONRE) produced in the form of a report called Impacts of Climate Change on Water Resources and Adaptation Measures (IMHEN)[64] explains the sea-level rise and river flow projections established on the assumptions and simplification.

Results are conducted from methodology.

As per the search data, the results generated in the case study by using the rainfall event of October 5, 2009, explain the future outcome that the event can enhance by 21% almost 18cm by 2050.[65] This is due to the change in urban growth which chances the land use. Therefore, this would change the hydrological and hydro-meteorological effects. As a result of this, the flood event will raise by 8%. This made the researcher pay attention more to climate change than a change in land use due to urban development. Can Tho city can experience a flood depth of more than 50cm due to a rise in sea level. However, the area which is high develops and densely populated has more chance to affected by flooding. Furthermore, the data of urban growth and climate impacts combine and provide another data that is 80% of the surface can flood almost 1.51m. This is because of the low capacity of drainage lines to handle that amount of excess water. This could block the major rivers and canals where the storm drainage water pipe connects. Due to this, the possibility of threat from climate is highly possible.

However, climate change is not the only reason for the rise in sea level. Although, in the case of Can Tho city this is a highly possible case. Since climate change sways the magnitude and nature of rainfall. It would be considered as the main reason for urban flooding in the city. Moreover, for the research data, some factors were kept constant for the analysis such as catchment zones, roughness values of pipe, ability pumping station, and the number of pumping stations. Additionally, there were some factors considered to change with time in the research to analyze the impact of flooding. Those factors are solid waste and blocked drains, this could improve later by authorities or become worse in the future. Hence it was not considered as a constant factor in the research.

1.6.1.2. Urban Flood Risk Management.

For flood risk assessment the maps were developed by using a digital platform called GIS. This is to acknowledge the risk evaluation which is mandatory for disaster management. It is essential to generate effective measures with mitigation solutions for urban flooding. The authorities come up with a new approach to get the measure of flood threat in coastal areas and the inner city. Government organizations and authorities have developed this by analyzing and joining the historical flood disaster data with vulnerability

63 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

64 IBID
65 IBID

data to get the precise information that assists in decision making. The maps to understand flood hazard is created by the hydraulic modeling approach,[66] which needs several data to input for instance time of meteorological, stream-flow data, and cross-section of the river. The map developed from this is used in Dinamica EGO digital platform to generate the result of the impact of climate on flooding. The flood risk map needs collaboration from the government department and policymakers for better results. The flood risk map needs collaboration from the government department and policymakers for better results. The maps assist efficiently to communicate with local floodplains area. This supports both the government agency and affected communities.

1.6.1.3. Outcome of the case study.

The study focus on the internal and external impact of urban flooding in the future concerning climate change. Climate change was considered as an external impact due to the rise in river level and predict the flow of the major river near the city Mekong river.[67] In the research, with the help of a digital platform map prepared for urban growth through land use. For the internal impact, the urban micro-climate and hydrological maps were used. Another outcome of the research explains that the event of heavy rainfall that occurred in 2009 showed the maximum hourly rainfall which cross the limit of 50mm.[68] However, the change in sea level with extreme rainfall causes devastating results in the city. The research tried to include both the internal pressure on urbanization and external scenarios. Can Tho is the most important and biggest city in Mekong Delta.[69] The city has proven to be affected due to the demographic changes, rapid urban growth, change in rainfall pattern, the intervention in the Mekong River basin, and rising sea level.[70] According to the result, the case study says the Can Tho city will face the same experience again in the coming years that to be with same or higher magnitude.

66 Luu, C. and Von Meding, J. (2018) 'A Flood Risk Assessment of Quang Nam, Vietnam Using Spatial Multicriteria Decision Analysis', Water, 10(4), p. 461. doi:10.3390/w10040461. Available at: https://www.mdpi.com/2073-4441/10/4/461

67 Huong, H.T.L. and Pathirana, A. (2013) 'Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam', Hydrology and Earth System Sciences, 17(1), pp. 379–394. doi:10.5194/hess-17-379-2013. Available at: https://hess.copernicus.org/articles/17/379/2013/

68 IBID

69 Zevenbergen, C., Gersonius, B. and Radhakrishan, M. (2020) 'Flood resilience', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190212. doi:10.1098/rsta.2019.0212.

70 IBID

1.7 Urban Flood Resilience

It can be defined as the capacity of a city to preserve future flood risk at tolerable levels by reducing destruction, preventing deaths and injuries, and recuperating rapidly a while later.[71] The concept of resilience is extensively used for Urban Flood Risk Management System, although it is still a conceptual factor and a complex process. [72] The notion on which resilience systems depends compromise social, ecological, and technical systems. The social system formulates to expand the process and interaction between human and natural structure. The ecological system develops measures for adaptive approaches and monitors and evaluates that for the short or long term. Whereas, technical approach contributes to the design, planning, and operations systems.

Moreover, the conceptual and technical systems convey to reducing risk factors that it is necessary to Protect, Prevent, and Prepare for flood hazards.[73] Therefore, authority, decision-makers, stakeholders need to acknowledge the growing need for Urban Flood Resilience and consider the adaptive and mitigate concept at the planning and designing stage of the Risk Assessment System. In contrast with the above, there is a thin line between a concept and a method. What seems to work on paper does not necessarily work on the site. Furthermore, the approach toward Urban Flood Resilience needs to change or develop by leaving behind or modifying the traditional system. Hence, the traditional method needs to balance its dependency on large-scale structures such as dams, embankments, dikes, and levees. This system with poor design and maintenance can exaggerate the flood risk. These systems are adopted globally, with the thought that the system will predict the upcoming flood risk without even considering the exceptional cases and scenarios. Therefore, the traditional method of resilience has not been considered a successful way to reduce the threat and a perfect system.[74]

Whereas, in the resilient approach, it ought to consider that the problem and change can be uncertain. The system needs to update the design and maintenance from time to time to raise the capacity to resist uncertainties. On top of that, a balance needs to be created between flood protection, preservation, and preparedness.

Moreover, it has been proven that the countries that have tried to shift from traditional to resilient approaches have been able to find a cost-effective way for urban flood resilience, such as the Netherlands with their technique of unbreachable embankments, dives, and levees. Also, another example is Tokyo, with a one-time investment in a technical, structural project trying to reduce flood risk in the city. The characteristics of these approaches consider the concept of inclusive of all. The method of urban flood resilience in these countries is further discussed in detail in Chapter 3, focusing on the Urban policies by authorities and technical and structure development to avoid flooding.

71 Morgan, M. and Fenner, R. (2019) 'Spatial evaluation of the multiple benefits of sustainable drainage systems', Proceedings of the Institution of Civil Engineers - Water Management, 172(1), pp. 39–52. doi:10.1680/jwama.16.00048. Availabe at: https://www.icevirtuallibrary.com/doi/10.1680/jwama.16.00048

72 Zevenbergen, C., Gersonius, B. and Radhakrishan, M. (2020) 'Flood resilience', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190212. doi:10.1098/rsta.2019.0212.

73 Ibid

74 Ibid

Table 3: Difference between traditional approach and Resilient approach in Urban Flooding.[75]

RESILIENT APPRAOCH TOWARD URBAN FLOODING		
Title	Traditional Approach	Resilient Approach
Insight towards the urban flooding.	This approach stated that it would be easy for the system to anticipate the changes in the future.	It would be complicated to anticipate the change in the process and system of urban flood resilience.
The foremost purpose of the system.	This system only focuses on the stability of techniques used and controls the changes in the system.	This system focuses on to rise the capacity of the design to anticipate future risk or any uncertainty.
Local authorities and	This system has developed a process that focuses on planning to reduce the	This system has based on the concept of adaptive and inclusive planning. It

Source: The Author collected the data from Zevenbergen, C., Gersonius, B. and Radhakrishan, M. (2020) 'Flood resilience', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190212. doi:10.1098/rsta.2019.0212.

Table 3 illustrates the main purpose of each traditional and resilient approach. In traditional approach shows it is easier to predict the change in the system, even can control the changes to bring stability, and pay attention to the possibility of flood reduction. Whereas, on the other hand, the resilient approach explains the change in the system is not predictable and focuses on the enhance the capacity of the system for better results. The goal of the resilient approach is to create an equilibrium between preparing for the flood, prevention from it, and protection from flood. A vital characteristic of the resilient approach is the cost efficiency and the advantages that come with the approach.

Furthermore, the resilience approach appears to follow the concept of collaboration with policymakers, scientists, flood control measures.

Table 4 illustrates the characteristics of a resilient system. The sages include 4 sets such as planning and designing, captivate, redeem, and adaptation. This includes the different attributes of the resilience framework used for urban flooding. It explains a system which the capacity to withstand any type of turbulence and the capability to recover from any type of obstruction. Furthermore, the resilience approach appears to follow the concept of collaboration with policymakers, scientists, flood control measures. The aim illustrates in the table enlighten on steadiness, constancy, determination, and transformation.[76]

75 Zevenbergen, C., Gersonius, B. and Radhakrishan, M. (2020) 'Flood resilience', Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 378(2168), p. 20190212. doi:10.1098/rsta.2019.0212.

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Table 4: Characteristic of Resilient System.[77]

Stages of Resilience	Resilient Attribute	Description
Plan and Design	Mandatory Function	This system helps to recognize the importance of understanding and planning of resilience system to withstand the disturbance. Moreover, it includes the stakeholders to evaluate the performance.
Captivate	Threshold	This system plays an important role in whether the method can captivate the shock and disturbance and in no time will come back to a stable state.
Redeem	Duration	This system assesses the duration of a system, after a flood or shock, how much time it takes to go back to the threshold state.
Adapt	Adaptive Measures	This feature provides an approach to managing and developing plans, learning from the past shocks, disturbances, failures, and success of the resilient system.

Source: The Author.

Therefore, accomplishing urban flood resilience needs change in planning, design, execution, management, and a better urban drainage system. To ensure adequate results, it is ought to upgrade and modify the flood risk, wastewater, and storm-water management plans. Resilience and a resilient city are defined by the United Nations Human Settlements Program (UN-Habitat) as:

The ability of any urban system to maintain continuity through all shocks and stresses while positively adapting and transforming towards sustainability. [78]

Hence, a resilient city evaluates, plans, and takes measures for risk, either sudden or moderate, anticipate or unforeseen.

77 Florin, M.-V. and Linkov, I. (2017) 'IRGC Resource guide on Resilience'. doi:10.5075/EPFL-IRGC-228206. Available at: http://infoscience.epfl.ch/record/228206

78 Resilience and Risk Reduction | UN-Habitat (no date). Available at: https://unhabitat.org/topic/resilience-and-risk-reduction.

CHAPTER 2

URBAN FLOODING IS A GLOBAL AFFAIR.

2.1 INTRODUCTION : Significance of case studies.

This chapter addresses the fundamentals of urban flooding, which has become a global affair. Around the world, many metropolitan cities are at high risk of flooding and have been facing the same issue every year. This chapter focuses on the two major countries one in Asia, another one in Europe. The Asian country is India discusses the risk of urban flooding in the capital City of Delhi focusing on the Yamuna river and its perimeters. Furthermore, in Germany, two cities are under consideration between the Rhine river which is the North-Rhine Westphalia, and Rhineland Palatinate. The reason to choose Delhi for a case study, it is the home city of the Author. As mentioned in the synopsis, the author has personally experienced the urban flooding. This section assists in acknowledging the problems and the key source of urban flooding in Delhi. Also, it looks into the policies developed by the Delhi Municipal Corporation and other organizations National Disaster Management Authority (NDMA). On the other hand, the reason to choose Germany in Europe as a matter of discussion is that it has the most efficient design system and one of the high GDP economies. However, even after this Germany has been suffering from flooding especially in the area near the Rhine river. This is further explained in chapter 2.3.

The key points addressed in the chapter are as follows:

- Overview of the impact of urban flooding.
- Explains the location and its limitations.
- Describes the difference between urban and rural populations.
- Describes the latest incident of urban flooding in the city.
- An overview of fatality and financial loss for a city.
- Explains the urban policies developed by both the cities to tackle urban flooding.

Furthermore, an overview on managing urban flooding. Nowadays, it is necessary to improve and modify the old ways of how urban areas are managing the flow of water to maintain it during the high risk of flood, drier summers, increasing urbanization, encroachment over green spaces, and focusing on embankments to make settlements away from natural water sources and the path of a river. Urban flood resilience can be defined as the capacity of a city to maintain future flood risk by anticipating injuries and death, reducing destruction, and recuperating rapidly later.[79] According to the research in the previous chapter, flooding in urban areas is occurring due to an excessive amount of rainfall, underdeveloped drainage system, unplanned cities, and a rapid increase in urbanization. Every year urban flooding is causing social and economic loss with a catastrophic impact on the environment. These two cities belong to two different continents and developed/developing countries. These two cities belong to two different continents and developed/developing countries. Both are dealing with the urban flood challenges and try to solve them by an integrated approach of urban flood risk management.

79 O'Donnell, E. et al. (2020) 'The blue-green path to urban flood resilience', Blue-Green Systems, 2(1), pp. 28–45. doi:10.2166/bgs.2019.199.

2.2 Case Study: Impact of Urban Flooding in India (South Asia).

As per the National Disaster Management Authority, the Government of India stated that there had been an expanding drift of urban flood catastrophes in India over time. The prime incidents were Hyderabad in 2000, Ahmedabad in 2001, Delhi in 2002 and 2003, Chennai in 2004, Mumbai in 2005, Surat in 2006, Kolkata in 2007, Jamshedpur in 2008, Delhi in 2009, and Guwahati and Delhi in 2010.[80]

Study Area: Delhi India

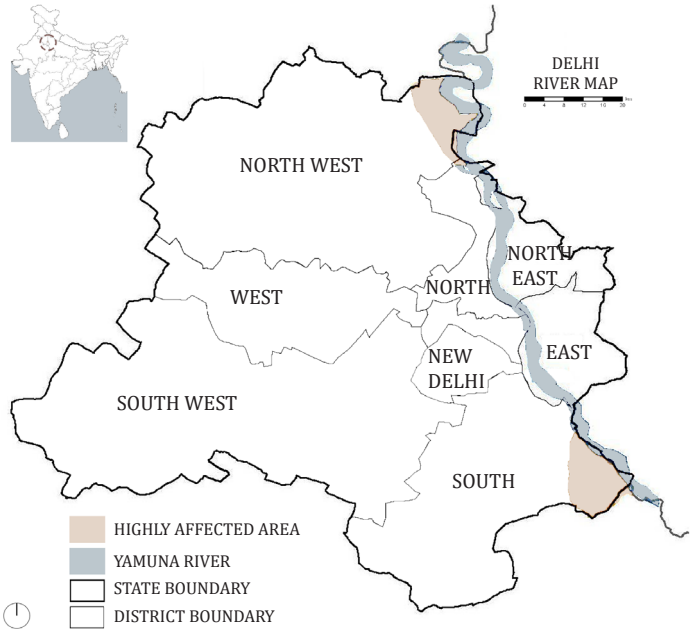
Delhi is a capital city located in the Northern part of India and surrounded by other states of India. It has situated on the right bank of the river Yamuna at the periphery of the Gangetic plains. The western side of Delhi has ridges of the Aravalli Range. The reason behind flooding in Delhi is mainly not because of nature: it is due to the negligence and irresponsibility of the authorities. Delhi has been encountering floods for the past few years in the Yamuna river. According to the data collected by Delhi Disaster Management Authority, the Yamuna river crossed its danger level 53 times during the last 33 years. Moreover, since 1900 Delhi has faced six catastrophic floods and recorded the Yamuna river level used to reach 204.49 mt.[81] In Delhi, the land use is divided into 9 zones; Residential, Commercial, Industrial, Semi-Public use, recreation, transportation, Utilities, and Civic zone.

Figure 10 illustrated the master plan of Delhi with the Yamuna river and the areas around the river are flood-prone areas.

The area near the river is supposed to work as a catchment area, in case of heavy rainfall and overflow of the Yamuna river. However, in reality, usually few slums can be found near the river. Additionally, 90 percent of the city occupies the portal water which is 60 deep from the ground level.[82] Besides, the city consists of three drainage basins which include the North basin, West basin, and South-East basin.[83]

Moreover, the city is densely populated and the settlements are constructed too close to each other.

Figure 13: Delhi River Plan.



Source: Delhi River Plan, https://bmtpc.org/DataFiles/CMS/file/VAI2019/dl.html

80 Urban Floods | NDMA, GoI (no date). Available at: https://ndma.gov.in/Natural-Hazards/Urban-Floods .

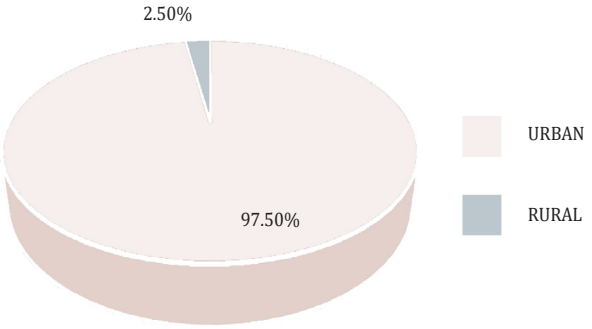
81 Department Of Delhi Disaster Management Authority (no date). Available at: http://revenue.delhi.gov.in/wps/wcm/connect/DOIT_DM/dm/home/vulnerabilities/hazards/floods.

82 Gupta, D.S. (no date) 'Impact of Floods in Delhi', p. 25. Available at: https://www.toi.no/getfile.php/1348333-1530707880/Publikasjoner/DELHI_%20Report%20on%20Floods%20%20and%20its%20impact_2017.pdf

83 Ibid

As per an estimate done by the Census of India, the **population of Delhi in 2021 is 1.96 Crore**.[84] Whereas the urban and rural population as per 2011 census is showing in the chart.

Figure 14: Urban/ Rural population chart of Delhi.



Source: Research Framework,https://www.census2011.co.in/census/state/delhi.html

Figures 13 and 14 explain the urban flooding issue, which is not happening only because of overflow in the Yamuna River also the immense amount of migrated people from rural to urban areas in Delhi. Moreover, heavy rainfall is not the only reason for the overflow of the river, temporary settlements near the bank of the Yamuna river disposed of tons of waste into the river. The recent flooding happened on Friday, September 10, 2021, due to record-breaking rainfall that raised the water level in the Yamuna river, illustrating in figure 12. This time the monsoon rainfall breached the 1000mm level: this occurred the first time since 1975.[85] On account of heavy rain caused the waterlogged at Indira Gandhi Airport (IGI) airport in New Delhi, which affected flight operations also affected the tracks at Delhi railway station, arterial roads, underpasses and residential areas because of the poor drainage and mitigation system.

This urban flood event showed the capital city and the authorities that the whole Delhi drainage system had collapsed. They have to reconsider the measures to build a city that can withstand the urban flood.

Figure 15: Water logged due to heavy rain in Delhi.

Source: PTI (2021) 'Delhi records 1,100 mm of rainfall in 2021, highest in 46 years', ThePrint, 11 September. Available at: https://theprint.in/india/delhi-records-1100-mm-of-rainfall-in-2021-highest-in-46-years/731858/

Table 5: What Urban Floods have cost India?[86]

LOSS DUE TO URBAN FLOODING IN INDIA OVER 65 YEARS.		
S.NO.	CATEGORIES	DATA IN NUMBERS AND RUPEES
1	FATALITY LOSS	1,07,535 No.
2	CATTEL LOSS	60,49,349 No.
3	PROPERTY LOSS	8,07,17,993 No.
4	REGION DESTROYED	466.335 million hectare
5	TOTAL FINANCIAL LOSS	Rs. 37,82,47,04,70,000

Source: Author.
Data collecetd from https://www.indiatoday.in/india/story/loss-due-floods-india-people-killed-crop-houses-damaged-in-65-years-1591205-2019-08-27

Table 5 illustrates the loss that Indian GDP (Gross Domestic Product) bears in terms of financial loss public property loss, and fatality loss.

84 Delhi Population Sex Ratio in Delhi Literacy rate Delhi NCR 2011-2021 (no date). Available at: https://www.census2011.co.in/census/state/delhi.html

85 Watch: Delhi Airport Flooded After Record Rain, City On Orange Alert (no date) NDTV.com. Available at: https://www.ndtv.com/india-news/parts-of-delhi-airport-waterlogged-after-heavy-rain-in-national-capital-2537203.

86 What India suffered due to floods in 65 yrs as skies rained death & destruction - India News (no date). Available at: https://www.indiatoday.in/india/story/loss-due-floods-india-people-killed-crop-houses-damaged-in-65-years-1591205-2019-08-27

The figures are too huge, which sometimes takes too much time to recover from the disaster. This data is showing the loss of over 6 decades, and the risk of urban flooding is still at its peak.

2.2.1 Land Use Land cover of Delhi, India.

Land cover is the observed physical cover on the surface whereas, Land use depicts the actual use of land on the biophysical cover.[87] Land use land cover is not only to calculate geological structure, altitude, and slope besides uses for institutional setups and socio-economic factors. Moreover, throughout the period, the factors of LULC have changed. Although, the reason for the changes has been both human and natural factors. Hence, the quantitative assessment of LULC is a highly effective way to record the change in landscape. However, the change in land use can be created by many factors which are managed on different levels such as local, regional, and global levels. Furthermore, the rapid urban growth with unmanageable rise in population, and industrial development has been constantly changing the land use pattern. The LULC has direct and indirect impacts on the urban environment. The rapid change in LULC has affected the climate pattern majorly in urban areas.[88] The LULC has direct and indirect impacts on the urban environment. The rapid change in LULC has affected the climate pattern majorly in urban areas. Mostly it affects the hydrological system, biodiversity, urban landscape quality, urban thermal environment, ecosystem, and air quality.[89] To develop a LULC map, the satellite imageries method is used for classification. In the midst of, many techniques supervised and unsupervised classification has been used more often. Further on, it is based on two factors that are internal homogeneity and external heterogeneity. The tool used to develop it is the Iterative Self-Organizing Data Analysis Technique (ISODATA).[90] The LULC is divided into six parts such as Agricultural Land, Water Body, Built-up, Vegetation, Open/Fallow Land, and Ridge. However, the accuracy rate of this method depends on the LULC distribution and mapping which are used to generate the maps. This accuracy rate decides whether to use the map to collect data or the map is applicable for further use. Therefore, a minimum of 80 percent has been set to calculate the accuracy rate for maps.[91]

Moreover, with respect to the study area, Delhi and Delhi NCR consist of a National Capital Territory Delhi is surrounded by 18 districts from states Uttar Pradesh, Haryana, and Rajasthan. The region NCR was developed in 1985 for the development of Delhi and surrounding districts which follows the same policies for land use.[92] The region NCR was developed in 1985 for the development of Delhi and surrounding districts which follows the same policies for land use. Delhi NCR has a composite climate along the ridge of Aravalli with the Yamuna river and the Ganga River.

87 Naikoo, M.W. et al. (2020) 'Analyses of land use land cover (LULC) change and built-up expansion in the suburb of a metropolitan city: Spatio-temporal analysis of Delhi NCR using landsat datasets', Journal of Urban Management, 9(3), pp. 347–359. doi:10.1016/j.jum.2020.05.004. Available at: https://linkinghub.elsevier.com/retrieve/pii/S2226585620300637

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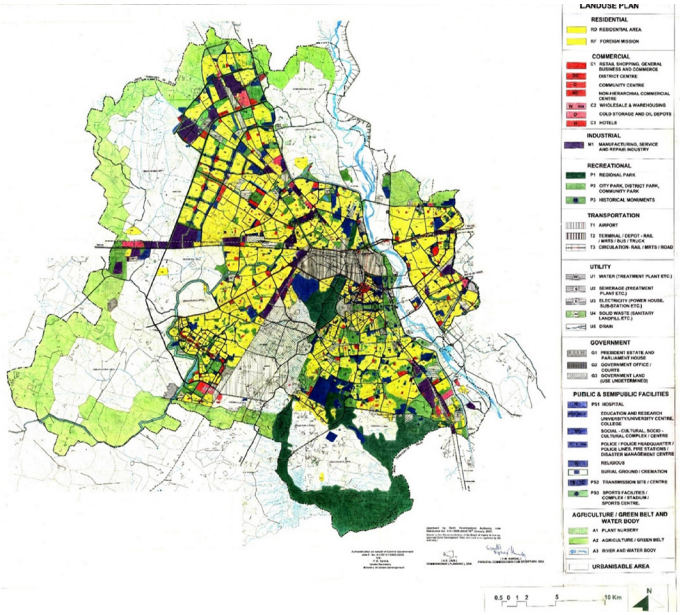
Moreover, in Delhi, the surface is mostly impermeable specially made of concrete for residential, industrial, and commercial areas. Delhi's population growth affected the built-up area causes the widespread LULC. Figure 16 shows the land use plan of Delhi.

Figure 16: Land Use plan of Delhi 2021.



Source: Master Plan for Delhi- 2021, Land Use Plan, Delhi Development Authority, India.
DDA (2020), Master Plan of Delhi, Delhi Development Authority, India, Official webpage, Reference: https://dda.org.in/planning.aspx#.

Delhi land use is divided into nine zones which include Residential, commercial, Industrial, Public use, Recreational, Transportation, Utilities, and Civic zone.

2.2.2 The drainage system in Delhi.

Delhi city has three drainage basins distinguished according to the areas which include North Basin, West Basin, and the southeast Basin. Delhi incorporates almost 24,840 hectares of flood plains and from which the Yamuna river has 68 percent of the total area.[93] According to the rule of the Supreme Court of India in 2014, states that on both sides of the Yamuna river the flood plain has to increase 300meters, along side the drainage of the Yamuna rivers has to increase 200meter in flood plains, and around lakes or ponds need to increase almost 50 meters.[94] Nonetheless, according to the research, it has been found that the width of flood plains has reduced from 800 to 300 meters from 1986 to 2016 respectively.[95] This has been a tremendous loss for the ecosystem and nature around the river. Furthermore, the topography of Delhi is not completely flat due to the presence of the Aravalli hills. Therefore, the area around the East side of the Yamuna river is low.

Moreover, the Government of NCT of Delhi (National Capital Territory) and the Irrigation and Flood Control Department have divided the city into six drainage zones. These zones included **Northern Zone, South Zone, East Zone, West Zone, Central North West- South East Zone, and Central South - Southeast Zone**.[96]

Additionally, the city comes under 12 municipal zones in order to tackle the excess runoff water from urban areas of Delhi. The whole city consists of around 350km of natural drainage line and 1700 km of man made floodwater drains. These zones are mentioned in the map in figure 17 along with the flood plain area around the Yamuna river. Also heightened the area is red to show the development of the drainage basin.

93 Gupta, D.S. (no date) 'Impact of Floods in Delhi', p. 25. Available at: https://www.toi.no/getfile.php/1348333-1530707880/Publikasjoner/DELHI_%20Report%20on%20Floods%20%20and%20its%20impact_2017.pdf

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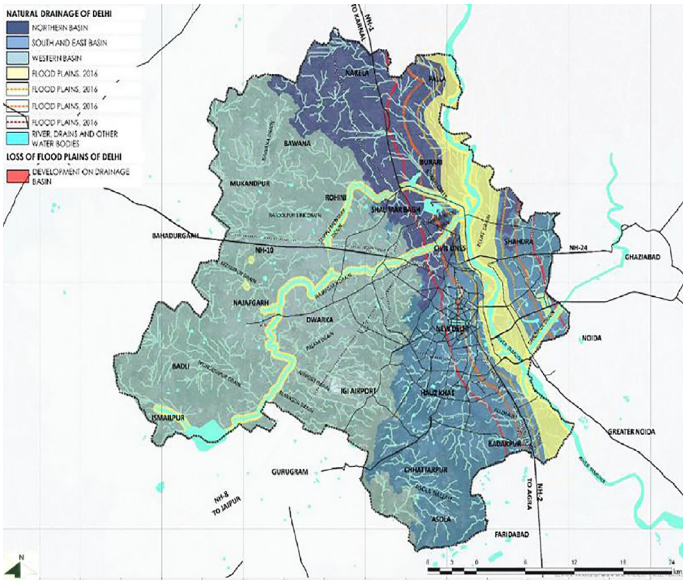
Figure 17: Drainage system and flood plains of Delhi.



Source: Gupta, D.S. (no date) 'Impact of Floods in Delhi', p. 25. Available at: https://www.toi.no/getfile.php/1348333-1530707880/Publikasjoner/DELHI_%20Report%20on%20Floods%20%20and%20its%20impact_2017.pdf

However, all the authorities are not in charge of flood risk management. This responsibility is divided among various authorities and national organizations. Moreover, the drainage system for the NCT of Delhi is divided between the Government of NCT of Delhi and the Government of India.

The civil bodies and departments are as follows:[97]

- Irrigation & Flood Control, Delhi.
- Delhi Jal(water) Board.
- Various Municipal Corporations of Delhi.
- Urban Development, Delhi.
- Ministry of Urban Development.
- New Delhi Municipal Council.
- Delhi Development Authority.
- Delhi Cantonment Board.
- Delhi State Industrial Development Corporation.
- Public Works Department, Delhi.

There are many other departments in government and civic bodies which do not come under direct responsibility are as follows:[98]

- Irrigation & Flood Control, Government of Haryana
- Traffic Police, Delhi
- Geo-Spatial Delhi Ltd.
- Central Water Commission
- Indian Meteorological Department.
- Various Resident Welfare Associations (RWAs).
- Central Pollution Control Board of Ministry of Environment and Forests.
- National Green Tribunal.
- National Highway Authority of India
- Civil society activist groups.

Even after so many government bodies, the lack of coordination is affecting the flood plain area of Delhi. The municipalities and the authorities that work for Delhi and Delhi NCR (National Capital Region) focus on this management of the urban and rural areas of the city. However, these civic bodies come under the Central Government not under the state government. This caused issues among the authorities since the presence of two different government political parties doesn't coordinate properly which affects the policies and their implementation.

97 Gupta, D.S. (no date) 'Impact of Floods in Delhi', p. 25. Available at: https://www.toi.no/getfile.php/1348333-1530707880/Publikasjoner/DELHI_%20Report%20on%20Floods%20%20and%20its%20impact_2017.pdf

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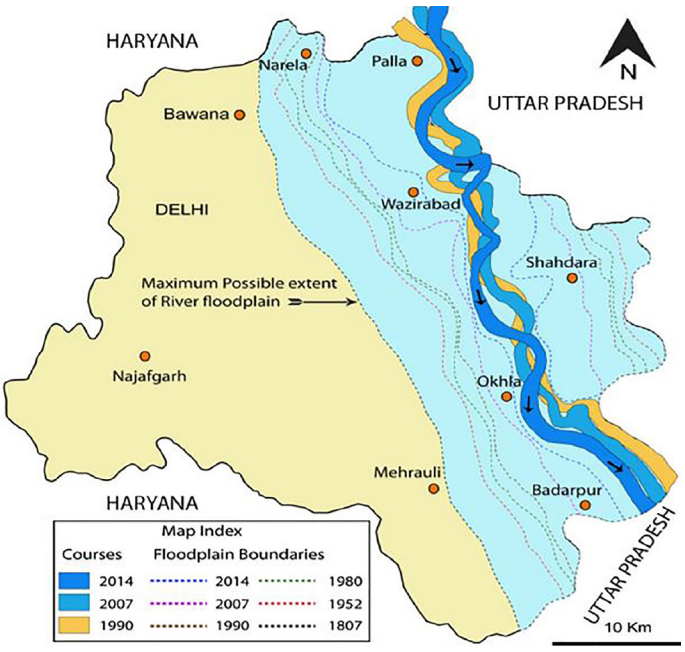
2.2.3 Flood Hazard Map of Delhi, India.

This section focuses on flood hazard maps generated by the Indian Meteorological Department and the National Disaster Management Authority. It discusses the maximum possible extent of the river flood plain near the Yamuna river. Figure 18 illustrates the change in flood plain boundaries from 1807 to 2014. The map depicts the reduction of food plains over time. As a result of which in case of heavy rainfall, and overflow of the river, the area marked in blue has more chances to affect by urban flooding. The map shows the huge area of the East, South, North, and Central zone that can be affected by the flooding. Moreover, since Delhi shares its borders with two states Haryana and Uttar Pradesh as shown in the figure, any future flood incident can have an impact on these two states as well.

Figure 18: The Yamuna flood map shows the reduction of the flood plain.



Source: Kumar, M., Sharif, M. and Ahmed, S. (2017) 'Flood risk management strategies for national capital territory of Delhi, India', ISH Journal of Hydraulic Engineering, 25, pp. 1–12. doi:10.1080/09715010.2017.1408434 . Available at: https://www.tandfonline.com/doi/abs/10.1080/09715010.2017.1408434

Measures have been taken to control the risk of flooding.

This section focuses on the measures that the NCT of Delhi has been using to reduce the flood risk.

- **Development of embankments along the sides of the Yamuna river.**

From 1955 to 1978, many embankments were constructed on the stretch of 210 km on both sides of the river to defend the rural areas.[99] The Delhi - Haryana construction was completed in 1978 which covered the area of 11.5km near East of GT road and protected 14 villages.[100] This construction and maintenance were under Haryana Irrigation Department.

- **Avoid soil erosion difficulty.**

To protect the embankments from the overflow of the river, the layer of studs and bed bars are used to avoid soil erosion in the location which is highly vulnerable. According to the reports, more than 30 shanks were developed on both sides of the embankments near the Yamuna river.

- **Development of drainage system.**

In the development of a drainage system, a network was spread which consists of six main drains as Shahdara Out Fall, Gazipur, Shahdara Link, TD-I, TD-II, and Karawal Nagar.[101]

99 Kumar, M., Sharif, M. and Ahmed, S. (2017) 'Flood risk management strategies for national capital territory of Delhi, India', ISH Journal of Hydraulic Engineering, 25, pp. 1–12. doi:10.1080/09715010.2017.1408434. Available at: https://www.tandfonline.com/doi/abs/10.1080/09715010.2017.1408434
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Each drain has a capacity of 45.2 cubic meters and a length of 5.47 km.[102] Moreover, a sufficient amount of pumps with high capacity has been installed at the Najafgarh drain in order to avoid water-logging in the drains. The capacity of this drain is around 283.45 cubic meters. However, in case of the failure of one pump and another pump was installed with the capacity of 141.7 cubic meters.[103]

- **Establishment of Dams**.

Construction of dam took place after the server flood in Delhi in 1977.[104] Later the organization and authorities decide to build a dam between two states i.e., Rajasthan and Haryana. the dam was constructed on Ajmeripura in Rajasthan and a barrier in Haryana at Masani. Along this small tanks were constructed to store water and to use it for irrigation. These structures help to control the overflow of the Yamuna river and cause flooding in Delhi.

- **Development of Ring bunds.**

Due to the high risk of urban flooding, and overflow of the river ring bunds were constructed around the villages in Delhi. These measures took place after the flooding in 1977. The height of these ring bunds was 6 feet.[105]

These are the old measures which were taken over 5 decades. Although, at that time some of these measures have proven to be sufficient. However, rapid urbanization and reduction of land cover have brought new challenges among the authorities. Besides, some measures are still helpful.

Interpretation of the flood control measures.

This focuses on the old measures and analysis that if these measures are still wolfing and giving a positive result.

- Lack of enough storage basin in the upper Yamuna basin, and the capacity of the existing basin is not enough now.
- Encroachment on a flood plain, that is rising the soil erosion problem.
- Due to improper maintenance, vulnerable stretches and gaps have been created on embankments which are affecting its efficiency to block the floodwater.
- Again due to improper maintenance and urban growth, the efficiency of the drainage system has been reduced. This drainage has started to backflow the excess water.
- Most of the pumping stations are lack out-falling drains to keep them working more efficiently. Due to this, sometimes drains started to flow back in low areas.
- Improver and lack of sewage system and connecting with the drainage network.
- Due to the lack of a storage basin, the capacity of water runoff retention has been reduced which causes the risk of flooding.
- Lack of floodplain development increases the chance of temporary settlements in the area.

102 Kumar, M., Sharif, M. and Ahmed, S. (2017) 'Flood risk management strategies for national capital territory of Delhi, India', ISH Journal of Hydraulic Engineering, 25, pp. 1–12. doi:10.1080/09715010.2017.1408434. Available at: https://www.tandfonline.com/doi/abs/10.1080/09715010.2017.140843

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2.2.4 Urban Flood Risk Management Policies Delhi, India.

This section focuses on the early warning system for flooding and coordination among national bodies and the challenges arise during urban flood risk management policies. Numerous factors need to address to generate dependable strategies for urban flood disaster management. It requires scientific research and technology for modeling, forecasting, and monitoring.

2.2.4.1. Early Warning System for flooding.

Early warning data network for monitoring and coordination.

It has been found that sometimes the data and information getting from national monitoring networks is not adequate for local authorities to take action again flood risks on a local level. Although, there are network centers located according to hydrological and meteorological needs. However, the network and communication are not sufficient. Besides these network station needs to be placed in the local and dense area according to the topography and be in coordination with National Meteorological and Hydrological Services (NMHSs).[106]

National Hydrometeorological Network

The national organization of Central Water Commission CWC has installed and maintained 878 stations all over the country. To achieve and collect accurate data from the river basin. Besides this, CWC has proposed to install new 222 stations in the location which is far and dense to deal with the growing threat of urban flooding.[107]

National Meteorological Network.

About National Meteorological Network, IMD (India Meteorological Department) was established in 1875 to observe the rainfall data.[108] This organization is the head to manage the rainfall data. All other organizations provide data to IMD to store it for future reference.

Real-Time Rainfall Data from Local Networks.

In older times, the point rainfall data system was used to model and examine the flood threat. However, in urban areas, it was not very successful due to the dense settlement. Due to this and the absence of rainfall data for urban areas the real-time rainfall data system was installed. This records the data with higher efficiency and is a great tool to improve the early warning system.

Doppler Weather Radars.

Doppler Weather Radars is an important tool to generate data for up to 3- 6 hours before.[109] This tool is used to monitor the high risk of rainfall that occurs at the local level. It has proven to be an efficient system for urban flood early warning management. It thoroughly analysis the thunderstorms and cloud bust.

106 Indien (2010) National disaster management guidelines - management of urban flooding. New Delhi: National Disaster Management Authority, Government of India. Available at: https://nidm.gov.in/pdf/guidelines/new/management_urban_flooding.pdf

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National Hydrological Information System.

National Hydrological Information System provides real-time rainfall information after getting data from various organizations which looks after this at the national, regional, and local levels. This provides the data for every 15-60 minutes based on the intensity of rainfall.[110]

2.2.4.2. Challenges in Urban Flood Disaster Risk Management.

Even after all the policies and involvement of all national bodies to maintain the early warning system for flooding, the threat of urban flooding is growing not just in the capital city Delhi, most of the states in India are suffering from the risk of urban flooding. The problems that occur in the process of urban flood risk management are as follows:

- Understanding and acknowledging risk assessment.
- Risk developed during the planning for policies in the structural process.
- Lack of communication and coordination between national bodies.
- Undersupply of the data and information among authorities.
- No or less involvement of stakeholders.

Use of Watershed as Basis for the Management of Urban Flooding.

In the urban areas, the watersheds consider a small catchment zone. The watersheds drain water into lakes and rivers.

Furthermore, while constructing catchment zones in consider floodwater drainage systems and plans to work efficiently to tackle the urban flooding. However, while constructing catchment zones, it is necessary to consider the natural watersheds in the area.

Evaluation of flood damages.

The damage and loss that happened after the flooding is estimated in two ways **direct loss and indirect loss.** Direct loss can be described as a loss that occurs after the encounter with flooding directly. It includes the loss of a building, infrastructure, human, and animal. Indirect loss includes the incidents such as transport disruption, loss of business, loss of family income.[111]

Hazard Risk mapping and zoning.

Hazard maps required mitigation measures in the form of structural and non-structural policies. Hazard maps required mitigation measures in the form of structural and non-structural policies. The technical method is GIS to develop a map with the help of hydrogeology data.

In the end, it is necessary to adopt mitigation measures in all the old urban flood policies to get desirable results. The challenges that authorities and other organizations face today can be solved by proper communication among these national bodies.

110 Indien (2010) National disaster management guidelines - management of urban flooding. New Delhi: National Disaster Management Authority, Government of India. Available at: https://nidm.gov.in/pdf/guidelines/new/management_urban_flooding.pdf

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2.3 Case Study: Impact of Urban Flooding in Germany (Europe).

In 2020, the population living in urban areas and cities 77.45 percent of the total population of Germany.[112] Nevertheless, Germany does not come in the list of the top 30 urbanized countries in the world where urbanization is rising more than 83 percent. Moreover, according to the survey in 2014, 25 percent of the German population is living in rural areas. Additionally, the population rate is declining because of the low fertility rate hence cities specially those which are located in the East are shrinking, due to which people are migrating to the major cities for economic opportunity.

In a very recent flood incident, some European countries have witnessed extreme rainfall and flood disasters in decades including Germany, Belgium, and France, in July 2021.[113] The western area of Germany has been found to be extremely affected by heavy rainfall, flood, and landslides. Flood has destroyed the highways, houses, and whole communities in the states **Rhineland-Palatinate and North Rhine-Westphalia.** Most of the houses in rural states were constructed by wood skeletons known as **Fachwerk** which provides less strength to withstand the weather effects, due to this, the casualties were more. After the flood, landslides collapsed many houses in the region, many floods occurred during midnight. German Interior Minister Horst Seehofer said there was little doubt that the flooding was related to global warming.[114] Heavy rainfall turned small rivers into torrential streams that devised the whole town. Dams were undermined to break whereas, power and mobile services were closed down.

Figure 19: Germany River Plan.

Source: Author

Figure 19 shows the path of the Rhine rivers, which cover west Germany. The cities around the river are at high risk of urban flooding. The latest flood event occurred in these cities only, which is illustrated in figure 20. Even the neighboring countries were also affected by the flooding. The main reason for the incident was heavy rainfall which over overs the river.

112 "Germany - Urbanization 2010-2020." Statista, Available at: https://www.statista.com/statistics/455825/urbanization-in-germany/.

113 Welle (www.dw.com), Deutsche. Germany Battles Deadly Floods | DW | 24.07.2021. Available at: https://www.dw.com/en/germany-battlesdeadlyfloods/av-58621927.

114 Pancevski, Bertrand Benoit and Bojan. "Germany Flooding Explained: What to Know About the Devastating Downpour." Wall Street Journal, 19 July 2021. Available at: https://www.wsj.com/articles/germany-flooding-bernd-whats-happening-11626446298.

Figure 20: Floods in Germany after heavy rain.

Source: PRESS, ASSOCIATED. "Heavy Flooding Prompts Chaos in Germany, Other Parts of Europe." Daily Sabah, 14 July 2021. Available at: https://www.dailysabah.com/world/europe/heavy-flooding-prompts-chaos-in-germany-other-parts-of-europe

The data recorded by Germany's DWD climate service shows devastating results, almost 80 liters of rain recorded per square meter in 12 hours. This flood event occurred in 2021 due to the heavy precipitation that caused the pluvial flooding as a result, it showed the catastrophic effects in large, medium, and small cities in Germany. Besides all the strategies of urban flood risk management, these latest incidents proved the lack of an integrated approach to prevent the negative impact of heavy rainfall.[115] The city is divided into 16 federal states. Also, there are three major and largest river catchments which are located in South-East the Danube catchment, in West the Rhine catchment, and in North-East the Elbe catchment. Furthermore, all these three catchments are crossing borders with neighboring countries of Germany.[116]

Moreover, several factors are responsible for the growing risk of urban flooding which includes unplanned land use land cover, old with less capacity drainage system, growing development, and lack of water catchment zones. The flood event that occurred in 2021, has left catastrophic results. This event occurred due to heavy rainfall in summers. There are three main sources and reasons that need attention such as) storm-water drainage, heavy rainfall, and catastrophic rainfall.

Impact of climate change.

In Germany, climate change is playing a vital role in the growing risk of urban flooding. According to the climate data, the occurrence of rainfall, heat, and drought has been enhanced. At the same time, rising sea level is causing the risk of coastal flooding.[117] Impact of climate change on flooding are as follows:

- The extreme shift in the amount of precipitation from summers to winters leads to an increase in the amount of the proportion of precipitation. This excess amount of precipitation does not store as snow, hence it causes extreme discharge and creates winter floods.

- During the severe winters in the North and Baltic seas, the rising sea level enhances the chance of storms. These storms have become constant along the German coastline.

115 Bosseler, B. et al. (2021) 'Living with Urban Flooding: A Continuous Learning Process for Local Municipalities and Lessons Learnt from the 2021 Events in Germany', Water, 13(19), p. 2769. doi:10.3390/w13192769. Available at: https://www.mdpi.com/2073-4441/13/19/2769

116 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

117 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

2.3.1 Adaptation of Urban Flood Risk Management in Germany.

Adaptation of urban flood risk management in Germany. The development and progress in urban flood risk management happened due to the events of the major flood that happened in the past in Germany. The flood history and the destruction by flooding brought the organization together to deal with the risk of urban flooding.

The catastrophic flood events occurred in 1993 and 1995 on **Rhine catchment**, which changes the perspective toward the traditional approach of urban flood risk management.[118] Another event that occurred in 2002 at The **Elbe** caused USD 11.6 billion total damage.[119] This is one of the most expensive disasters that occurred in Germany. The next major event that occurred in 2013 caused almost 8 to 10 USD billion damages. Moreover, from the year 2014 to 2017 several flood events occurred in the form of flash floods and pluvial floods which expand from the river to coastal flooding.

Management and Involvement of various Institution.

The flood risk management has been divided among this national organization which sets responsibilities for each sector.

- **Federal (Bund)** regulates the general standards.
- **State (Länder)** focuses on all water problems which included civil protection and risk management of ground. This mainly supervises the fluvial and coastal flood risk.
- **Municipalities and local authorities** focus on the pluvial flood risk.
- Flood Risk Management is connected with several inter-government organizations, for instance, **Bund-Länder** focusing group on the water.
- The legislative institution works for the major floods.

The involvement of these institutions provides a different approach for urban flood risk management. For instance, the water cooperatives were starets in North Rhine-Westphalia. This maintains the small rivers on the district level and follows the plans developed by Flood Risk Management. Moreover, in other parts of Germany, the alliance carried out to implement the Flood Directives all over the states and river basin. Furthermore, after the change in Federal water law, the flood risk management plans were first implemented in 2005 in all 16 states.[120] Before this implementation, the informal organization was working in states with fewer restrictions.

Legislative Measure.

As mentioned above, these institutions or floor risk management legislative came into action after the flooding in 2002.[121] Several integrations have been seen in Germany after this.

118 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

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Furthermore, to improve the flood risk management, a five-point action program was introduced which involves the federal-state FRM process, a strategy for river basin boundary, and the plans with coordination of the European Union. This came under the new act called Omnibus Flood Control Act of 2005 from the Federal Water and Spatial Planning Acts.[122] This five-point action program also includes the construction and management of catchment zones according to the level of flood danger. Nevertheless, the Federal Water Act or Wasserhaushaltsgesetz does not provide any necessary building codes to authorized the new construction. The second Omnibus Flood Control Act was introduced in January 2018, which focuses on the management of regulation for the use of flood-prone areas.[123]

2.3.2 Urban Flood Risk Management Policies.

The urban flood risk management policies are not under only one organization. The responsibility is divided among three organizations as the Federal creates basic standards, State (Länder) is accountable for water issues, risk management on the ground manages fluvial and coastal flood risk, and Municipal (local authority) supervises pluvial flood risk. Moreover, Flood Risk Management has been facilitated by many intergovernmental factors, such as the combined intervention by Federal and State authorities to develop structural and non-structural measures. . The proposal and the development of a flood hazard map are usually not done by one authority. However, it includes the different levels of management from early warnings to risk assessment.

RISK GOVERNANCE[124]

The responsibilities have been distributed to each government association:

- Federal creates basic standards.
- State (Länder) is accountable for water issues, risk management on the ground, manages fluvial and coastal flood risk.
- Municipal (local authority) supervises pluvial flood risk.

Flood Risk Management has facilitated by many intergovernmental factors, such as the combined intervention by Federal and State authorities.

Multi level governance:

- Early warnings linked to emergency preparedness.
- Risk assessment and Communication.
- Risk Reduction.
- Risk prevention through planning and land use.
- Risk financing for public assets.
- Response and reconstruction.

122 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf
123 IBID

124 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 8. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

It also includes the measures which try to control or reduce the threat of flooding or try to reduce its impact. Also, involves the organization dealing with the funds. However, in case of failure of all the measures, a risk assessment team provides a quick response for reconstruction.

Flood Hazard Map.

The state ministries mainly the state environmental agencies develop the flood hazard risk map.[125] In this way, the flood hazard map is available for each state in Germany which is easily accessible also.

Table 6: The Flood map description provided by the agency according to the use.

Provider	Description	User
Federal states/The German Federal Institute of Hydrology	Public river and coastal flood risk maps[11]	Planners, homeowners and modellers, but not specifically targeted to any of these groups
The German Insurance Association	Flood risk zoning maps with four river flood risk levels and risk zones for heavy precipitation (ZÜRS Geo)	Insurance industry
The German Insurance Association	Risk maps for different natural hazards including flooding[12]	Private households, businesses (proof of concept for a future nationwide online portal on natural hazards; as a consequence only available for 5 out of 16 federal states)[13]
Federal states and the German Weather Service	Current river water levels and flood warnings (Hochwasserzentralen), meta portal that links all the flood information pages of the 16 Länder[14]	Publicly available, used by emergency responders, private households and businesses (only partially suitable for non-experts)
Federal states	Five-day flood forecasts (availability and quality varies between states)	Publicly available, used by emergency responders, private households and businesses
Commercial modellers, insurers	Probabilistic flood risk models, insurance catastrophe models	Insurers, brokers and reinsurers
The German Weather Service, federal offices	Targeted flood warning service for infrastructure as part of a disaster warning service through different warning apps[15]	Publicly available, used by emergency responders, private households and businesses
Cities, local authorities	Local pluvial flood maps	Homeowners, planners and emergency responders

Source: Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

The flood hazard maps are usually explained in the form of color visualization and according to different states where as the flood risk maps are consistent. The geoportal of the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde, BfG) is used to genetare dthe flood hazard maps for all 16 states in Germany. Also, it connects with the flood risk mas provided by the agencies of the 16 federal states. However, another platform was introduced in 2017, known as WasserBlicK web-mapping program. [126]

The table 6 provides insight into the organization, and the data provide by each agency according to their use. It explains the role of each agency which are involved in the flood risk management policies. Furthermore, the flood risk data and information are provided by each agency of each 16 states.

This data also provides information about the level of the flood threat. Nonetheless, after increasing the risk of flooding many local authorities have started to generate their own surface water flood risk maps.

125 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

126 IBID

The policies also focus on:

- Flood risk awareness
- Flood alerts and early warnings
- Emergency preparedness measures
- Risk reduction measures
- Property-level protection measures
- Prevention through development planning and land us.
- Disaster risk financing measures for government.
- Flood insurance and other risk transfer solutions.
- Reconstruction.

Moreover, the high risk of flooding made authorities develop an approach with anticipation and coordination. Although, the growing risk of flooding has garbed the attention of political figures, the public, the industry, and stakeholders. Moreover, the flood occurred event in 2022 has marked the regeneration of the flood risk management policies.[127]

The leverage of the urban flood risk management policies in Germany.

The main strength of the policy is the possibility and the standard of information and data. nevertheless, lack of coordination makes it challenging to share data with stakeholders.

With the help of digital platforms and regular reviews of the flood after taking place has been undertaken.

The involvement of national bodies and their investments in the policies is to upgrade the measures for flood risk.

The collaboration between the government organization and insurance companies helps to raise risk awareness and provide risk information.

The flaws in the urban flood risk management policies in Germany.

Requirement of high precision flash flood and surface water flood hazard map.

The lack of alliance between land use and building code regulations.

Lack of coordination for the policies of resilient approach and stakeholders

Mostly the information on flood hazards is not easily accessible on the maps.

Lack of attention of measures for protection standards.

No clear vision for long-term climate change and with lack of coordination of climate with flood risk management groups.

The flood risk management organizations have not foreseen the coordination with local authorities, agencies, different sectors, and government organizations.

127 Surminksi, S., Roezer, V. and Golnaraghi, M. (no date) 'Flood Risk Management in Germany: Building flood resilience in a changing climate', Flood Risk Management, p. 48. Available at: https://www.genevaassociation.org/sites/default/files/flood-risk-management-germany.pdf

2.4 The outcome of case studies.

The case study has shown two different countries from different continents. Both the countries have no similarities except that both are dealing with urban flooding. Where one is a developing country (India) with a high population density, on the other hand (Germany), the other is a developed country with manageable pollution. Besides, both the countries are undergoing rapid urbanization which is raising the issue of land use land cover. In both cases, the lack of communication and coordination among different organizations to deal with urban flooding is the utmost issue.

Although, both countries are upgrading their urban flood risk policies and upgrading the traditional approach by resilient approach. Moreover, the problem is similar lack of maintenance for the drainage system and lack of proper maintenance for embankments.

However, mostly the non-structural urban flood risk management policies are a bit similar among these countries, even structural policies are not different from each other. In the end, both counties ahs realized which policy is working successfully and where it needs to mitigate.

2.5 ANNEXES: Global Affair.

Urban flooding has become a serious issue in developing as well as developed countries. Floods have been getting worse with rapid urbanization, climate change, and unplanned development. For instance, flooding is one the foremost common natural disaster in the United States and Africa.

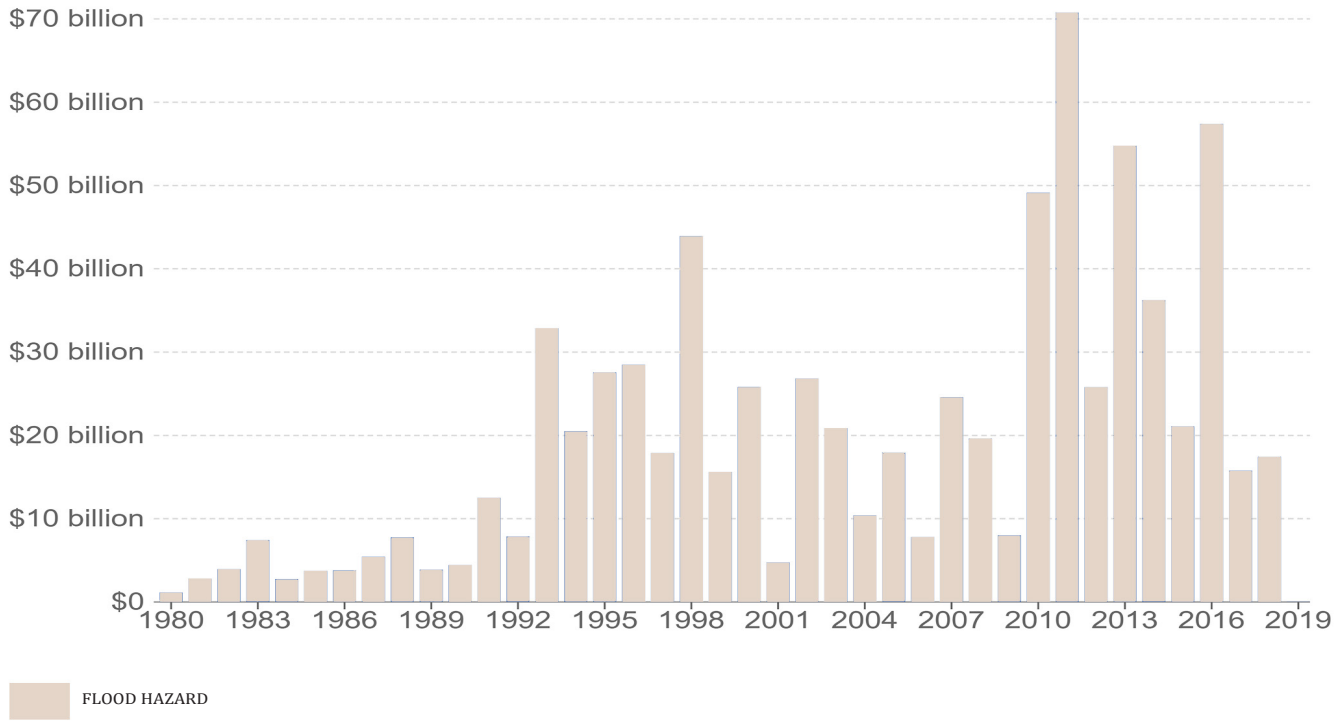
In the United States of America, most cities have been dealing with urban floods, and global warming is making it worse and frequent. These floods or typhoons are the results of snow-melt, heavy rainfall, and an overpowered sewage system. In 2019, the total economical loss was approximately 3.75 billion U.S. dollars which include property and crop damage.[128]

Moreover, in the African continent, western and central Africa are dealing with Urban Flooding. Almost 669,000 population and 77,000 houses[129] have been affected by floods and heavy rainfall in a year: explicitly in Niger, Chad, Nigeria, Togo, the Republic of Congo, the Central African Republic, Democratic Republic of Congo, Ghana, and The Gambia.

128 Economic damage caused by floods in the U.S. 2019 (no date) Statista. Available at: https://www.statista.com/statistics/237420/economic-damage-caused-by-floods-and-flash-floods-in-the-us/.

129 West and Central Africa: Flooding Situation (As of 30 August 2021) - Democratic Republic of the Congo (no date) ReliefWeb. Available at: https://reliefweb.int/report/democratic-republic-congo/west-and-central-africa-flooding-situation-30-august-2021.

Figure 21: Global Financial Loss due to Flood.



Source: Global damage costs from natural disasters (no date) Our World in Data.
Available at: https://ourworldindata.org/grapher/damage-costs-from-natural-disasters.

Figure 21 illustrates the financial loss that countries have to bear over their GDP around the globe. The countries around the globe are dealing with immense economic and fatality losses due to flooding. Such countries are, Bangladesh dealt with flooding during monsoon multiple times. In Africa, few developing countries have suffered the impact of flooding and damages. Furthermore, in South America, Mexico is also dealing with the constant threat of urban flooding. Therefore, urban flooding is a global affair.

CHAPTER 3

CITIES ACHIEVING URBAN FLOOD RESILIENCE

3.1 INTRODUCTION

This chapter consists the international case studies to understand Urban Flood resilience. To acknowledge how to tackle urban flooding threats using structural and non-structural policies. The previous chapter helps to understand that urban flooding is a serious issue, and many cities around the world are suffering from this. Although, this section focuses on how some cities are successfully tackling urban flooding. The key focuses in the study are Netherlands and Japan. The reason two selected these countries for the international research case study is that both have proven to be an example of tackling urban flooding to some extent.

However, both the countries belong to a different continent, with different geographical areas and different climate impacts. Besides, there are similarities in their approach towards urban flooding. Both the countries have used an immense amount of money to develop a mechanical, structural, and technological solution that helps in avoiding the access of excess water inside the city. Furthermore, their structural policies are not completely similar. The Netherlands has used the Dike and levees method to protect its cities from the overflowing of the rivers. On the other hand, Tokyo is using the underground discharge tunnel. Though, some non-structural policies have some similarities.

The primary points addressed in this chapter are as follows:

- Describe the problematic areas in Netherlands and Tokyo.
- Explains the principal source of flooding.
- A brief about the past flood events in the country leave disastrous results.
- Both countries approach urban flood risk.
- Describe the urban policies developed by the authorities and implementation to reduce the growth of flooding in the future.

Moreover, after many incidents of urban flooding, these countries have started to reach toward the resilient approach from the traditional way of planning for urban flooding. Their policies are inclusive of all such as, stakeholders, local people, and authorities. They are trying to spread awareness of this growing issue all over the globe. Also, they are taking missing measures which can help during the failure of any policies in case of emergency.

Furthermore, it also explains how many authorities they have to tackle this threat, as well as what is the role of each authority in achieving urban flood resilience. Besides, in their approach, the policies were developed based on the water act. Also, have a concept of shared responsibility which policies include every department. Whereas, the Japanese approach is leaning more toward the investment approach. Since their underground water collection structure is massive in the world which explains in detail in chapter 3.4.

In the end, there is a conclusion to understand the similarities and differences between the approach of these two countries. Although, even after taking similar types of measures it usually affects less than both the countries belonging to different continents and with their type of topology.

As mentioned earlier, these two countries are known by the world, one of the reasons for that is their massive structural approach toward urban flood resilience. Moreover, achieving that measure in a successful manner is what makes these two countries an example in terms of urban flooding. These cities that have developed a way to deal with Urban Flooding from their own experience. The main questions that needed to address such as How severe and frequent are the flood risk? What are the Flood Risk Management techniques they have used? Understand the system which is going side by side with climate change. How today's system can withstand the future effects of climate change?

3.2 Case Study of Netherlands.

In the Netherlands, almost more than half of the ground surface area is under threat of flooding with canals, lakes, and rivers. In other terms, with the high water level in rivers and lakes,60 percent of the surface area is below sea level. The whole population is living on the substructure of lakes that dried by using pumps two centuries ago.

Moreover, the Netherlands has been using **Dikes and Levees** to prevent lakes from refilling floodwater because of this, the surface is not sagging. In addition to the above, levees are the system that protects land which is usually dry might flooded, whereas the land that is naturally underwater has protected by dikes. To provide safety from flooding, The Netherlands has divided into 53 dike rings areas.[130]

130 Zeeberg, J. (2010) Flood control in the Netherlands: a strategy for dike enforcements and climate adaptation, pg.5. doi:10.13140/RG.2.1.5127.9445.

Figure 22: River Map of Netherlands.

Source: Author.

What Dutch has learned from history?

In 1953, the last catastrophic tidal waves flooded the Northern Sea along the South-West part of the country, drowning more than 1800 people.[131] Later after one year in 1954, another storm similar to last year threatened the Netherlands, even so, this time there were no causalities. Figure 23 shows the destruction after flooding.

131 Jonkman, S.N., Kok, M. and Vrijling, J. (2008) 'Flood Risk Assessment in the Netherlands: A Case Study for Dike Ring South Holland', Risk analysis : an official publication of the Society for Risk Analysis, 28, pp. 1357–74. doi: 10.1111/j.1539-6924.2008.01103.

Figure 23: The village in Netherlands after the storm flooded the Northern Sea in 1953.

Source: Village of Oude-Tonge.
Kuper, S. (2020) 'Can the Dutch save the world from the danger of rising sea levels?', Financial Times, 30 January. Available at: https://www.ft.com/content/44c2d2ee-422c-11ea-bdb5-169ba7be433d.

Figure 24: The Delta Work Flood Defense Mechanism by Netherlands.

Source: Jha, A. (2016) What can Britain learn from Dutch flood defences?, ITV News. Available at: https://www.itv.com/news/2016-01-05/dutch-flood-defences-show-what-can-be-achieved-with-investment.

Approach to flood defense mechanism.

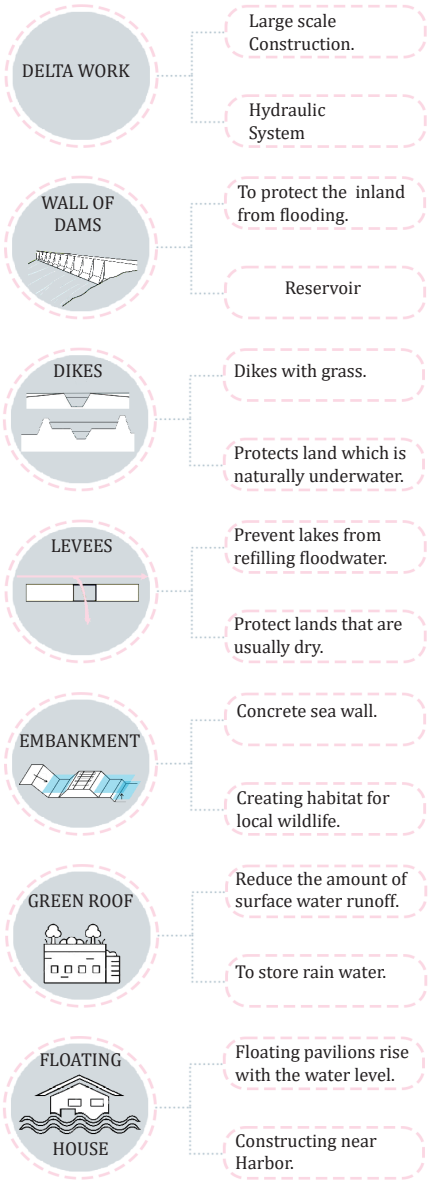
The Netherlands had created the Delta Committee after the flood to inquire into the probability of a Flood Risk Reduction Approach. The committee proposed standards and regulations again flooding, in which they proposed to divide the most flood-prone areas into dike rings areas. The new approach was an innovative technology and construction development such as hydraulic structure which can be activated by computer sensors in case of emergency also the basic approach dikes, dunes, and high ground.

In addition to the above, the hydraulic structure is a pair of 240-meter steel arms. The hydraulic structure barriers have been using 680 tonnes of ball joints and moving along wind and waves. The first on site installation of the Maeslantkering was just one part of a massive interlocking system to control the overflow of water and floods known as Delta Works.

After the 1953 incident, the Delta Commission initiated by the Netherlands government first looked into the highly populated cities with the goal to lower the annual chances of flooding. However, to fulfill this goal a large-scale project needed to cover the whole southwestern coastal area. Additionally, a series of dams were built result the creation of small lakes. Eventually, in 1998 government had finished the project Maeslantkering with auxiliary barriers such as dikes with grass, and embankments.

Moreover, in the following decades, The Netherlands proposed another solution or should say another protection plan again storms and floods, which is the **"Room for the River"** idea. The plan was to widen the embankments and dikes to make them away from the bank of rivers and lakes. This allows the river to follow its natural path with the possibility to spread out more without causing any damage to humans and their settlements.

Figure 25: A brief of strategies to reduce the Risk of Urban Flooding.



Source: Author.

These are some strategies that help the Netherlands to manage urban flooding. However, the country has needed to find new techniques and approaches to make its cities resilient to flooding in the future. While climate change is still a threat in the present as well as in the future, it can cause rising sea levels. The Netherlands has shown the world how to live with nature!

3.2.1 Urban Flood Risk Management Policies by Government.

In the time of climate change, the most endangered area is Urban settlements. Heavy rainfall affects the cities because of the excessive use of impermeable materials in cities. In densely developed urban areas, the system does not drain off the excess water. Besides, it can cause a high amount of economic loss due to the traffic disturbance, phone lines shut down, and dealy of public transport. Hence, to defend with heavy rainfall after effects, the Dutch Government has come up with new approach inclusion of climate change and Urban Water Storage.

Furthermore, The Netherlands Government has combined all authorities to share responsibility equally and generate plans for Flood Risk Management. Hence, the policies have based on the following acts:[132]

- Water Act (Dutch National Government, 2009).
- Spatial Planning Act (Dutch National Government, 2006).
- Environmental Management Act.

132 Dai, L., Wörner, R. and van Rijswick, H.F.M.W. (2018) 'Rainproof cities in the Netherlands: approaches in Dutch water governance to climate-adaptive urban planning', International Journal of Water Resources Development, 34(4), pp. 652–674. doi:10.1080/07900627.2017.1372273.

The major three cities of the Netherlands have developed and implemented policies that are mainly similar from each other.

The approach of Municipality of Amsterdam.

The municipality of Amsterdam aims to handle almost 60mm of rainfall per hour by the current time and an almost complete percentage by 2050[133] without causing any destruction to the infrastructure and inner city. The development has been carried out with respect to the climate adaptation strategy and developing the policy system such as Amsterdam, Rainproof, which involves measures to acknowledge the raising issue of rainfall. This basically works under the water company the Public Enterprise Waternet.[134]

Moreover, the company offers soft policies which include informing residents, business owners, and engaging with government officials. Also focuses on the knowledge of workers for designing the streets, gardens, roofs, squares, and parks, places which can carry excess water from heavy rainfall. Besides, the Municipality of Amsterdam mostly doesn't approve large infrastructural projects. These measures are taken only to make the city more climate and flood resilient. Moreover, the policy of making Amsterdam Rainproof[135] has been executed with the inclusion of several stakeholders, private parties, and government parties.

133 Dai, L., Wörner, R. and van Rijswick, H.F.M.W. (2018) 'Rainproof cities in the Netherlands: approaches in Dutch water governance to climate-adaptive urban planning', International Journal of Water Resources Development, 34(4), pp. 652–674. doi:10.1080/07900627.2017.1372273. Available at: https://doi.org/10.1080/07900627.2017.1372273

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The approach of Municipality of Rotterdam.

According to the Dutch, Rotterdam has a history to live a life around water and developing the city around it. The Municipality of Rotterdam aims to achieve complete climate and flood protection by 2025.[136] This city is at the delta of the Rhine and Meuse rivers. The inner part of the city is below sea level, although it has rings of inner- dikes. Besides, some part of the city is on outer dikes. Moreover, in terms of measures, the outer dikes have used adaptive construction solutions such as flood-resistant built space, flood-proof buildings, and floating communities. Besides, dikes have a system to store floodwater, and rainwater, which makes the city work like a sponge system. Furthermore, the measures also include the green roofings system, less use of the impermeable system, water squares, and more green-space followed by the Rotterdam Climate Change Adaptation Strategy, 2012.[137]

The approach of Municipality of Utrecht.

The Municipality of Utrecht focuses on preventing public space, streets, and public infrastructure from flooding. Their measures are used in case of rainfall of more than 20 mm per house,[138] the public spaces can be used as a water collecting zone. Their measures are used in case of rainfall of more than 20 mm per house, the public spaces can be used as a water collecting zone. Moreover, if it is more than 60mm per hour, the Municipality of Utrecht has the responsibility to take measures for traffic to work smoothly.

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In 2016 the Municipality of Utrecht developed a policy mentioned in Gemeentelijk Plan Water Taken 2016–2019.[139] The policy was focusing on urban adaptation in the city. This policy has separate attributes for public and private areas. Also, the municipality is taking into consideration replacing non-porous surfaces with a porous surfaces. Moreover, to municipality developed communication among local municipalities and the residents to deal with the urban flooding. Their system works with an adaptation approach and is inclusive of all including stakeholders. Besides, Utrecht has a plan to reach a complete flood-proof city level before Amsterdam and Rotterdam.

Table 7: A brief of Urban Policies by the Netherlands Government and Local Authorities.

Adaptation of Water Governance in the Netherlands.

S.No.	Policies	Sub-Divison	Discription
1	Based on Water Act	National Adaptation Strategy and Delta Programme are working together.	Develop policy related to the adaptation of climate change.
2	Delta Programme Principles	Solidarity, Flexibility, and Sustainability.	
		Pay attention to Spatial adaptation Policies.	Spatial Planning, Land Use Planning, Urban Water Management.
3	Shared responsibility of local authority and residents.	Installation of Rainwater Drain System.	Discrete wastewater system.
4	Three-Step approach.	Capturing, storing, and draining of water.	
5	Small-scale spatial planning projects.	Green roof gardens and green strips in residential areas.	Replacing concrete and asphalt with permeable materials.
6	Involvement of Stakeholders.		

Source: Author.

Table 7 illustrates the adaptive measures by the Water Governance of the Netherlands. The responsibility for water governance is divided among several authorities such as Water Act, Delta Program Principles, Three-step approach, small scale spatial planning projects, and shared responsibility of local authorities and residents. Further, the measures execution responsibility is among National Adoption Stregaty working with Delta program. The measures considered in the policy include installation of the rainwater drainage system, construction, and design should be sustainable and flexible enough for any future intervention. Also, it includes the installation of a green roof, green facade, more storage space for rain and floodwater. These measures focus on inclusivity which involves the stakeholders, residents, authorities, and government. Furthermore, most of the new adaptive measures include the climate change factors. Also, policies have incorporated a discreet wastewater system. In the end, their structural and non-structural risk management policies focus on inclusivity. In addition, the adaptation of spatial planning, land use planning, and urban water management to reduce the threat of urban flooding in the inner city.

139 Dai, L., Wörner, R. and van Rijswick, H.F.M.W. (2018) 'Rainproof cities in the Netherlands: approaches in Dutch water governance to climate-adaptive urban planning', International Journal of Water Resources Development, 34(4), pp. 652–674. doi:10.1080/07900627.2017.1372273. Available at: https://doi.org/10.1080/07900627.2017.1372273

3.2.2 Non- Structural Integrated Flood Risk Approach.

The purpose of non-structural measures is to develop and supervise the flood risk. The government does not provide an extreme budget for these measures. Also, the authorities have the control to implement it on their own. The non-structural integrated urban risk policies have played an important role in the development of the city. The base of this measure is **awareness, acknowledgment, acceptance, and change in manner**.[140] In order to spread the issue of urban flooding and its policies, there are several programs run for awareness.

The non-structural integrated approach includes several factors, which works for the different attribute of flood risk policies. Those attribute are as follows:

- Communication and coordination awareness.
- Structural awareness.
- Management and monitoring awareness.
- Health awareness which requires different groups of people such as:[141]
    - Municipal staff, volunteers, and Health professionals.
    - The general public and vulnerable groups.
    - Media employee.
- Land-use zone planning.
- Integrated Risk management.
- Acknowledging the flood zones.
- Flood disaster insurance.
- Upgrade municipal waste management.
- Development and maintenance of drainage system.
- Planning for an emergency.
- Rescue management.
- Incorporation of an early warning system.
- Flood recovery and reconstruction.

3.2.3 Structural Integrated Flood Risk Approach.

The structural approach is majorly helpful to control the overflow of water within and outside the city. It works within the urban flood risk integrated approach. Although, the measures that come under this are expensive to construct. It needs the support of funding from big organizations and government bodies. This approach includes structural solutions such as drainage systems and wetlands. Although, an integrated approach is requisite of both structural and non-structural measures.

The **integrated flood risk** approach also describes that it is not completely possible to remove the threat of flooding.[142] However, intervention and a resilient approach can assist to enhance the capability of the approach to reduce the flood risk.

The structural integrated approach includes several factors, which works for the different attribute of flood risk policies. Although, these approaches require a huge amount of funding. Those measures are as follows:

- Management of the path of the river by making it wider as per the requirements.

140 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

141 IBID

142 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

- Management of the river banks.
- Protect banks from soil erosion.
- Raise the height of banks (levees and dikes).
- Construction of embankments and floodplains.
- Provision of floodwater storage in the form of public spaces as mentioned in chapter 3.
- Proper development and maintenance of drainage and sewers.
- Semi-natural System (SUDS)[143] means it works as an artificial drainage system such as Filter drains Retention ponds, wetlands, detention ponds, and Infiltration basins.
- Management for surface water.
- Management of groundwater and uses of rainwater harvesting.
- Availability of **environmental buffer zone**[144] which included the area spaces and green vegetation. This helps to reduce the overflow of the water, due to the porous surface helping in water run-off retention.
- Involvement of resistance and resilient approach in the new design of a building.
- Development of flood barriers for coastal region.

In the end, both the measures have similar approaches nevertheless one needs to construct a huge structure that requires more funding whereas, the other one needs to spread the awareness on a ground level. Besides, the cities in Netherlands are showing the best example to use both approaches in order to deal with the urban flooding risk.

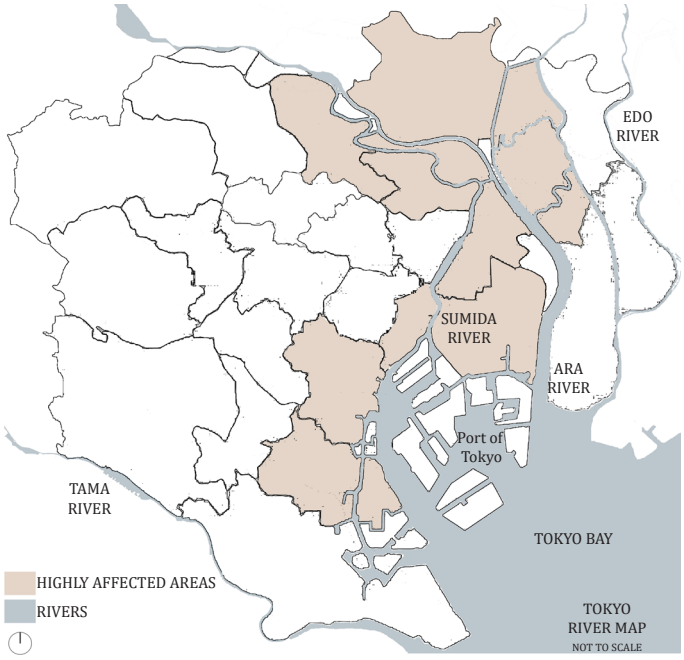
143 Jha, A.K., Bloch, R. and Lamond, J. (2012) Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century. The World Bank. doi:10.1596/978-0-8213-8866-2. Available at: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8866-2

144 IBID

3.3 Case Study of Tokyo, Japan.

Japan has a history of flood threats. In 1742, two typhoons hit the country along with heavy rain and flooding almost all main rivers. The impact of the flood was massive in that it covered the affected areas with mud, destroyed the levees, and recorded 6000 causalities.[145] In 1896, Japan set up the Japan River law to reroute floodwater into the sea. However, the second most destructive typhoon was recorded in 1956.[146] Between the 1960s to 1970s, the growth of urbanization had increased immensely: hence the Japanese Government established **Comprehensive Flood Risk Management Measures (CFRMMs)** to deal with floods and water runoff systems.

Figure 26: River Map of Tokyo, Japan.



Source: Author.

Moreover, as per geographical location, Japan is located in the Eastern part of Asia and comes under a heavy monsoon zone. The average monsoon recorded in Japan is 1718 mm that is double the global average of 880mm. Hence, this is the reason behind the inland flooding in the cities of Japan. It gets worse when the drainage system is inefficient to drain the excess water. Floods in Tokyo are majorly due to inland flooding. In 2019, Typhoon hit the city brought inland flooding with it and raising the water level in the Tama River flowed back into the sewerage and flooded the city.[147]

Furthermore, recently on 15 August 2021, Japan was hit by massive flooding with mudslides and landslides due to heavy rainfall. Moreover, the effect of flooding was not seen in Tokyo city, nevertheless, other cities in Japan as affected by the heavy rainfall.

Figure 27: Flooding after heavy rainfall in Japan.

Source: Photo: Japan Ground Self-Defense Force
Japan – Dozens Rescued From Floods, 3 Killed in Mudslide after More Heavy Rain – FloodList (no date). Available at: https://floodlist.com/asia/japan-floods-update-august-2021

145 Integrated urban flood risk management: Learning from the Japanese experience (no date). Available at: https://www.preventionweb.net/news/integrated-urban-flood-risk-management-learning-japanese-experience.

146 Fan, J. and Huang, G. (2020) 'Evaluation of Flood Risk Management in Japan through a Recent Case', Sustainability, 12(13), p. 5357. doi:10.3390/su12135357.

147 Ltd, P.H. (no date) Floods in Tokyo and Safety Tips and Preparation, PLAZA HOMES. Available at: https://www.realestate-tokyo.com/living-in-tokyo/emergency-disaster/flood-in-tokyo-japan/

Figure 22 illustrates the after-effects of heavy rainfall and over the flow of the Rokkaku river in the area of Ōmachi in Saga Prefecture. The active Japan Ground Self-Defense Force came to recuse the residents.[148] According to the Japan Meteorological Agency, the rainfall recorded was 743mm in 48 hours in the city of Japan Unzen in Nagasaki, [149] after the rainfall heavy mudslide killed many people in the city.

Moreover, the effect of flooding was not seen in Tokyo city, perhaps they have developed an outstanding marvelous underground water tank on a grand scale, which is fulfilling its purpose. At the same time, other parts of Japan are still suffering from flooding.

3.3.1 Japan's approach for Urban Floods.

In Japan, Tokyo is the most populated city. The city has a history of inland urban flooding, due to which the government had come up with a massive and engineering marvel solution. Tokyo has built an enormous tunnel approx 50m underneath the surface, with 35m diameter and 70m high. This project is known as the **Metropolitan Area Outer Underground Discharge Tunnel** or **"G-Cans Project,"** was completed in 2009.[150] It is the largest surge tank in the world by passing a low-lying basin and connects five major rivers to five massive cylinders controlled by turbines. This underground tunnel is stretched from Showa in Tokyo to Kasukabe in Saitama.

According to the authority, this reservoir has minimized Urban Inland Flood by almost 90 percent, and it can store 500 tons of cubic water.

Figure 28: Underground Water Tank Tunnel, Tokyo, Japan.

Source: Ortiz, D.A., The underground cathedral protecting Tokyo from floods. Available at: https://www.bbc.com/future/article/20181129-the-underground-cathedral-protecting-tokyo-from-floods.

Their approach majorly focuses on the structural integrated urban flood risk management. This size of project requires funding from the government agency. This system drains the water into the Edo River after the overflowing of the medium and small rivers in the city. This system works under the supervision of **the Metropolitan Area Outer Underground Discharge Channel**, and it avoids the surrounding and the residential area getting flooded. This whole tunnel system is located under the areas of Edogawa, Nakagawa, and Ōotoshi Furutonegawa in Saitama prefecture.[151]

Moreover, the city also focuses on the non-structural measures for urban flooding.

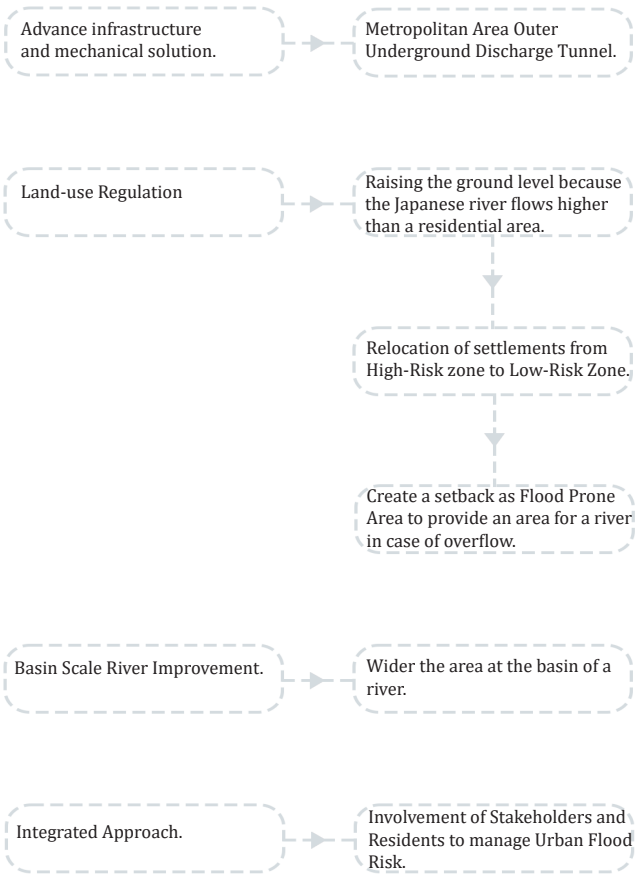
148 Japan – Dozens Rescued From Floods, 3 Killed in Mudslide after More Heavy Rain – FloodList (no date). Available at: https://floodlist.com/asia/japan-floods-update-august-2021

149 IBID

150 Japan's underground flood control tunnel (2020) Telangana Today. Available at: https://telanganatoday.com/japans-underground-flood-control-tunnel.

151 Ltd, P.H. (no date) Floods in Tokyo and Safety Tips and Preparation, PLAZA HOMES. Available at: https://www.realestate-tokyo.com/living-in-tokyo/emergency-disaster/flood-in-tokyo-japan/

Figure 29: A brief of strategies to tackle Urban floods.



Source: Author.

The figure 29 explains the measures taken by the authorities to tackle urban flooding. The use of advanced infrastructure and mechanical solutions to protect the metropolitan area of Tokyo. This is helping the inner city as well as the outer area of the city. There is a huge underground discharge tunnel that stores the flooding water. As per the data from Japan Meteorological Agency, the rivers in Japan flow higher than the ground surface. Due to which cities in, Japan usually faces inland flooding. The municipality of Tokyo has follows the regulation for Land-use. To change the land use away from the riverside as well as it is necessary to keep the ground level higher than the existing building for future.

For most high-risk areas, authorities have proposed to relocate the settlements from high to a low risk areas. Besides, a setback is needed to create especially in flood-prone areas in order to protect the city from the overflow of the risk. This has been done in the form of embankments.

In addition, the measures also include the policies for the river basins. This involves the improvement and management of the river basins. As well as the policy plans to widen the width of the basin. The non-structural integrated approach focuses on the involvement of stakeholders and residents to manage and spread the awareness for urban flood risk.

Integrated Urban Flood Risk Management.

The factors consist in the integrated flood risk management policies[152] are as follows:

- The risk assessment coordination and communication approach focuses on the type of flooding and climate change. Also coordinates these factors with different stakeholders.

- The national government supports the local authorities and local government for the planning and implementation of the flood policy.

- For investment and implementation of any measures, a multi-functional system generates the funding to manage the flood threat.

- The operation and maintenance of the structural and non-structural measures are necessary for long-term results.

152 Ltd, P.H. (no date) Floods in Tokyo and Safety Tips and Preparation, PLAZA HOMES. Available at: https://www.realestate-tokyo.com/living-in-tokyo/emergency-disaster/flood-in-tokyo-japan/

Early warning system for flooding.

The warming system is divided into 5 levels by disaster prevention organization. This is to help the residents to act on the situation accordingly. These levels were developed by the Japan Meteorological Agency further followed by the local government and local authorities.

- Warning level 5 asks for immediate evacuation of the house and the flood area.
- Waring level 4 asks for evacuation.
- Waring level 3 asks for preparation and evacuation for elder people.
- Warning level 2 asks just to be prepared.
- Warning level 1 no need to evacuate and prepare.

3.3.2 Urban Policies by Government.

According to the geographical location, Japan has been dealing with floods and typhoons over time. However, the government has tried to mitigate the flood threat by developing flood resilient cities and inclusive urban policies. The Japans Flood Risk management plan are as follows: [153]

Planning and Prioritization Approach:

The participation of the Government has a vital part to play in this approach. Besides, they have the capacity to manage the plans that include all such as stakeholders.

Investment Implementation Approach:

This approach consists of the possibility of mitigation and flexible design that can act as a multifunction solution that can fulfill other needs along with managing flood risk.

Operations and Maintenance Approach:

This approach focuses on the use of sustainable solutions, as well as regular inspection, maintenance, repair, and replacement of the Flood Risk Management system.

Risk assessment and Communication Approach:

This approach consider the factors of climate change in both the present and future. The system or solutions needed to choose based on flood type and the attributes of the area. Several acts developed after the 1980 **Act Comprehensive Flood Risk Management Measures (CFRMMs)** came for Flood Risk Management.

In 2003, the **Act on Countermeasures** against Flood Damage of Specified Rivers Running cross Cities was developed for the eight major rivers in major cities. It stated that the River Management Authorities needs to save urban areas. Additionally, they created an integrated plan between flood management and sewerage authority.

Later on, in 2004, Government amended the **Flood Fighting Act** in which all the responsibilities of rivers and lakes were transferred to the municipal authority.

153 Integrated urban flood risk management: Learning from the Japanese experience (no date). Available at: https://www.preventionweb.net/news/integrated-urban-flood-risk-management-learning-japanese-experience.

In 2013, **the Ministry of Land, Infrastructure, Transport, and Tourism** came with an urban safety plan to deal with the heavy rainfall in urban areas. Furthermore, in 2018, the Act of Urban Reconstruction was amended especially for highly flood-prone areas.[154]

Furthermore, the Japanese approach for Flood Risk Management shows a positive result to reduce the flood risk and flood damages in cities. Their integrated approach works for the improvement of the river basin, improvement of the floodplains, and incorporation of a non-structure approach.[155] Although, the master plan prepared by the authorities plays an important role to set the land use for the city. It assists in acknowledging the spaces in the city such as green space, open area, built-up area, and water run-off retention. Moreover, this base map compares with the scientific data and hydro-metrological map.

For the same, the responsibility has been divided among different organizations that collaborate to get the result. However, Japan has more cities with the same problem; will it be possible to apply the same structural flood risk approach! Besides, the cities are already upgrading the non-structural flood risk management system. The system also involves the early warnings, and the policymakers focus to make the city flood resilient by including everyone and spreading awareness about the real issue coming up as a threat to the cities such as climate change, urbanization, and urban flooding. At long last, Japan is still developing its systems and approaches to tackle Urban Flood for the most vulnerable area

154 Ibid

155 Ishiwatari, M. (2016) 'What are Crucial Issues in Promoting an Integrated Approach for Flood Risk Management in Urban Areas? ', Japan Social Innovation Journal, 6(1), pp. 15–26. doi:10.12668/jsij.6.15. Available at: https://www.jstage.jst.go.jp/article/jsij/6/1/6_15/_article/-char/ja/

3.4 Outcome of the case studies.

In conclusion, the issues mentioned in chapter 2.2 and chapter 3 show that Urban Flooding is a global challenge. However, the Netherlands and Japan have developed urban policies to deal with flood risk. They have different structural technology, but their approach to tackling Urban Flood Risk is more or less similar, including flexible and sustainable design systems. In both international studies, it is clear that the concept of resilience is used not just to tackle the flooding in the present as well as in the future by anticipating the risk and damages caused by floods. Both the countries are on different continents, with differences in climate and geographical conditions. However, the approaches are the same for flooding which is inclusive of all included stakeholders, habitats, local authorities, and government. At last, both the cities are presenting a great work in Urban Flood Resilience. Besides, the Netherlands has been developed policies all over the country whereas, on the other hand, Japan has developed its policy majorly in Tokyo. At the same time, other cities are still suffering from urban flooding. Both countries have invested a lot of funding in structural integrated urban flood risk management. Moreover, these two countries are an example of urban flood resilience. Although not all countries can take the same measures especially the developing countries.

CHAPTER 4

RESEARCH AREA FOR URBAN FLOODING

4.1 INTRODUCTION

This chapter addresses the fundamentals of urban flooding in Italy. Understanding the situation of urban flooding in Italy focuses on the longest river i.e., the Po river. The research area focuses on the Northern part of Italy, which is the Piedmont region, mainly discusses the city of Cuneo and Turin, the capital city of Piedmont in northern Italy. Both the cities are suffering from urban flood risk, however, to acknowledge the risk, this section discussed the incidents that occurred in the recent past. The initial step is to understand the process of Urban Flood Management in these cities to reduce the flood risk due to rainfall, precipitation, rising temperature, and urban development.

Moreover, How climate change is affecting and causing a considerable threat in urban areas, especially after the rising of heavy rainfall and other climatic events causing an impact on the urban population. (This was explained in chapter-1, although need to understand this concept with respect to the cities in Pediment). Especially, Turin has changed a lot over the course of time because of rapid urbanization which explains later in this chapter. The effects of rapid growth in urbanization can be seen in the present time which is explained in chapter 4.2.2. The threat of minor urban flooding and heavy rainfall can flood the city. The reason to choose Turin as a research area is because it is a city of old architecture, urbanization, and students. Due to many government universities and the quality of education, many international students came to Turin.

The author is also an international student and has experienced water-logging in the city after heavy rainfall in the area of San Salvario and Via Roma in Turin. From there this idea comes to take Turin as the study area, to figure out the problem and the source.

The point of focus in this chapter is:

- A brief about the flooding phenomenon in Italy with a map showing the major rivers in the country.

- A case study of Savigliano, Cuneo, Italy. To understand the problematic zone in the city. In the interviews mentioned in the annexure, two of the interviewee are from Cuneo, and they shared their experience of flooding in Cuneo. A flood map was developed from GIS to understand the condition properly and to find out where is it possible to have urbanization in the future.

- Describe the research area in detail and focus on the three major rivers and their interaction.

- By using ArcMap, discovered the highly flood-prone area and the land-use map, which compared with the hazard map provided by Città di Metropolitana di Torino.

- The use of urban area map to understand the availability of permeable and non-permeable surfaces in Turin.

This research assists to acknowledge the cause of flooding, and the source of flooding is substantially similar in many countries. Even most of the continents are using the nonstructural integrated urban flood risk management system. To develop the hazard maps, one of the modes used by the author is the use of Geographic Information System GIS AchMap 10.7.1, which uses source maps and scientific data.

Moreover, the impact of climate and heavy rainfall has been discussed by using the weather charts, which assists to understand the effect of the higher amount of precipitation on flooding. The case studies explain the effects of urbanization and climate on urban flooding, which has been discussed in previous chapters.

4.2 Flooding phenomenon in Piedmont, Italy.

The event of flooding is very common: flash floods or urban floodings all over Italy, such as Southern, Northern, and Mediterranean coastal regions. From 1991 to 2001, there were 1000s of cases recorded only for floods. However, the events that occurred after 2003 affected more than 2 million euros of financial damage and 300,000 fatality loss.[156] The total cost of reducing the risks of floods and landslides in Italy has estimated at 42 billion Euros. But this estimate does not take into account the higher risks from climate change scenarios, for which no assessment currently exists. The last two decades show that 28 large floods hit Italy between 1939 and 2004.[157]

Figure 30 shows the major rivers in Italy are the Po River which covers 405 miles and is the longest in Italy after this Arno River, Tiber River, Adda River, and so on.

The most endangered area is the Po River basin in the northern part. As per the data recorded by the Ministry of the Environment and Land Protection, the most destructive floods occurred in Po River in 1951, 1994, 2000, and in Arno River Basin in 1966.[158]

Figure 30: River Map of Italy.

Source: The Author.

Every year many cities of Italy face minor and major flooding incidents, including Venice at the top. In 2019 November, Venice was hit by the worst flooding, which is getting worse due to urbanization and climate change. Moreover, the Venice lagoon is sinking, and many projects were developed by the government and local authorities, who spent millions of euros on the Adriatic sea to save Venice from sinking.

156 River floods in Italy (no date) Climatechangepost.com. Available at: https://www.climatechangepost.com/italy/river-floods/

157 Ibid.

158 Ibid

In addition to the above, the regions that are affected by urban flooding and heavy rainfall almost every year are Piemonte, Lombardia, Liguria, Calabria, and Veneto.

Furthermore, in this chapter, the issues of Urban Flooding due to major rivers are discussed in the two important cities of the Piedmont region, Cuneo and Turin. In the province of Cuneo, few towns are highly affected by urban floodings, such as Savigliano and Saluzzo (North- Western Italy). Whereas in Turin, the Dora river cuts the north part of Turin, and the Po river divides the east side.

4.2.1. Case Study of Savigliano, Province of Cuneo, Piedmont, Italy.

Savigliano is a comune in the Province of Cuneo, North-Western Italy, with a population of 21,442 and an area of 110.79 km square. The River Maira coming from the Po river is dividing Savigliano into two parts. Moreover, the Cuneo province has surrounded between the Maritime Alps (South) and the Po River (North). Due to the multiple river belt in Savigliano and Cuneo, it becomes more vulnerable to urban flooding. In 2008, Savigliano was struck by massive rainfall which, affected 21000 inhabitants in the city.[159] Additionally, this area has been facing the threat of landslides and flooding due to the geographical location, a hydrological factor of the high Po plain, and the Stura di Demonte river. For over five decades, urbanization has enhanced near or bank of the rivers for the need water. Nevertheless, the increasing development disturbs the flow of rivers that resulting in damaging the geomorphological growth of the river. And this sudden disturbance led to having stripes of land. This city is always in the light for discussion also, the researcher has conducted a survey for Geo-Hydrological Protection.[160]

In figure 31, the map explains the location of Cuneo in the whole of Italy and the piedmont, sharing borders with Turin and France. The Po river and Tarnaro river pass the province of Cuneo, and the Stura di Demonte river divides the whole province of Cuneo in two.

In the beginning, the Tarnaro river was flowing from the Po river, although, with time, the deposits of alluvial formed of gravel sediments on the plain of Bra resulting in the separation of two rivers. The Cuneo region has been found quite unstable, on account of which it has a history of landslides and floodings. After the deposition of alluvial soil and cutting the connection between the Po river and the Tarnaro river, the land became more unstable, and the Tarnaro river started to get overflow every rainfall season.

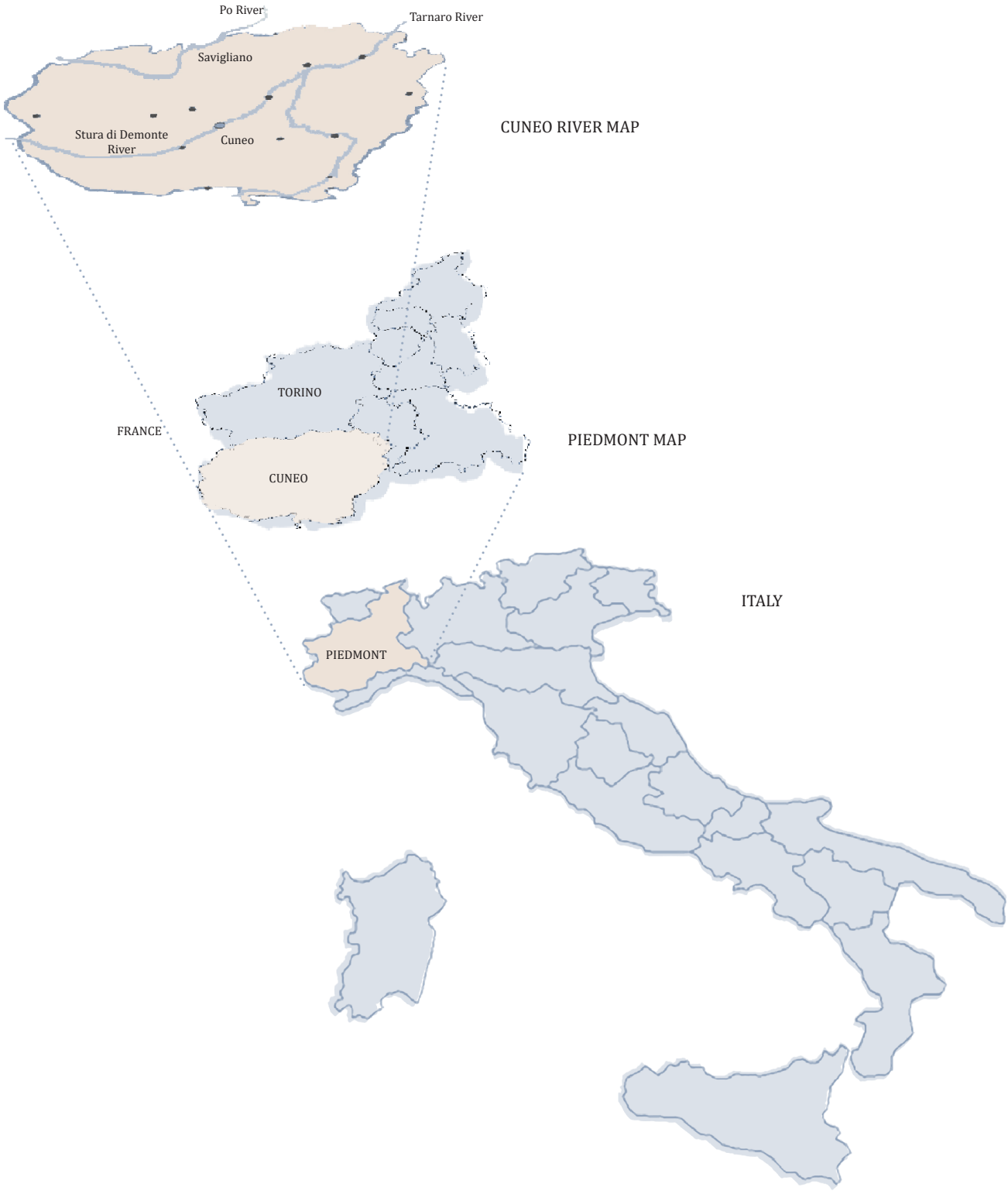
Another season for flooding and landslide in the region is that the Cuneo and nearby small towns are surrounded by mountains, with heavy precipitation, snow, and rainfall enhancing the chances of landslides in the area. Over the decades, the tectonic plates near the Tarnaro river have prompted the erosion in the east side formed hills near the city of Bra, resultant of which the river used to get flooded more.[161]

159 Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

160 Ibid
161 Ibid

LOCATION MAP OF CUNEO

Figure 31: Exploded Cuneo River Plan.



Source: The Author.

Apart from geological conditions and hills, climate change is another factor causing heavy rainfall. Figures 33 and 34, the graphs explain the average monthly relative humidity and precipitation in Cuneo. The bar chart helps to understand the weather condition in the region, especially to generate data which figure out at what time of the year it is more high and low. The data informs the average monthly precipitation reaches between 100-150mm, which is the main reason for rainfall and overflow of the river. On the other hand, the average monthly humidity is moderate throughout the year from 60-80 percentage.

Figure 32 shows the effects of flooding that occurred in 2008 in a town called Mellea near Savigliano, Cuneo. The million euros embankment failed to save the whole stretch of Borgo Marene during severe flooding along via Cuneo and via Suniglia.

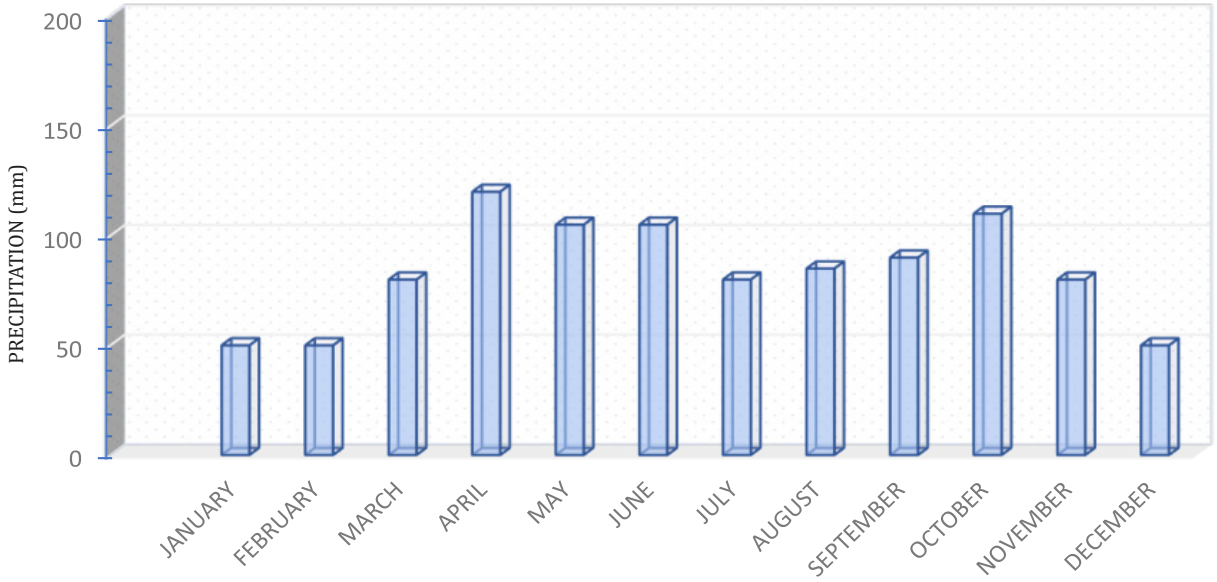
Even after a decade, the residents of Mellea can not forget the disastrous effects of flooding when they woke up and saw their car submerged in water, basements were flooded with mud, and water. The authorities and municipality refunded almost 1.2 million euros for the damage caused by flooding.[163]

Figure 32: Savigliano, Cuneo after the flooding of 2008.

Source: Picture taken by ANDREA GIACCARDI
https://www.lastampa.it/cuneo/2018/05/31/news/savigliano-a-10-anni-dall-alluvione-mancano-i-soldi-per-finire-i-lavori-nel-mellea-1.34021160/

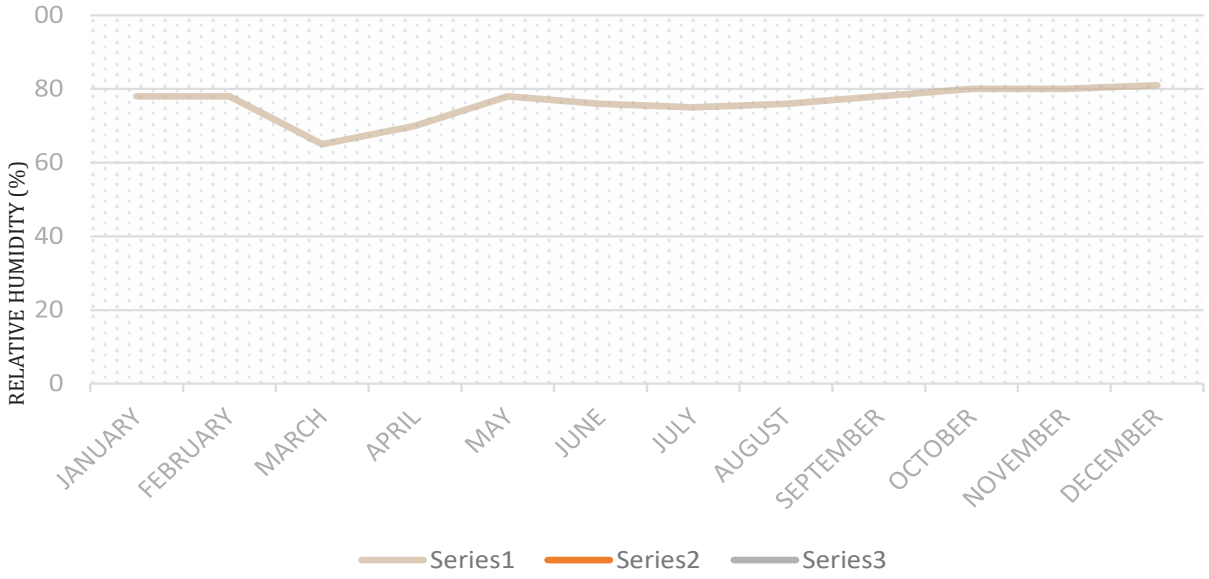
163 Savigliano, a 10 anni dall'alluvione mancano i soldi per finire i lavori nel Mellea (2018) La Stampa. Available at: https://www.lastampa.it/cuneo/2018/05/31/news/savigliano-a-10-anni-dall-alluvione-mancano-i-soldi-per-finire-i-lavori-nel-mellea-1.34021160/

Figure 33: Graph showing the average monthly Precipitation in Cuneo.[162]



Source: The Author.
The graph is prepared by the author with the help of the data available on https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,cuneo-piedmont-it,Italy

Figure 34: Graph showing the average monthly Relative Humidity in Cuneo.



Source: The Author.
The graph is prepared by the author with the help of the data available on https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,cuneo-piedmont-it,Italy

162 Climate and average monthly weather in Cuneo (Piedmont), Italy (no date) World Weather & Climate Information. Available at: https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,cuneo-piedmont-it,Italy

This case study considers the incidents of landslides and floods in a hilly area. Both are different events, although the result of flood the natural destroy is impactful. Heavy rainfall can cause flooding, despite the fact that it can also cause landslides. These incidents are mainly due to the reciprocity between environment, hydrogeology, meteorology, and man-made factors. These incidents are causing an extreme financial and economic loss in Italy. For almost 80 years, Italy has faced 5400 flood incidents and 11000 cases of landslides.[164] The Italian government has spent almost 42.4 billion euros since 1980 to restore the city after flooding and landslide.[165] Nonetheless, this survey uses the technology of GIS to find the marks of the increase in urbanization by comparing the floods in 1896 and 2008. The study area is the alps in Savigliano, which uses the historical data to recognize the growth of land use and flooding.

The historical data for the flood occurred in 1896 October in Savigliano collected from the library archives and local newspapers. The data shows the area affected by the flood had low pressure in the circulation part.[166] The list of food according to the intensity level is mentioned in table 8. It shows the occurrence of floods in October is more as compared to the rest of the time. Even the most severe flood with intensely level 3 occurred during October. The 3rd level floods caused the crucial destruction of the buildings, bridges, areas near rivers, houses, and shops filled with water.

Table 8: The historical event of flooding in Savigliano from 1700 till the late 1900s, with the intensity level.

Flood level	Occurrence
Level 1 (Flood with less intensity and causes less damage)	1706 January/October/Novemnber, 1713 May, 1715 August/ September, 1724 August, 1726, 1729, 1777, 1800, 1811, 1832, 1839, 1841, 1858, 1860, 1890, 1893, May 1977
Level 2 (Flood with medium intensity and damages the building)	1708 June, 1846 May, 1945 November, 1984, 1957, 1981, 2008 May.
Level 3 (Flood with high intensity and causes severe financial and fatality loss)	1705 November, 1810 Spetember, 1896 October, 1898 October, 1949 MY, 1996 October

Source: Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

On the other hand, due to the heavy rain between 27-30 May 2008, the city was flooded with severe damages as mentioned above in figure 26. Taking into consideration the geographical area of the city which is surrounded by the alps. Hence, the reason for the disaster was not low and heavy rainfall it was the constant rainfall during that time.[167] Due to this, the Maira and Grana-Mellea streams overflowed and flooded the Cuneo in a night.

Although, the area was flooded mainly in the East and South of the city. The 1896 flood hazard map explains illustrated in figure 35, the overall impact of flooding and the area covered by it which is shown in the blue line. Also, the small red circle shows the Torino and Cuneo connecting bridge over the Grana-Mellea River. 21km square of the area was covered with flooding due to heavy rainfall.[168]

164 Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

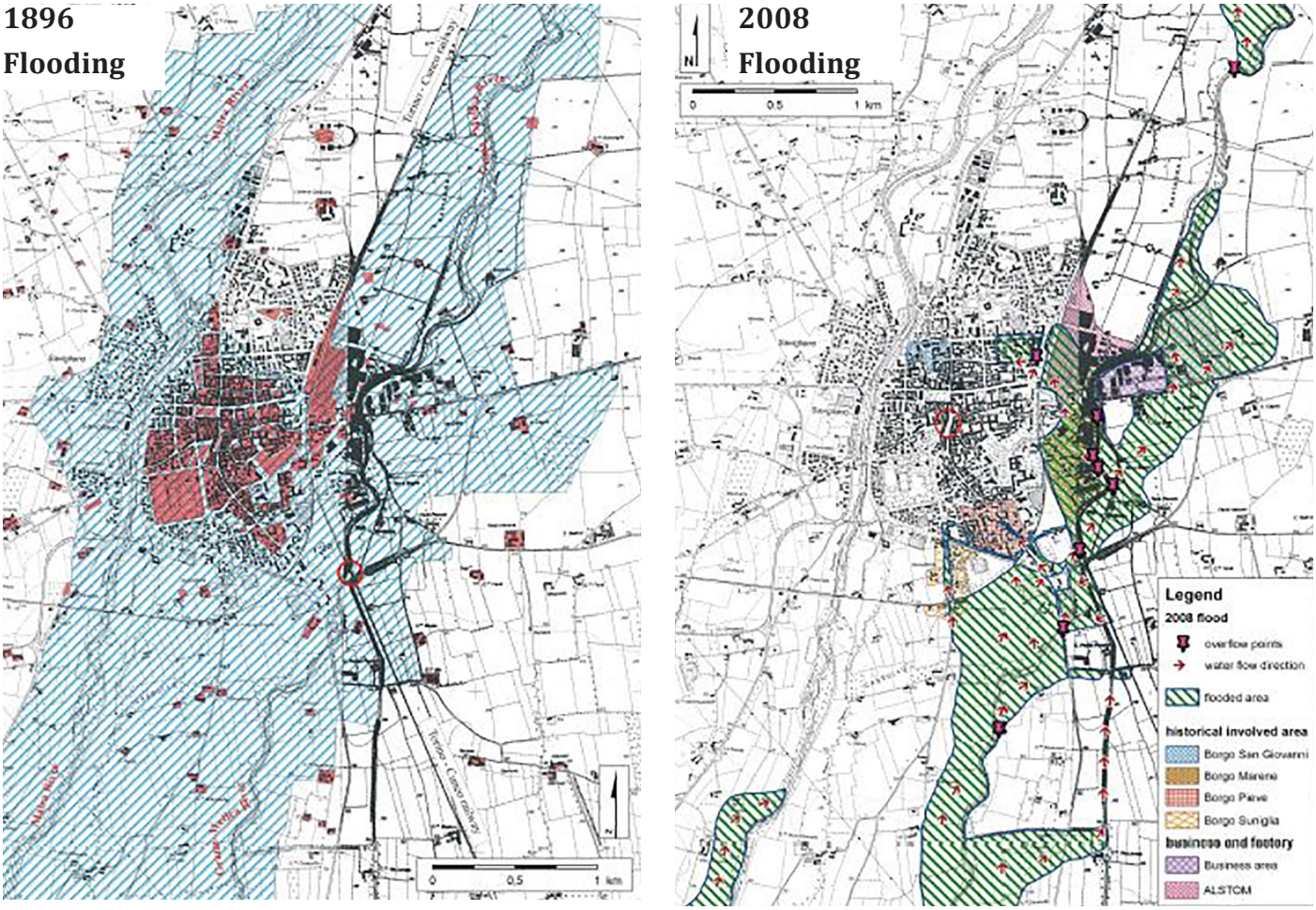
165 Ibid

166 Ibid

167 Ibid

168 Ibid

Figure 35: Flood Hazard Map of Savigliano showing the flood event on 1896 and 2008.



Source: Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

Furthermore, the second map in figure 35shows the flood event that occurred in 2008. The green lines show the flooded area, which is lesser than the 1896 flood. Usually, the countryside and farms were affected by the flooding in 2008. However, the side bank of the river was affected more. Even the railway bridge over the Grana-Mellea River, which connects Cuneo to Turin, was under the influence of flood. Moreover, the loss of land and property was also mentioned by the farm owners living on the right side of the bank.[169] As a whole, many houses, buildings, offices railway tracks, and major roads were flooded. The methodology was used to develop a map, and the difference between them was GIS. The case study used this to research the build-up area and the changes in the same. The year choose to have discussion 1896 and 2008 in the case study only. However, the flood that occurred during 1896 was with the intensity of level 3and 2008 comes under the category of 2nd level flooding.[170] Moreover, the reason to compare both the years is the number of financial damages that happed during both periods of flooding.

169 Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

170 Ibid

Furthermore, the research in the case study focuses on some factors such as availability of historical data and period, the total area affected by the flood in both years, growth in the built-up area from 1896 to 2008. However, in the period before the 1700s, there is no historical data found from there.[171] Additionally, the meteorological condition mentioned in the maps for the years 1896 and 2008 explains, that due to wind circulation in the region of Alpine the climate become more composite. Also, both the flood occurred in the Maira and Grana-Mellea streams, though in 1896 one was more severe and brought more danger and destruction with it, whereas 2008 one was not that destructive. In 1896 flooding most of the bridges, farms, and countrysides were affected, on the other hand in the flooding of 2008 countryside was also flooded, however, this time more commercial areas were affected too, due to the growth in urbanization.

Outcome of the case study.

As a conclusion of this case study, it explains that during the time of 1896 the space was more open with less urbanization. Hence, the destruction during 2008 was the result of human action by reducing the urban green areas and cutting streams from rivers converting them into artificial channels. Hence, there are a few similarities even after a huge time gap and differences in both the events that occurred at the same place. Although, results show the difference in the built-up area, which has been increased since the first event. The hydraulic and historical data explain it is possible to construct on the zones mentioned in the case study.

However, it is not mandatory to construct there, because recently that area will suffer from more flooding, and due to urbanization it will cause more damage to the city.[172] Hence, the solution for this is to use the structural integrated urban flood risk management technique. A simple design of embankment near Maira and Grana-Mellea streams can help to protect the railway bridge which connects Cuneo to Turin. Moreover, the issues acknowledged in the case study can be reduced by inclusive of the residents, stakeholders, and policymakers.

171 Audisio, C. and Turconi, L. (2011) 'Urban floods: a case study in the Savigliano area (North-Western Italy)', Natural Hazards and Earth System Sciences, 11(11), pp. 2951–2964. doi:10.5194/nhess-11-2951-2011. Available at: https://nhess.copernicus.org/articles/11/2951/2011/

172 Ibid

4.2.2. A brief of Urban Flooding in Turin, Piedmont, Italy.

Torino (Turin) is the capital city of Piedmont in Northern Italy, with a population of 886,837. The city has surrounded by the Alps and has three major rivers passing through it. The longest river of Italy the Po river is dividing East-West of Turin, and two rivers separate from the Po river going towards West; the rivers are the Dora and Stura Di Lanzo rivers. Moreover, this small-scale metropolitan city has been changed a lot since the 20th century due to the development of the FIAT industry.

However, Turin has been suffering from high precipitation and rainfall, which has developed events of urban flooding in the city. The impact of climate change is making the condition worse by making the city vulnerable to flood very often. Although climate change is not the only threat, rapid growth in urbanization has made the city densely populated. The urban land in Turin is so innate that it is impermeable and densely built structures, which makes the city more vulnerable to rain in every monsoon.[173] Additionally, Turin is an old city with an old drainage system and an old road network in the central area. To develop mobility in the city, the internal road network was modified into today's system. Furthermore, the axonometric view in figure 36 shows the location of Turin city in Piedmont along with major rivers in the city. Turin has located between the Lombardy region of Italy and the France Alps. This city is located 248 meters above sea level, and almost 36% area has hilly land whilst the remaining is a low land area.[174] According to the Land Cover dataset (2017) of the National Superior Institute for Environmental Protection and Research (ISPRA), the high amount of artificial land covers Turin, which is almost 100% impermeable land. The land has an amalgamation of floodplains soil and nonporous surface which makes the Turin flood-prone, especially during rainfall. The heavy rainfall events can be worse after a cloud bust, which is common in a hilly region. Furthermore, figure 37 and 38 shows the average monthly temperature and precipitation in Turin. Throughout the year, the climate is rainy, with annual precipitation of 864mm. However, the driest month is January, with only 38mm of precipitation, whereas, May is the month with the highest precipitation of 108mm.[175]

Additionally, the constant rainfall in Turin fills the road with water, and the old drainage system has less capacity to run off the water from the surface. Also with the impermeable surface on the streets of Turin makes it harder to run off the floodwater. Despite the capability, the tools to record the data, and the occurrence of heavy rainfall or flood, the city has not been able to reduce the phenomenon of urban floods. The flood of 2016 or 2020, keeps happening and Turin is dealing with the loss of fatalities, homes, and finances. The Po river overflows and takes down most of the nearby towns in Piemonte, not just Turin. To acknowledge the vulnerability of Turin toward urban flooding firstly needs to start with the issue of runoff water, secondly have to come up with an inclusive of all solutions, and finally, use the concept of resist and mitigate in an old town.

173 Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

174 Ibid

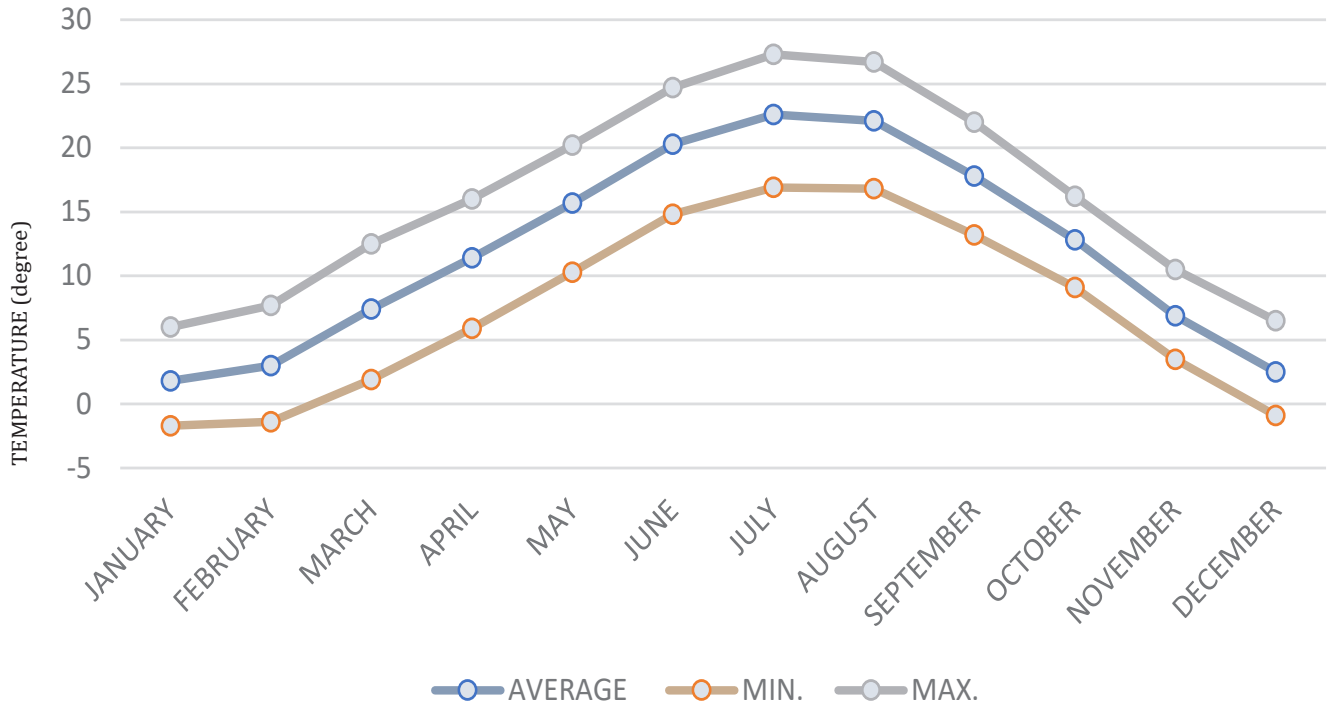
175 Ibid

LOCATION MAP OF TORINO

Figure 36: Exploded Torino River Plan.

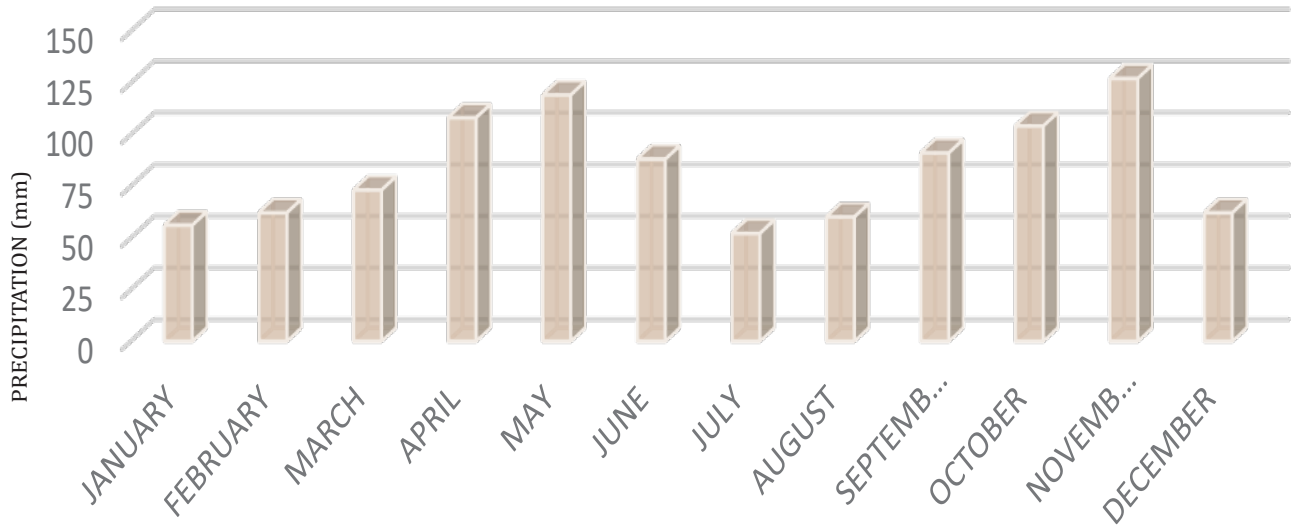
Source: The Author.

Figure 37: Graph showing the average monthly Temperature in Turin.[176]



Source: The Author.

Figure 38: Graph showing the average monthly Precipitation in Turin.



Source: The Author.

176 Turin climate: Average Temperature, weather by month, Turin weather averages - Climate-Data.org (no date). Available at: https://en.climate-data.org/europe/italy/piemont/turin-1108/#temperature-graph

Figure 39: The flood occurred after the rainy event in Turin, affecting transport in the city.

Source: Pictures taken by Alex Oberto.
Maltempo a Torino 17 agosto 2020 (no date) TorinoToday. Available at: https://www.torinotoday.it/foto/cronaca/maltempo-a-torino-17-agosto-2020/

The images in figure 39 show the result of heavy rainfall on August 17, 2020, of almost 70mm of rain that happened in an hour. The flood caused a blackout in the city and damaged the infrastructure, and the old drainage system collapsed, unable to run off the extra water from the surface. After the heavy rainfall, two metro stations were filled with water and did not work for almost two days, even the sewage system was filled with debris.

Regardless of the issue, there was no proper planning or strategies to incorporate or proposed to tackle or reduce urban flooding. The approach adopted by the authorities needs to upgrade and allow mitigation with new solutions.[177] The authorities have to come up with a solution that involves the complex area, highly flood-prone area, and reduce the vulnerability in those areas.

177 Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

4.3 Study Area for Urban Flooding in Turin by using Master Plan.

This chapter describes the detailed layout of the city, land use map, Urban green spaces to understand which is a highly flood-prone area in the city. The maps have been generated through ArcMap (ArcGIS) with detailed data. The study of these maps help to understand the source, areas of issue, and the measures that have been taken. The land use map for the particular areas has developed from the current master plan of Turin, which has been compared by the hazard map given by Città Metropolitana di Torino. The hazard map shows the three levels of flood type according to their intensity (low, medium, and high).

The location described in the chapter is the intersection of three rivers within the city are as follows:

- The intersection between the Po River and Dora River.
- The intersection between the Po River and Stura Di Lanzo.
- The land-use maps of the city in relation to the rivers.
- The Urban green area plan concerning the rivers.

The land-use map developed from GIS software includes all the data of zoning. These days adequate planning of land use is a necessity for urban development. The prime motive of this chapter:

- To understand the land use planning of an old city.
- To focus on the development near the rivers and how it is helping or affecting the city.
- To find out the urban green areas which assist in understanding the permeable and non-permeable surfaces in the city.
- To understand the source and the problem accurately, the author carried out a survey, and the interviews are the resident of Turin mentioned in Annex.

The purpose of the master plan of Turin city, as illustrated in Figure 40, shows the location and intersection of the rivers. The master plan marked the position, where the Dora river connects to the Po river, and Stura Di Lanzo connects with the Po river. The land use map and flood conditions are developed by digital modes which, however, is a disputable matter. Although, the approach follows the integrated flood risk management system to tackle threats from the present to the future. Regardless of the technology and computer software, these are helping to generate maps for the events that have already been occurring and giving a warning for the new occurrence and its intensity.[178] Additionally, even after all this technology and historical data, the event has been increasing with more intensity, high amount of rainfall, and cloud bust. Hence, while figuring out a way to make the city resilient at the same time need to come up with some measures to make the city less vulnerable to flood threats and to research if the existing measures need intervention.[179]

178 Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

179 Ibid.

Figure 40: Turin Master Plan emphasizes three major rivers.

Source: The Author.

In this case study, with the help of the master plan research addresses the major issue by using digital technology. The master plan is used to prepare a land use, urban green area for ran-off retention, and hazard map. The master plan is used to prepare a land use, urban green area for ran-off retention, and hazard map. The master plan indicates the area divided by the three rivers. The Po river is diving Turin between East-West and the Dora River, and Stura Di Lanzao is dividing the Turin between North-South. The areas which come under a high-risk zone for urban flooding are Bargo San Paolo, Pazzo Strada, Centro, and Cit Turin.

However, according to the source, the highly affected flood-prone area in Turin is near the Dora River (Citta di Metropolitana Torino). The heavy rainfall event that occurred in August 2020 is illustrated in figure 39. That event of rainfall and urban flooding affected Turin's historical area was Cento and Cit Turin.The utmost issue with Turin is that it is a historic city with less possibility to take substantial measures. The sewerage system that is used by the city is old. Although, authorities take masseuses to clean it in some time gap. Still, an event like this proves that the sewage system needed up-gradation. Moreover, as mentioned in chapter 4.2.2 Turin has grown its built-up area since the 20th century.[180] The rapid growth in urbanization has put pressure on the historical city by reducing the capacity of the drainages and the run-off retention areas. Overall the typology of Turin city is considered as a lowland region.

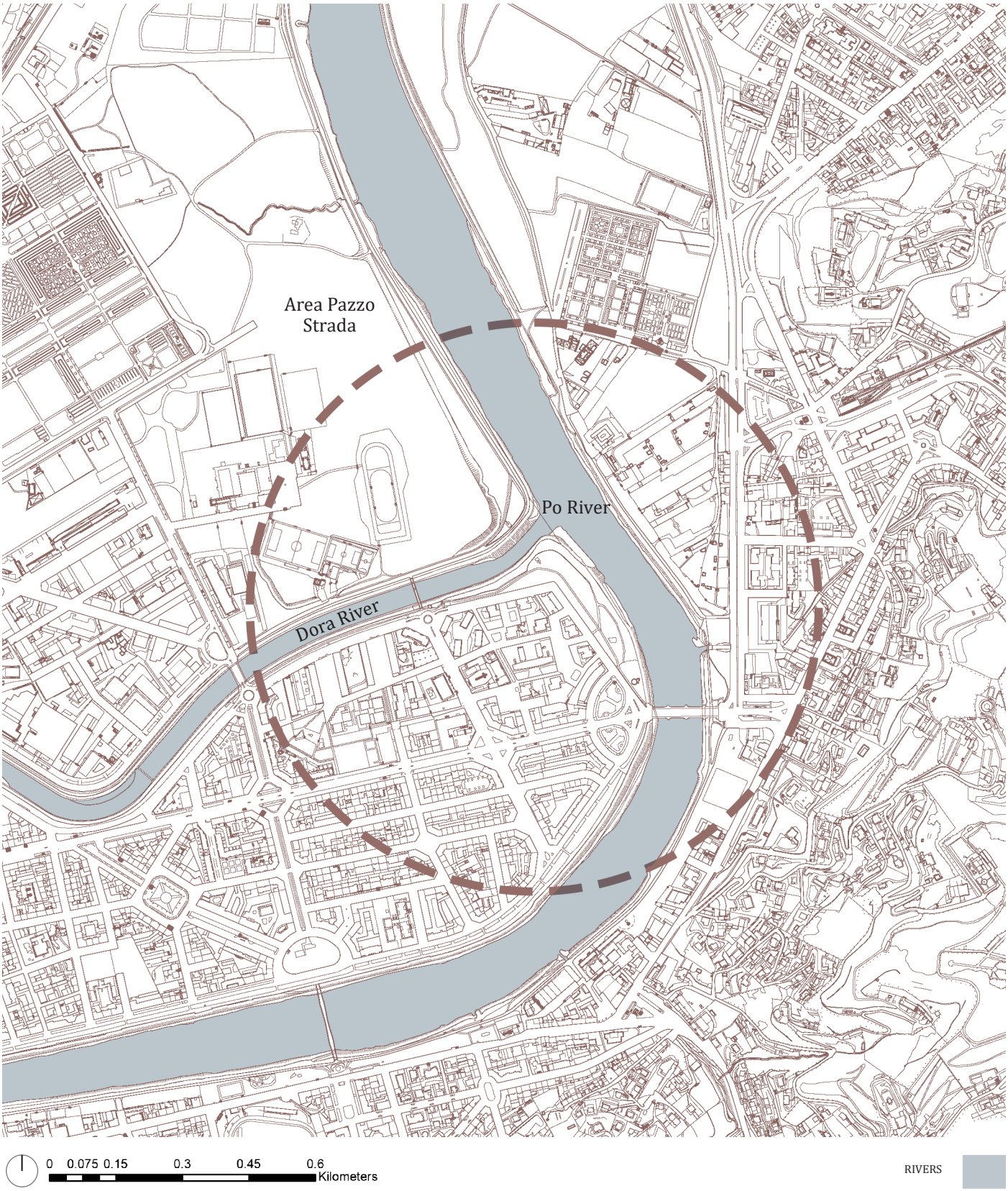
Nevertheless, the master plan helps to acknowledge the vulnerability of this moderate size historical city by explaining the urban social, ecological, and structural systems. This city has semi-dense built-up arrangements on heterogeneous land use, which makes it a more rainfall-prone zone.[181] Bargo San Paolo and Pazzo Strada, areas as mentioned earlier which are close to the two intersections.

As explained in chapter 5 the intersection of the Po river and the Dora River is a highly flood-prone area in Turin. The interview with the architect in città Metropolitana Torino also confirms that this is the area that needs more attention from authorities. This is elaborated in chapter 4.3.3 as to why the Dora river comes under a high flood risk zone and what measures authorities are taking to tackle the growing risk of flooding in the area! However, the municipality of Torino follows the guidelines prepared by the hydrogeological urban management Master plan department. Hence, the policies prepared to deal with the Dora river are still under process, although a few projects have been proposed. Moreover, to develop this map it is necessary to have a municipality master plan that confirms after comparing it with the hydrogeological urban management Master plan department. The role of each department is explained in detail in chapter 5. Besides, some part of this is developed properly such as huge park called Dora Park is alongside the river. But most of the area is underdeveloped. Also, this provides the open space near the river, even in case of flooding there will be less damage to the infrastructure.

180 Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

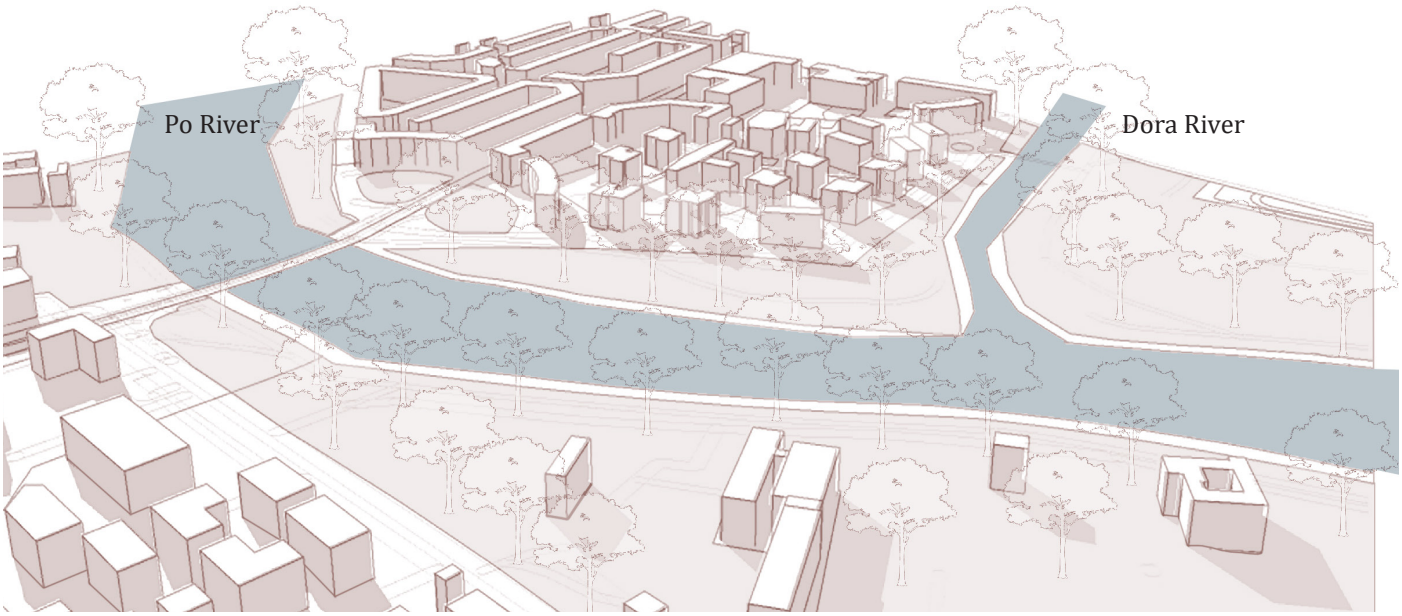
181 Ibid

Figure 41: Site Plan of the Po River and the Dora River Intersection.



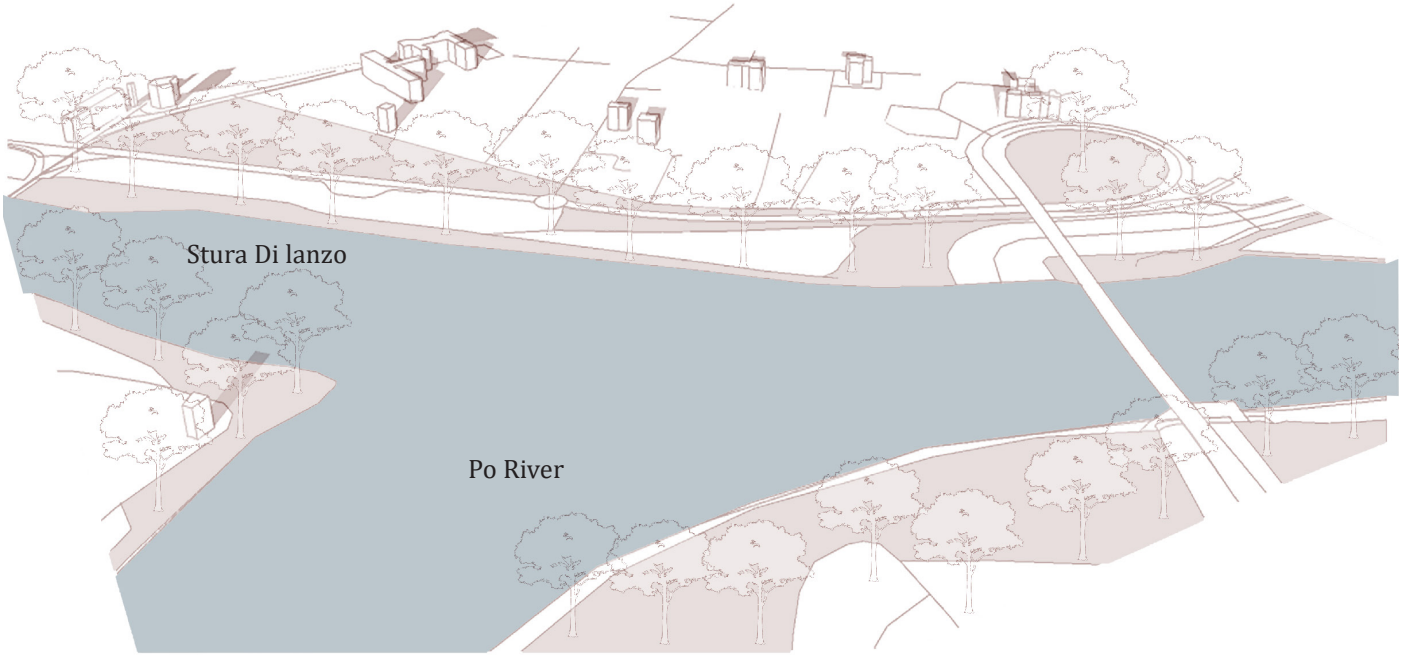
Source: The Author.

Figure 42: Axonometric View showing the area near the Po River and the Dora River.



Source: The Author.

Figure 43: Axonometric View showing the area near Po River and Stura Di Lanzo.



Source: The Author.

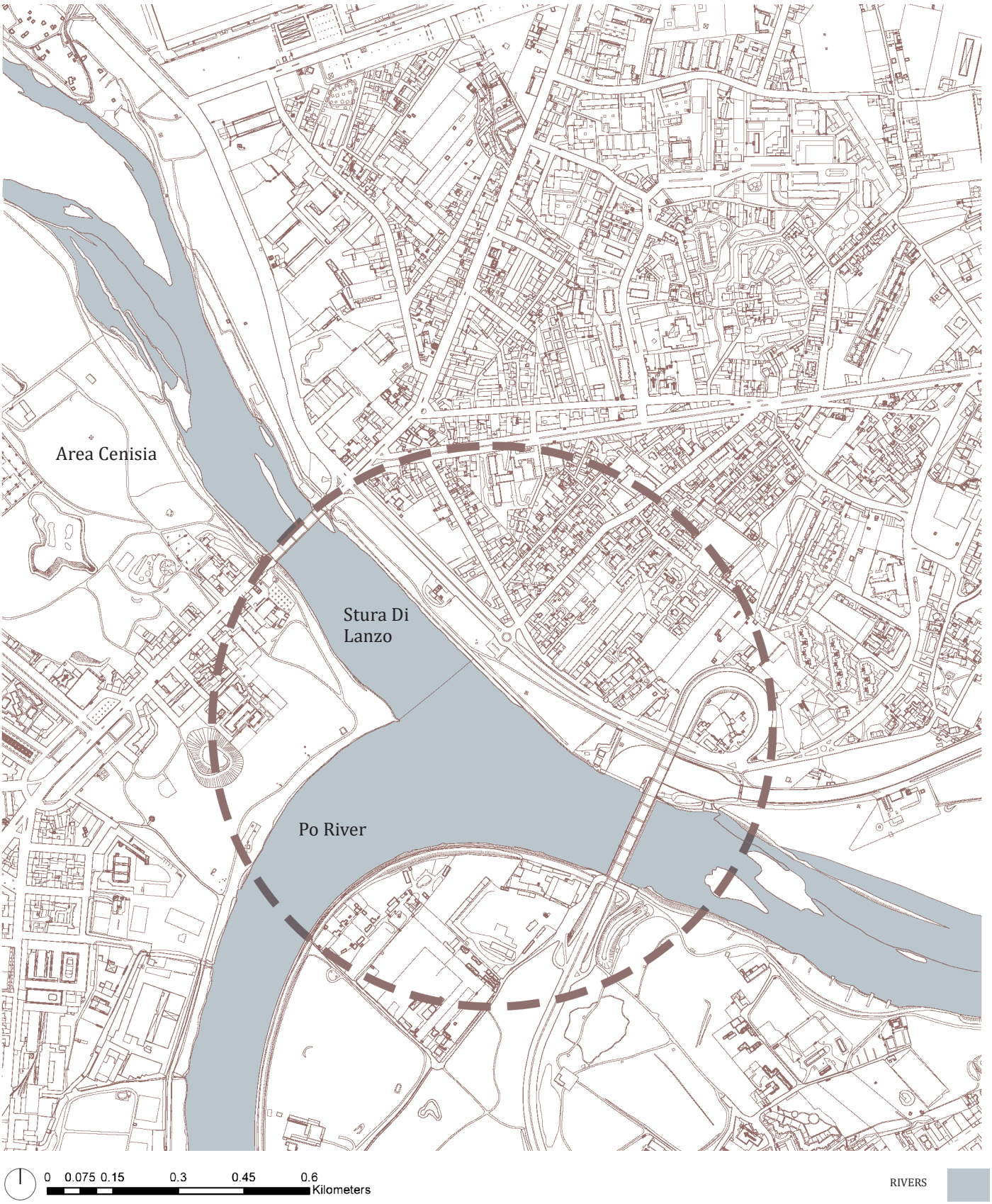
Figure 42 illustrated the view of the intersection of the Po river and the Dora river majorly emphasizing the intersection. The surrounding around the rivers can be shown in 3d. A bridge is connecting both sides together, however, most of the area is open and covered in non-permeable soil. There is a highway which is connecting the inner city with the outer ring road.

Figure 43 shows the view of the Po River and the Stura Di Lanzo intersection with the surrounding, which included the residential building. Although, most of the area around the rivers has open space, green urban space, and the presence of the permeable surface. It is easy to absorb the excess water through the surface due to the availability of permeable surfaces around the river. However, it has some limits, although it is effective as compared to concrete, and stone surfaces. This is further elaborated in chapter 4.3.2.

Furthermore, figure 44 illustrates the close-up site plan of the Po River and the Stura Di Lanzo Intersection. This river is the 3rd major river in Turin. The river starts from the point of the Po river and goes outside the Turin into the West. The plan indicates the part of interaction and locality around the two rivers. This river is 68.8 km long and contains catchment zones of around 836 km square.[182]
Stura Di Lanzo goes through three separate dams such as Mezzenile, Germagnano and Lanzo.[183] The map illustrates the area around the rivers which is a densely accommodated area. The land use map has shown in figure 40 chapter 4.3.1. However, it is shown on the map that the width of both the rivers is covering so much area, in that case, the settlement should be developed far from more than their width. These maps are used to develop the land use plan from ArcMap GIS digital platform. Furthermore, this intersection is also not considered a safe zone. However, the settlement in the area is lesser than compare to the Dora river area.
Both the intersection have fewer similarities, such as the width of the Dora river is lesser than the Stura Di Lanzo. Hence, the Stura Di Lanzo has more space to spread even in the season of monsoon which can overflow the river. On the other hand, the width of the Dora river is very less, which makes that zone more feasible to flood-prone. Besides, the open space near Stura Di Lanzo is quite more applicable than the Dora river. This information is mentioned in the master plan and land use map.

182 'Torrente Stura di Lanzo' (2020) Pesca Fiume, 19 June. Available at: https://www.pescafiume.it/torrente-stura-di-lanzo/
183 Ibid

Figure 44: Site Plan of the Po River and the Stura Di Lanzo Intersection.



Source: The Author.

4.3.1 Land Use Land Cover Study of Turin.

This chapter describes the land use map of Turin in order to understand the available built-up area. The land use map is focusing on the two intersections of the rivers as mentioned in the master plan in chapter 4.3. These maps shown in Figures 45 and 46 are developed with the help of a digital tool called ArcMap 10.7.1 GIS. The importance of land use and the land cover map is very well explained at the beginning of chapter 4. Also, discussed the necessity to use traditional land use maps and data to develop and compare it with the latest data. The purpose of having land use on a land cover map is to compare it with the old map to find out the total exceed covered area as well as the change in the land-use planning. This research provides data about the open space in the city, green area, and densely developed area.

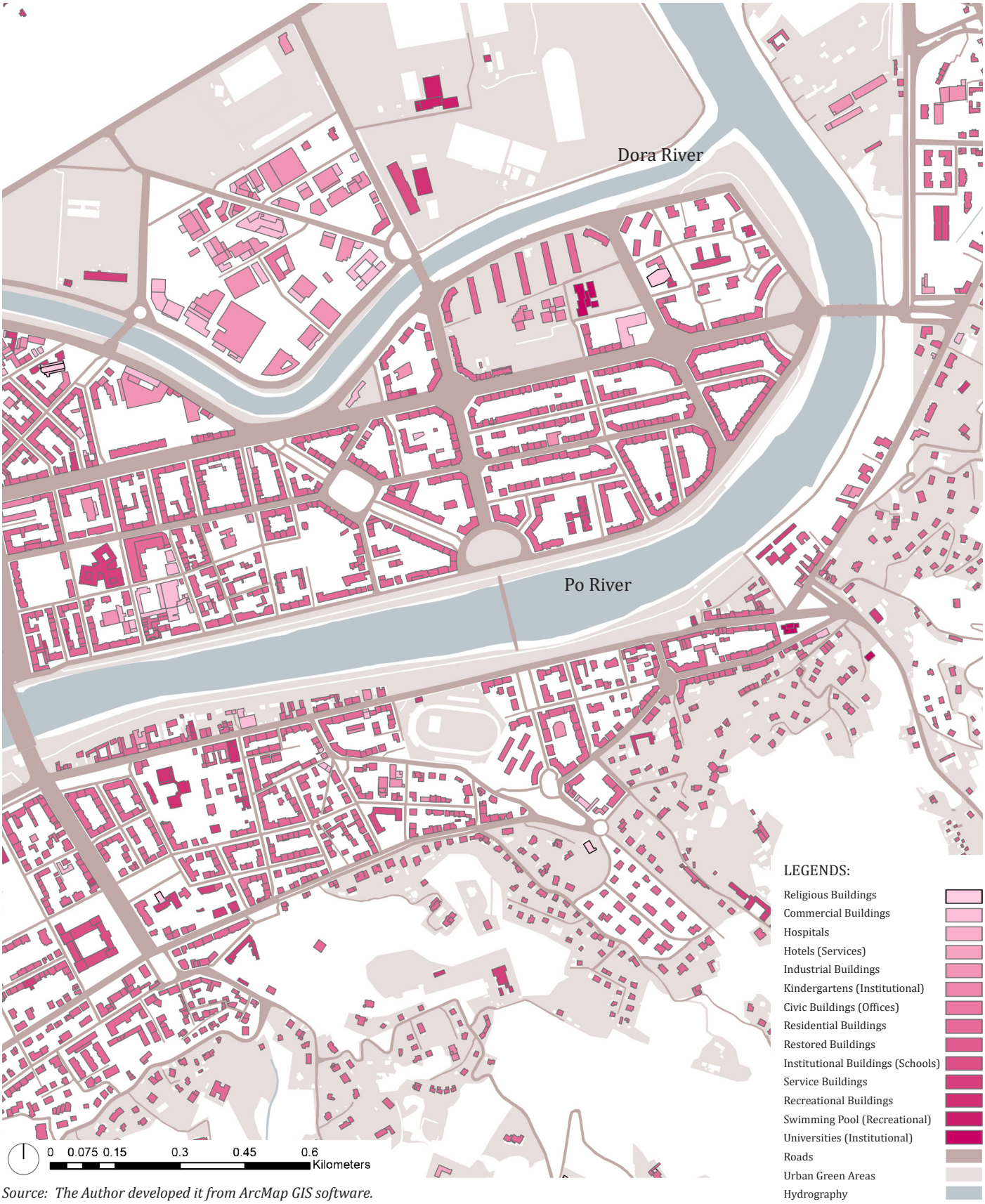
Table 9: Land Use of Turin according to zones.

Land Use Zone	Area (ha)
Mixed use area : craft, commercial, tertiary, and residential	318.89
Areas for different activities AdA	236.93
Residential area : defined by the general urban Plan as "historical-environmental urban areas", as the parts of the city characterized by historic residential settlements and quality green spaces	167.38
Residential area : Residential area with limited mixed functions included in the consolidated urban fabric	159.29
Total areas with low retention	882.52

Source: Land use data
Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

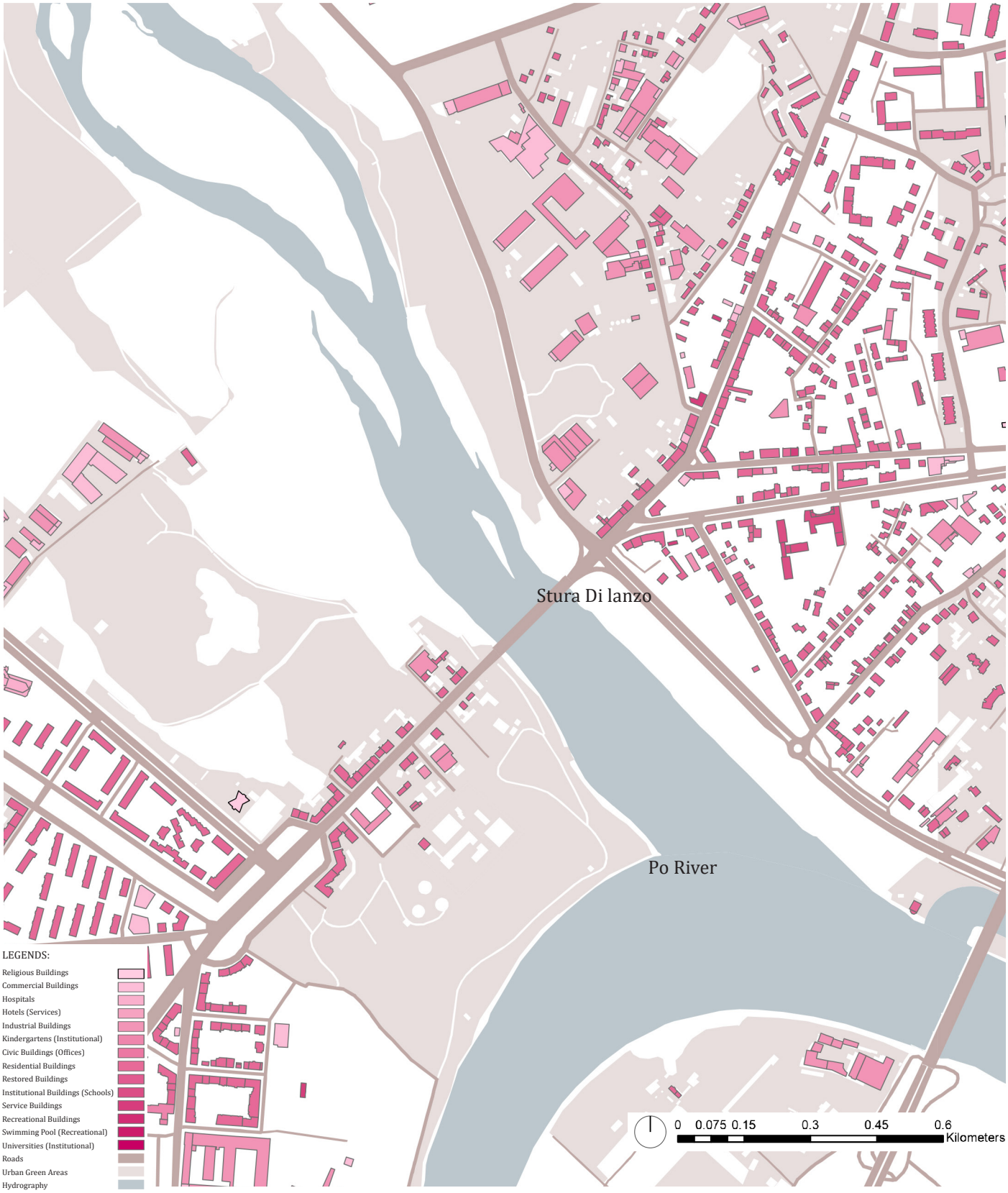
This helps to develop a new urban master plan for the city. Both the figure only focus on the area around the rivers, which describe that the area around the Dora river has more residential buildings. To understand the result of flooding in case of police measures failure, these maps assist to gather the data to know the affected area and property. Table 9 illustrates the land use in Turin according to the low level of retention water runoff. This explains the interconnectivity of these maps. According to this, it can be fixed by planning and later by intervention. This could correct by planning the land use map efficiently, also through changing the material of the surface from non-porous to the porous material. Moreover, as design factors rain garden can be planned which can act as a collecting zone in case of heavy rainfall. A reference regarding this is mentioned in the case study of the Netherlands.
In addition, the land use maps also assist to calculate the land cover by comparing it with old maps. This explains the availability of built-up areas in a particular area.

Figure 45: The land-use map of area near intersection of the Po River and the Dora River has developed from a World imagery source ArcMap GIS software.



Source: The Author developed it from ArcMap GIS software.

Figure 46: The land-use map of area near intersection of the Po River and Stura Di lanzo has developed from a World imagery source ArcMap GIS software.



Source: The Author developed it from ArcMap GIS software.

4.3.2 Runoff Retention map of Turin.

This section focuses on the excess water run-off system by comparing it with the urban green area. This assists to understand and make the permeable surface and non-permeable surface in Turin. To understand this an urban green area map has been generated by using the ArcMap GIS software to figure out the permeable area in the whole of the Turin. The map in figure 47shows the urban green spaces, and the dots show the location of trees. Moreover, according to the map, clearly mentions the Availability of green and permeation area are less. It is usually available around the rivers and the parks. To acknowledge the concept of water run-off retention, it is necessary to figure out the urban green spaces in the city. The concrete surface all over the city and the less capacity of the old drainage system is the key reason for water logging during heavy rainfall.

The data of trees assist to understand the area and it helps to avoid the problem of soil erosion in the city. Furthermore, the map illustrated in figure 48, is showing the water run-off retention map for the whole of Turin city. It was generated with the help of a master plan, land use plan, and urban green space plan. Map describes the level of water logging in the city which is as follows: Low Retention, Medium-Low Retention, Medium Retention Medium-High Retention, and High Retention zones.[184] According to the map, most of the central part of the city is a historical part and the riverside area comes under the high retention zone.

The combination of urban green area and retention map and the level of retention assists to solve the problem in any region by mitigation. This could also provide the land use values according to the retention level as explained in chapter 4.3.1. This would assist to understand how much area is under the porous surface, and where it is possible to modify the surface. Moreover, as per the level of retention solution could be done to make it work.

- In case of a low retention zone, can switch green over grey by means of retrofitting.[185] This could be done by having wastewater treatment, a green facade, and a green roof. By switching to a more porous material that can collect 95 % of the rainwater.[186] Also, the use of small rain gardens to collect the excess rainwater, which can be placed in low line areas, along with the driveways, etc.

- In the case of the medium-low retention zone, one can work on the impermeable parking spaces by changing the surface interlocking tiles with green. Besides, the filter drains or filter strips[187] can be used through semi-natural soil drainage which assists to block the soil movement and focuses to let go of the rainwater to the first layer of the soil.

- In the case of the medium retention zone, in this case, can incorporate the presence of dry ponds which can be used at the time of flooding. These dry ponds have the capacity to store the water. Although, it is not possible to create dense urban space.

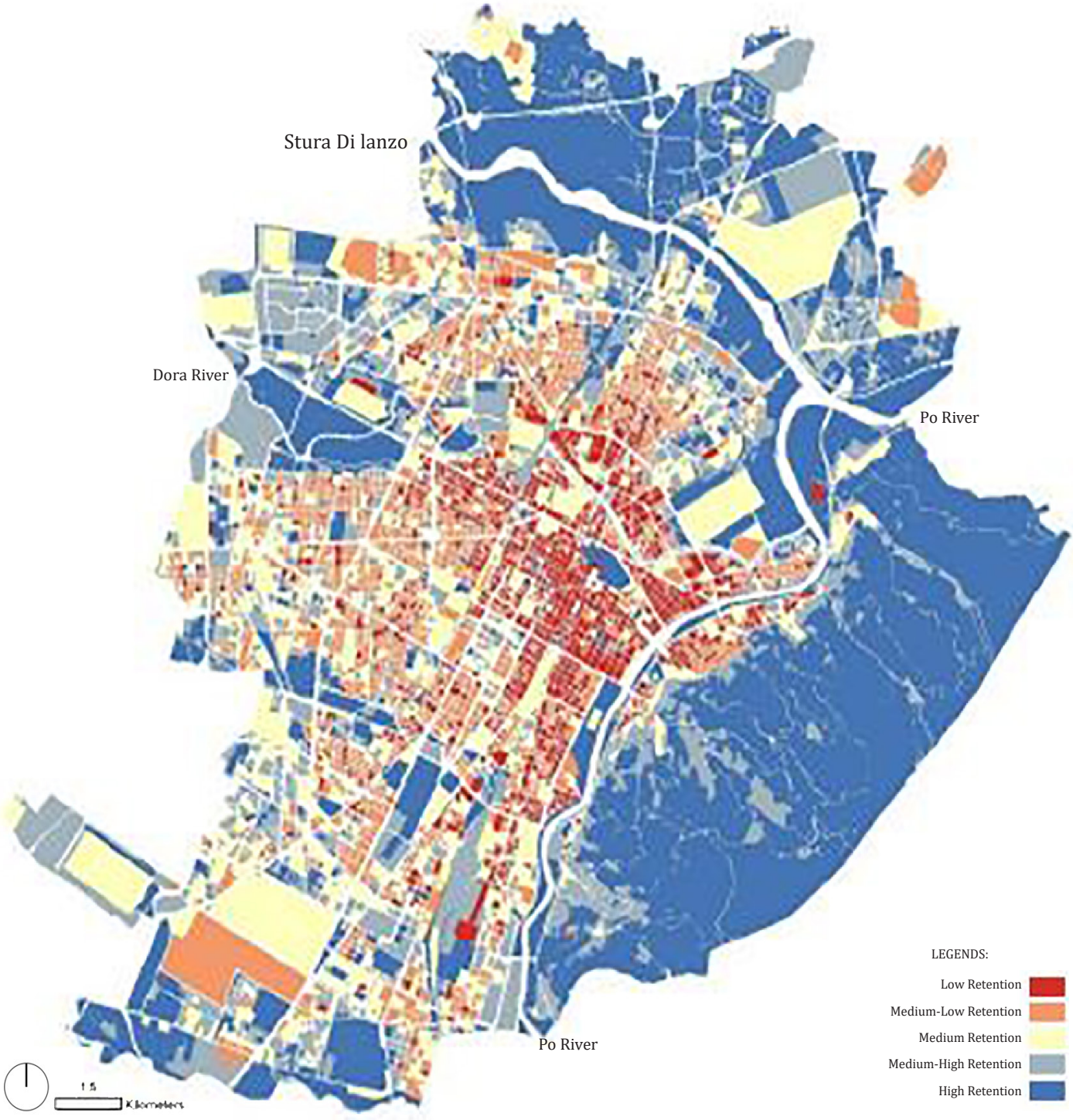
184 *Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697*

185 IBID
186 IBID
187 IBID

Figure 47: The Urban Green area map has developed from a World imagery source ArcMap GIS software.

Source: The Author developed it from ArcMap GIS software.

Figure 48: Water Runoff Retention map of Turin.



Source: Run off Retention Map of Turin.
Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

• In the case of the medium-high retention zone, it is possible to tackle this by adding more trees in urban spaces. It can help to reduce the effect of flooding in urban spaces. Another way is to add vegetated semi-natural canals to prevent soil erosion.[188] In the presence of vegetation, it is easy to retain the water. The combination of these two solutions can enhance the retention of the surface from 59% to 68%.[189]

• In the case of the medium-high retention zone, can distinguish the topography for green and hard surfaces. The use of a vegetated detention basin can enhance the efficiency of sediment settling by reducing the flow in the basin.[190] Moreover, the construction of embankments and wetlands can control and monitor the run-off quality. Also, by using the concept of the urban forest it is possible to reduce retention. This could be done by adding trees and plants in natural and semi-natural spaces. With the help of these solutions, it is possible to enhance the retention of the surface from 98% to 100%[191]

This data would assist to choose the use of over impermeable to permeable, especially in urban areas. Further on, this map was also used to generate the flood hazard map.

188 *Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697*

189 IBID
190 IBID
191 IBID

4.3.3 Development of Turin Flood Hazard Map.

This chapter describes the development and use of a flood hazard map. The flood hazard risk map is generated through the assistance of the city master plan, city land use map, and the data hydrogeological to which the author would thank the head of the hydrogeological department Dottor Gabriele Papa from Città Metropolitana di Torino to provide data to generate this map. The map illustrates the three typologies of flooding danger levels, Typology A, Typology B, and Typology C. These levels were developed and marked by the hydrogeological management Master plan which explains the level of danger for the areas around the river. This is further elaborated in chapter 5.

Furthermore, figure 50 illustrates the flood map of the whole Turin focusing on all three rivers such as the Po River, the Dora river, and the Stura Di Lanzo. The data collected from the map elucidates the different levels of danger with the help of separate colors. In accordance with the map **Risk Level, 3 shows Typology A**, which means the area around the **Dora rivers** comes under the high flood-prone area in Turin. Moreover, it also describes in case of overflow of the river due to heavy rainfall and causes flooding, hence it will affect that much area marked in the map.

Moreover, the retention map supports the result which explains clearly in figure 48, that the area around the Dora river has less retention for water runoff. Also, the land use map shows the settlements around the Dora river, which mostly consist the residential areas.

Moreover, in the recent event, it was recorded that the Dora river was getting overflowed on November 24, 2019.[192] The level of the river rose overnight due to the heavy rainfall.

Figure 49: Overflow of the Dora River.

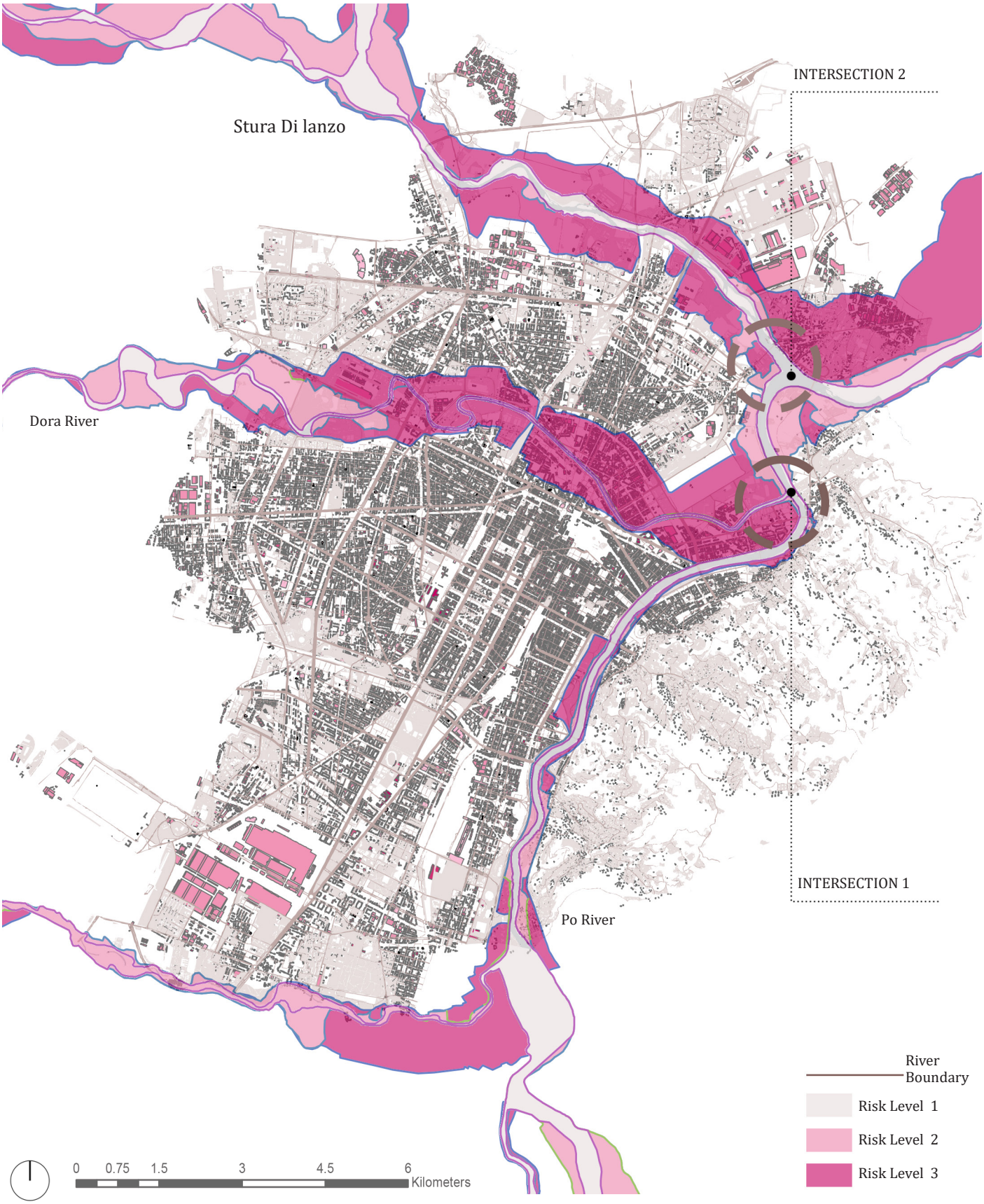
Source: Photo by Massimiliano Ferraro/NurPhoto via Getty Images. Available at: https://www.gettyimages.in/detail/news-photo/the-river-dora-riparia-in-turin-on-november-24-2019-after-news-photo/1184432603

Figure 49 shows the overflow of the Dora river in 2019. These events can turn into huge urban flooding, which can affect a large space of residential area in Turin.

However, this raises one question why does the area near the Dora river is comes under a high-risk zone? In October 2000, the Dora River was hit by severe flooding that caused the flooding in Turin city. This flood caused a lot of damage to the infrastructure and created inconvenience to the people of Turin. It has been considered a high-risk zone due to some reasons.

192 The river Dora Riparia in Turin on November 24, 2019 after its level... (no date) Getty Images. Available at: https://www.gettyimages.in/detail/news-photo/the-river-dora-riparia-in-turin-on-november-24-2019-after-news-photo/1184432603

Figure 50: Turin Flood Hazard Map.



Source: The Author developed it from ArcMap GIS software with the help of data provided by Citta Metropolitana di Torino.

The main reasons are the return time of the flood being less than 200 years, also the depth of the flooding on the surface is more than 1meter, sometimes it is more than 2-3 meters. Another reason is the magnitude of the current is extremely high. The source of the information is Città Metropolitana di Torino.

Furthermore, according to the area's risk level 3, is it not allowed to have construction to maintain the land use land cover of the area. However, authorities are taking some measures to protect the area such as **the rolling basin upstream of Turin, construction of embankments, and civil protection measures**. Besides, to reduce the flood risk is essential to have the knowledge of settlements at the local scale which is more exposed to flood threat. Also, to figure out if the existing measures are sufficient to tackle the threat. This is also necessary for land use maps to have spatial dynamic information of settlements. Besides, all the measures both the intersection are under high flood risk zone.

In addition, the area close to the riverbed has a more permeable surface to absorb the excess water. Although, after that, there is a belt of development, and according to the map in case of heavy flooding the residential area will get affected. Moreover, it depends on the success rate of the measures that are taken under consideration. Besides, all the measures both the intersection are under high flood risk zone. Although, the Stura Di Lanzo also covers a lot of space in case of flooding, however, the land use around the river is less of a settlement which can not cause too much destruction.

In addition, this hydrogeological master plan has an important role in the development of a master plan which is under local authorities. Hence, at the present time, it is mandatory to follow the hydrogeological master plan before commencing with the master plan and deciding the land use of the area. These maps provide information about if a particular area can have the construction. Although, even if the area comes under risk level 1, most authorities don't allow for any kind of construction. Moreover, in the end, everything is under policymakers and authorities for implementation and management. Also, with the policies, it has to be more inclusive of all in order to tackle the growing threat of urban flooding efficiently.

CHAPTER 5

TURIN URBAN FLOOD RISK MANAGEMENT POLICIES

5.1 INTRODUCTION

This chapter addresses the concept of municipalities and other organizations in Turin or overall Italy. It focuses on How the authorities developed the policies and which authority is majorly taking all the decisions to tackle urban flooding in piedmont. The major part of this chapter is written after taking the interview of Architect Dottor Gabriele Papa from Città Metropolitana Torino. He is the head of the hydrogeological department in Regione Piedmont, Italy. Moreover, a brief is given in this chapter explaining the types of organization works in Italy. Later explains the flood danger zones and how do they develop the flood hazard map for a city.

The key questions addressed in this section are as follows:

- Describes the hydrogeological management Master plan and its methodology of work.
- Explains how hydrogeological management developed flood hazard zones.
- Describe the role of Regione Piemonte, Citta Metropolitana, and Municipality of Turin.
- Explains the part of AIPO Agenzia Interregionale per il Fiume Po.
- Describe the urban flood risk management policies developed by the organizations.
- Describe the structural urban flood risk management strategy.
- Explains the use of historical data and digital technology to generate the maps.
- Elaborate on the high flood risk area in Turin.

Moreover, it also elaborates on the growing water logging problem in an old part of Turin. The way it has been affecting Turin resident's life. Also, what measures the authority are taking to deal with the issue. Since it is a growing prime in the city, it can even fill the basement with water. This chapter discusses the action of authorities for Turin and the masseuses they are proposing to tackle water-logging due to heavy rainfall and flooding due to the overflow of the Po River.

Additionally, the same problem can see in the nearby cities of Turin in Piedmont. Also, the method which needs the involvement of authorities from different municipalities and regions. Although, the hydrogeological management department plays an important role not just in Turin but all over Itlay. Because without consulting their master plan municipalities can not develop the city master plan. It indicates the high flood risk and landslide risk zones.

This chapter also focuses on the measures of mitigation that has been developed or proposed by Città Metropolitana Torino and the hydrogeological management Master plan. This includes the structural and non-structural measures to deal with the growing threat of urban flooding in and around the city of Turin. Although, the growing urban flood risk is a huge problem not just in Turin even in the cities around it.

Citta Metropolitana does not look after the urban flooding directly. It is an organization that has been put in charge of the implementation of the policies, which is managed by the Region Piedmonte.
In Italy, there are three regional systems such as;

- Provinces.
- Metropolitana Cities.
- Municipalities.

The management of the flooding in Itlay is under an authority which is the main in charge for it which is called the authority of the river. It concerns Turin, there is an authority for the basin of the Po river. This authority is settled in **Parma.** This authority prepares the detailed urban planning tool is called **piano di sotto di hydrogeological** before it was the hydrogeological management Master plan.

The hydrogeological management Master plan details the three typologies of flooding danger levels.

- Typology A
- Typology B
- Typology C

Moreover, these levels assist to detail the area along the river, the sides, and the surrounding of the sides are managed by the typologies of danger. About these three zones, some management rules have been developed. For instance, in Municplaity di Torino if the area is under Zone A. Hence, the urban master plan has to avoid most of the urbanization in the zone due to hydrogeological and flooding issues, and in some areas, it is forbidden.

The intermediate zone B, the developed comes under by considering the hydrogeology plans and urban master plan by considering the limits which are likes with zone A and C.

In zone C, Although, in zone C, some areas come under risk but not as much as zone A. The municipality allows to have development, however, in the construction, it is not allowed to build the ground floor the developers have to make stilt level with three floors.

If the **piano di sotto di hydrogeological management mater plan** provides all the limits that the municipality needs to follow in order to avoid the threat of flooding. There is another topic to address, How to make the structure strong enough to protect the area from flooding. For all the operational protecting issues there are two typologies of authorities. The first one concerns the major rivers in the city such as the Po river and the Dora river. The institution which is in charge to manage the Po river mainly for structural walls and operational things to protect the Po River is called **AIPO Agency Italian for managing Po river flooding (Agenzia Interregionale per il Fiume Po)**.

On the other hand, for minor rivers, there is another organization, another office that manages the flooding problems, known as Regione Piemonte. In the end, to protect lands and avoid flooding, there are hydrogeological master plans. This assists to develop an urban master plan for the city.

5.2 Urban Flood Risk Management Policies.

The strategies to tackle urban flooding developed thoroughly especially after the experience of the flooding events that occurred in Turin in 2000.

There are three main strategies for urban flood risk such as:

- First, it corners Urban planning.
- Second, it concerns the new strategies which are currently going on.
- Third, it corners the management of the unit which helps people after the flooding.

The first one Urban Planning describes that every municipality produced an efficient new master plan considering and comparing with the hydrogeological master plan. For instance, if there is a site that comes under zone A, hence municipality is not allowed to permit for any time of construction project. However, after the experience of flooring in 2000, authorities have identified to **implement the technical strategies** which are going to add in the current year 2022. These strategies include developing the **catchment zones**, a water collected basin. The main reason behind this is to avoid the overflow of the River Po into the city of Turin.

The authorities are digging the catchment zones on the Northern part of the river outside the Turin. Hence, the development of the catchment area proposed outside the city in case the river overflows then before entering the city the catchment zone can collect and store the excess water. This could help the city work efficiently without the threat of urban flooding due to the overflow of the Po river. Even though authorities are also developing this system in the Emilia Romagna Region where they are going through the same difficulty. This project is ongoing, and the discussion with other authorities is ongoing. However, this might take a while since the residents, private owners, and hotel owners are living in these areas, which is the suitable choice to develop a catchment zone first need to vacate the area. Probably the institutions have to distribute money in order to vacant the land since this is an ongoing project and authorities would like to complete it for better results in the city.
Moreover, the Quater Codice Civile is an organization that helps residents with the equation of finance. This organization does not only work in the piedmont. Besides, it is for the whole of Italy to assist during that time of emergency after urban flooding.

The technical tool is implemented by the authorities is the main tool for the urban master plan and sets the limit for urbanization. Hence, the technical tool used to develop the master plan is similar to the hydrogeological urban plan. The digital and technical sources that the authorities use to develop the hydrogeological urban, flood hazard map and the zones of flood hazard map are developed by GIS Geographic Information System. However, in the old-time, these maps were used to hand draft, which used to give accurate data. Although, even now authorities use the historical maps to compare it with the austerity technology, and with the amalgamation of both the maps or the old and new events a new flood hazard map produced. This was explained in chapter 4.2.1 in the case study of Cuneo.

Moreover, the hydrogeological master plan was a matter of discussion and one of the main issues for the last decades. Because a few years back, the municipality was not obligated to follow the laws and policies developed by hydrogeological urban management. Besides, developing the flood hazard map hydrogeological urban management master plan also details out the areas with a high risk of landslides in the hilly region. To mark the areas with high avalanche risk zone, so that municipality will not give authority to construct any project in the high-risk zone. Before municipality was not obligated to follow this in older times, nevertheless now it is mandatory to generate a city master plan after consulting the hydrogeological urban management master plan only. In order to reduce the threat of growing urban flooding and reduce the amount of destruction.

Moreover, in the case of the Po river, it covers so much area that, it has its agency to develop policies for the Po River. Besides, the length of the Po river, the main issue authorities are dealing with is the lack of man force to handle that much area. The Turin municipality is a part of Citta Metropolitana, hence Turin municipality require to follow the laws and rules developed by Citta Metropolitana. Under the Citta Metropolitana, there are 315 municipalities among which Turin is the bigger one. The Turin city shares the border with many cities which comes under the province of Turin such as; Baldissero Torinese, Beinasco, Borgaro Torinese, Caselle Torinese, Castiglione Torinese,Collegno, Druento, Gassino Torinese, Grugliasco, Leinì, Mappano, Moncalieri, Nichelino, Orbassano, Pecetto Torinese, Pianezza, Pino Torinese, San Mauro Torinese, San Raffaele Cimena, Settimo Torinese, Torino, Venaria Reale, and Volpiano.[193] Whereas the cities like Cuneo, Biella, Alba comes under the Regione Piemonte.

Moreover, Turin is an old city with an old urban area. Hence, there are already settlements available as a result, authorities can not allow developing catchment basins in the city which makes it difficult to defend this area. Moreover, to deal with such problems, organizations are planning to come up with a solution in the coming years. To deal with this, a proposal came out to provide insurance not to an individual but to a community that comes under the old settlement. This proposal is for the financial safety in the area which comes under one of the danger zones out of three. Hence, in case of any flood events and the stakeholder's losses in their house, in that case, the district insurance companies can return their relief fund.

Over and above that, in most municipalities and authorities, digital and technical tools are available to understand the flood patterns and develop the flood hazard map. Although, it is always required by experts and hydrogeologists to observe the site in person. Even at the time of flooding or after it to have a clear image of the destruction and to compare it with the past occurred events. It is also important to manage the roads, hence, it is an essential part of their jobs. Furthermore, another issue that is addressed by the municipalities is waterlogged in the city due to constant or heavy rainfall. This usually causes major city problems, by affecting the traffic, by flooding the basements mainly in the historical part of the city.

193 Salata, S. et al. (2021) 'Performance-Based Planning to Reduce Flooding Vulnerability Insights from the Case of Turin (North-West Italy)', Sustainability, 13(10), p. 5697. doi:10.3390/su13105697. Available at: https://www.mdpi.com/2071-1050/13/10/5697

Hence, it has become a vital topic addressed, although to deal with this municipalities need to maintain the sewerage system in the city. Also, it needs funds to manage and redesign the sewerage in order to collect all the excess water. However, it is not possible to do this in old developed areas. Into the bargain, to deal with this issue authorities have two policies. In the case of new construction of the residential and commercial buildings, it is mandatory to build a small collecting water system. This should be involved in the initial level of master planning. Although, the municipality has already commenced with this solution in Moncalieri, comune right outside of Turin.

Into the bargain, to deal with this issue authorities have two policies. In the case of new construction of the residential and commercial buildings, it is mandatory to build a small collecting water system. This should be involved in the initial level of master planning. Although, the municipality has already commenced with this solution in Moncalieri, comune right outside of Turin. However, this solution is not for the old part in Turin such as Via Roma and San Salvario. To deal with this, a proposal is under discussion which is to start incorporating the green roof solution in the buildings which are in the central part of Turin. This proposal is to catch the rainwater and avoid flowing it out into the streets. In the contrast, the main action to take is to maintain the sewerage system regularly.

Furthermore, according to the Citta Metropolitana di Torino, the area in Turin which comes under the high urban flood risk zone is Dora Riparia and the interaction between the Po River and Dora Riparia. This has been explained in detail with the land use map and flood hazard map in chapter 4.3.

After the occurrence of heavy rainfall or flooding, the emergency unit actives, that is Protezione Civile (Servizio Nazionale Della Protezione Civile), is in charge of risk management. This agency works at different levels i.e. national, regional, provincial, municipal, and district levels respectively. This agency played an important role especially for the first-aid for the residents.

In the end, the supervisors and professionals need to be on-site to have a better understanding of the urban flood risk.

5.3 PAI - Piano Di Assetto Idrogeologico.

PAI is an official organization that looks into the hydrogeological resistance of a particular area from landslides and floods. The main objective of the PAI is to extract a plan for the hydrogeological structure is to reduce the hydrogeological risk with respect to the soil in the area; in a way that minimizes the movement and damage.[194] It merges the basin planning with the hydrogeological structure. It controls and coordinates with the previous plans and makes necessary adjustments to ensure the integrated nature of the planning.[195]

PAI compares the previously used plan and provides information for the whole basin are as follows:[196]

- PAI focuses on the accomplishment of the framework including the **intensive structural intervention** on the rivers and slope compared with the old plans.

194 Piano per l'assetto idrogeologico (PAI) (no date) Regione Piemonte. Available at: https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/difesa-suolo/strumenti-per-difesa-suolo/piano-per-lassetto-idrogeologico-pai

195 IBID

196 IBID

• Distinguish the framework for **extensive structural intervention.**

• It explains the non-structural intervention with the guideline and controls the land use in the area of hydrogeological risk.

• The delimitation of the river belts on the major waterline of the basin and compared it with the previous plan of the river belt.

• Distinguishing and delimitation hydrogeological risk in the part of hills and mountains.

Furthermore, the Piedmont Region operates the PAI applications in the local area and later upgrades according to the hydrographic district authority. It aims to regulate plans with the technical point of view of interventions subjected to environmental impact assessment.[197] Additionally, these applications and processes are carried out with the collaboration of the AIPO Interregional agency of the river Po (Agenzia Interregionale del Fiume Po).[198]

Correlation of PAI and Master Plan.

The data obtained from the flood hazard map in reference to the (PGMA) Flood Risk Management Plan (Piano di Gestione del Rischio Alluvioni) offers the upgrading for the river belt and IAP structure lines of watercourses for the Po basin.[199] This allows the chance of upgrading especially in the areas where the flood has occurred.

5.3.1 Piano Stralcio delle Fasce Fluviali (PSFF)

The Extract Plan of the River Bands is a tool on the watercourses of the catchment area of the Po river. This tool is used for the delimitation of the river region, a process to gather the physical structure of the watercourse compatible with hydraulic safety, uses of water resources, use of soil, and the protection and underlying the natural environment.[200] This plan is majorly focusing on the non-structural measures and aimed to protect the hydraulic risk, recovery of the river and maintenance, and conserve the landscape.[201] It explains the levels of catastrophic effects of the flood, such as Band A of the flow of the flood, Flood Band B, Flood Band C for full catastrophic.[202]

PSFF works in follwing ways:

• Recognize the limitations of flood areas and intervene to defend the built-up area and avoid infrastructure which can cause risk.

• It focuses on sustaining the excess floodwater to create an equilibrium, ensure the safety of the residents, and control the outflows in the downstream hydrographic network.

• It supports the natural path or morphological evolution of the riverbed.

197 Piano per l'assetto idrogeologico (PAI) (no date) Regione Piemonte. Available at: https://www.regione.piemonte.it/web/temi/protezione-civile-difesa-suolo-opere-pubbliche/difesa-suolo/strumenti-per-difesa-suolo/piano-per-lassetto-idrogeologico-pai

198 IBID
199 IBID

200 PSFF – PAI (no date). Available at: https://pai.adbpo.it/index.php/2016/05/25/psff/

201 IBID
202 IBID

• Try to sustain and maintain the natural environment and condition. Also, work toward the recovery of the same.

The categorization of the river bands mentioned by a specific graphic on the hazard maps are as follows:

• Band A- The flood outflow band comprises the actual path of the river flow and compares it with the flood path of the outflow.

• Band B- focuses on the area where the riverbed is affected by the latest flood occurrence concerning the past flood occurrence. This assists to control the band from a point where the land becomes higher than the water level through embankments.

• Band-C focuses on the area which comes outside band B, to understand the situation which may be affected by flooding when it occurs at higher them than the previous one.

5.4 Mitigation approach for Urban Flooding.

The traditional and resilient approach to tackle the risk of urban flooding needs constant monitoring and upgrade for better results. As explained the way authorities in Piedmont trying to deal with it and develop new measures in the situation. Hence, there is a need for mitigation for the policies to work for a long time successfully. However, the landscape, natural development are not able to deal with climate change which brings heavy rainfall with it, and urbanization which makes the flooding worse as explained in previous chapters and Turin Urban flood policies. For that reason, the mitigation approach includes structural mitigation and safety measures related to emergency plans and land use plans.[203] In connection, the widely used structural mitigation measures are levees and catchment zones.[204] These solutions are usually proved a successful solution, also it gives feasibility and possibility of mitigation. Nevertheless, the problem that comes with this mitigation approach is that there is always a chance of failure in the structural approach.[205]It is hard to detect the weakest part of the structure which can cause more damage during heavy rainfall and overflow of lakes, streams, and rivers.
Furthermore, the measures might not work for hilly regions and lakes and streams in hilly areas. Due to the issue of soil erosion, the changes of mitigation and man-made intervention reduces.[206]

On the other hand, the non-structural mitigation approach is a part of the authorities. Because it usually concerns the perimeters. The reason behind this, the Po river comes under the jurisdiction of AIPO Agency Italian for managing Po river flooding (Agenzia Interregionale per il Fiume Po), which follows the maps, laws, and policies developed by the Hydrogeological Urban Management Master plan as explained in chapter 5.2.[207]

203 Rabuffetti, D. and Barbero, S. (no date) 'ITALY: PIEMONTE REGION METEO-HYDROLOGICAL ALERT AND REAL-TIME FLOOD FORECASTING SYSTEM', p. 4. Available at: http://www.floodmanagement.info/publications/casestudies/cs_italy_sum.pdf

204 Ibid.
205 Rabuffetti, D. and Barbero, S. (no date) 'ITALY: PIEMONTE REGION METEO-HYDROLOGICAL ALERT AND REAL-TIME FLOOD FORECASTING SYSTEM', p. 4. Available at: http://www.floodmanagement.info/publications/casestudies/cs_italy_sum.pdf
206 Ibid
207 Ibid.

The policies and rules developed by this authority control all the actions from mitigation to human intervention in the plain and hilly region. As mentioned in chapter 5.2 topic, the authorities are proposing insurance for urban flood and hydrogeological disastrous and financial loss. However, this is under discussion before implementation.[208] Over and above that, the non-structural measures come into the policies in1978 by hydro-meteorological forecasts to develop an alert system or an early warning for Civil Protection purposes.[209] Although, there are factors to measure the risk levels and zones. Even so, the Alert system assists during the time of emergency. It looks after the issue of flooding in many ways such as, the risk of flooding because of continuing rainfall for a long time which can affect catchment zones, risk of landslide and storm in areas around the catchment zones, and last heavy snowfall in a lowland which can disturb and disconnect the connection between low land and highlands.[210]

Therefore, it is mostly not easy to mitigate already existing policies, newly developing policies, and the policies which are under the proposal phase.

208 Ibid
209 Ibid
210 Ibid

CONCLUSION

The conclusion of the research comprises the following points:

Outcome of the research with respect to case studies.

The outcome of the thesis with respect to case studies describes that urban settlements and growing urbanization play a vital role in the devastating result of urban flooding. In most of the case studies, the urbanized area is densely populated. This makes it more challenging for the authorities to deal with the threat of flooding. Moreover, the research explains that most of the urban cities are affected by urban flooding, which has been proven to create less destruction in rural areas. As the result explains, the reason is the availability of more open spaces, which according to the case studies are lacking in urban cities. As is the lack of built-up area, lack of open space and lack of permeable surface put pressure on the cities sewerage system.

Outcome concerning climate change.

Another outcome is concerning climate change which describes the change in climate as not as responsible as the densely populated cities. However, the climate is affecting weather as a result of which the percentage of precipitation in the atmosphere increases and causes heavy rainfall during the time of the rainy season. Moreover, heavy rainfall can cause waterlogging if the drainage capacity is not adequate. Due to the web of concrete and solid surfaces, which is not permeable the excess water is unable to go inside the ground. Besides the densely populated cities are putting pressure on drainage system which was never built to cater to present-day urbanization. Additionally, rainfall is one of the prominent issues in the hilly region. With heavy rainfall in the hilly region, the probability of landslides has enhanced.

Outcome concerning case study of India.

The outcome of case studies from India is most likely similar to European case studies. India is also dealing with rapid urbanization and urban structural development. However, the utmost difference among these countries is the population. The population of the cities mentioned in the case study Mumbai and Delhi is making it tough for the state municipalities and national organizations to deal with the growing problem of urban flooding. Although with intervention and mitigation in the same policies, the government is trying to tackle the issue, which can provide the least disastrous result.

Outcome from countries achieving urban flood resilience.

Furthermore, the countries which are achieving urban flood resilience in the uncertain future are also dealing with the rapid growth of urbanization. Although, these countries mentioned in the case study have proven to tackle urban flooding by

their structural and non-structural integrated urban flood risk management approach.

Outcome of the research area Turin Italy.

The outcome of the research in Turin as a study area enlightens the similar issue and their sources. This city has changed a lot, to which the residents can experience the result. The problems mentioned in the research are the very latest. Even the same problems can be seen in Turin for instance, reducing built-up space, streets are having a non-porous surface, and the sewerage system is old. As a result, this city was not ready to handle urban growth.

Outcome with respect to Citta Metropolitana Di Turin.

Additionally, the urban flood hazard map provided by the Città Metropolitana Torino and land use map developed by using digital platform GIS developed the map which shows the high flood-prone areas. This map can assist in future urban master planning, in order to avoid any flood incidents in the future. Research and interview with professionals enlightened the problems in the city and the measures have been taken under consideration by the authorities and municipalities.

Final remarks.

At last, the case studies and research regarding the study area have proved that rapid urbanization is the key to failure. However, it is not easy to control and stop urbanization. For better living style, job opportunities and future people will migrate from one place to another. Hence, the cities and the countries need to come up with some inclusive and mitigated approach to achieve urban flood resistance. Also, it is important for proper monitoring for a professional to go for regular checks and maintenance on-site. Regular maintenance can be the key to success to avoid the urban flood risk. Furthermore, flood resistance and flood resilience are not new words or concepts in urban flood risk management. Although, what makes it more famous at present time is the non-structural approach which spread awareness in people regarding urban flood resilience. Moreover, cities all over the world are facing the same problem that can learn from each other and the policies developed by each city. Although it would not completely feasible for cities to follow similar rules because of the different typography, weather effects, climate change effects, and location. This research helps to understand how to tackle the growing risk of urban flooding. Moreover, in the author's opinion, it is not completely possible to stop urbanization and migration. However, it is possible to provide a better lifestyle and work opportunities to the people living in rural areas so that they would not decide to move to the urban area. This will help to reduce the burden on metropolitan cities. This is only possible by means of the Governmental approach, not by authorities. This way it can be possible to reduce the threat and development and management of the urban flood risk management system.

ANNEXES

SURVEYS

RESIDENT OF TURIN AS PERSONA FOR THE SURVEY

This section addresses the good and bad aspects of Turin city, focusing on the lives of residents of Turin, inclusive of all age groups. For this survey, I prepared an outline of questions before conducting the interviews. The residents who participated in this belong to different professions, living in Turin for over a decade, born in Turin, and moved five years back.

In the survey, questions are regarding urban transport, the impact of urban flooding on each of their lives, their opinion about the measures taken by the authority, if they are aware of the Urban Flood Risk Management System developed by the authorities, and at last as a resident of Turin would they like to suggest to help or overcome this circumstance.

I am grateful to the participants who helped me throughout this survey and provided the necessary information to understand the condition of Urban Flooding in the cities of Piedmont: Turin and Cuneo. Their experience gave me insight to better acknowledge the good and bad aspects of urbanization in this city.

Persona 1
Dottor Gabriele Papa

Persona 2
Marina Spadaro
Age 70

Persona 3
Domenico
Age 33

Persona 4
Simona Giuffrida
Age 32

Persona 5
Steven Corso
Age 25

Persona 6
Elena Maritano
Age 25

01 INTERVIEW

Name : Dottor Gabriele Papa
Occupation : Architect in Città Metropolitana Torino

01. As an expert on urban flood in the Città Metropolitana of Torino, in your opinion, what are the current strategies in place to protect the city by Citta Metropolitana?
As explained by him , Citta Metropolitana does not look after the urban flooding directly. It is an organization that has been put in charge of the implementation of the policies, which is managed by the Region Piedmonte.

02. Which strategy has proven more beneficial against the risk of Urban Flooding?
The strategy of developing a catchment basin outside the city.

03. How are Flood Risk Management or Protection Policies are linked to Urban Master plan tools?
The technical tool to develop the master plan is similar to the hydrogeological urban plan.

04. Would you like to share your experience in Piano Assetto hydrogeological of Region Piemonte?
In my experience, the municipality was not obligated to follow this in older times, nevertheless now it is mandatory to generate a city master plan after consulting the hydrogeological urban management master plan only. In order to reduce the threat of growing urban flooding and reduce the amount of destruction.

05. Is Turin Municipality in connection with other municipalities to tackle the urban flood threat?
Turin municipality is a part of Citta Metropolitana, hence Turin municipality require to follow the laws and rules developed by Citta Metropolitana.

06. What would you suggest for future hydrogeological assessments?
In my opinion, the cities which are densely accommodated, hence it is not possible to propose a catchment zone inside the cities. in this case, a proposal came out

to provide insurance not to an individual but to a community that comes under the old settlement. This proposal is for the financial safety in the area which comes under one of the flood danger zones.

07. Have you ever been affected by Urban flooding in Turin?
No! Although in my profession I have deal with it many times.

08. According to you and research, which area is more flood-prone in Turin?
According to the research, the area in Turin which comes under the high urban flood risk zone is Dora Riparia.

09. Would you explain the Flood Risk Management System developed by the authority?
In case of meregncy, the Protezione Civile (Servizio Nazionale Della Protezione Civile) takes charge for first-aid.

10. How is urban flooding affecting your life or Turin or Piedmont?
At personal level it is not affecting. Although on professional level it is all I manage. I don't live in Turin, I live near Pinerolo.

11. Would you like to suggest any idea which can help in Urban Flood Resilience?
In my opinion, a professional regular check of the maintenance of the landscape. Regular maintenance especially in a hilly region is one of the most important ways to avoid the risk.

02 INTERVIEW

Name : Marina Spadaro
Occupation : Professor in Department of Philosophy at Università Di Torino
Age : 70
Residence : 63 years, Turin, Italy.

01. What Part of Turin do you live in?
I live in Centro Torino.

02. How long have you been living in Turin or Cuneo Piedmont?
I was born in Cuneo and moved to Turin in 1958.

03. How do you commute?
Mostly I use public transport sometimes I use a private vehicle.

04. What is your opinion about Urban growth in Turin?
I belong to a family where my mother is from Northern Italy, and my father is from Southern Italy hence the cultural difference was too much to create conflicts. However, after the Fiat, an industrial revolution started in Turin where people from the southern part came to Piedmont to work and grow urbanization. This growth made the city inhabitable as well as the architecture style of the building had changed.

05. Are you satisfied with Urban development in Turin?
Turin was famous for its elegance, fashion, and Barque Architecture. After the 2nd World War and Fiat development, the city was started to lose its architectural charm. However, now due to vehicular access near the center and tacks of trams everywhere, it has been making it hard for people to walk, arcades are crowded and dangerous. The city needs more pedestrian-only streets.

06. Do you think Turin is an age-friendly city?
No! I don't think that because of square stones which makes it hard to walk, tram tracks are everywhere, and most of the space on road is occupied by cars.

07. Have you ever been affected by Urban Flooding in Turin?
Yes! Only during the time of rainfall. This is majorly happing because they are not cleaning the drainage system.

08. Do you think the authority has developed the drainage system or used the old system?
They are using the old system, but they have cleaned it.

09. Do you think authority is taking necessary measures to deal with Urban Flooding?
Yes! Sometimes they are cleaning the rivers.

10. Are you aware of the Flood Risk Management System developed by the authority?
No! It is very difficult to communicate with authority and to propose anything. In small cities, it is easy to contact their mayor, but not the same case in Turin.

11. As a citizen of Turin, What would you like to suggest which can help the city deal with Urban Flooding and Urbanization?
I would like to suggest to make the city vehicle free, keep the Rivers and drainage system clean.

03 INTERVIEW

Name : Domenico
Occupation : Industrial Engineer Fiat, Torino.
Age : 33
Residence : 10 years, Turin, Italy.

01. What Part of Turin do you live in?
I live in the outskirts area of Turin.

02. How do you commute? Have you faced any difficulty in that?
I use my private vehicle to commute. Moreover, living far from downtown is not very difficult, it takes just 15 min.

03. What is your opinion about Urban growth in Turin?
I think the urban growth in Turin is under control.

04. Are you satisfied with the Urban Development in Turin?
I think that urban development is appropriate for a city with this dimension.

05. Have you ever been affected by Urban Flooding in Turin?
No.

06. Do you think authority is taking necessary measures to deal with Urban Flooding?
I think yes, but I don't have a clear picture of those measures.

07. Are you aware of the Flood Risk Management System developed by the authority?
No.

08. As a citizen of Turin, What would you like to suggest which can help the city deal with Urban Flooding and Urbanization?
To make the livelihood and house closer to the river safer.

04 INTERVIEW

Name : Simona Giuffrida
Occupation : Architect
Age : 32
Residence : Since Birth, Turin, Italy.

01. What Part of Turin do you live in?
I live near Porta Susa.

02. How do you commute? Have you faced any difficulty in that?
Not now, but when I was at university I used to take the number 9 cable car to get to Valentino: delays or too full to get on especially in the morning.

03. What is your opinion about Urban growth in Turin?
As per I remember from my Politecnico studies, in the mid-1990s the City of Turin began to intervene on the theme of urban renewal and regeneration, with a long list of policies and instruments still in use today, such as the Cagnardi- Gregotti PRG: new neighborhoods and new urban centers were born. Think of the transformations of the "Spine", of the re-fictionalization of large abandoned industrial areas.
The Olympic investments have given a further impulse to urban transformation, of low design quality in my opinion.
Today the forms of living have changed, of getting out of the city or rather bringing the "outside" into the city: huge green space, light mobility, and implementing gentrification policies

04. Are you satisfied with the Urban Development in Turin?
Average quality depends so much on the neighborhood you live in. I will say OK, with more public infrastructure and mobility like the subway or a good connection to the airport.

05. Have you ever been affected by Urban Flooding in Turin?
No.

06. Do you think authority is taking necessary measures to deal with Urban Flooding?
I do not trust too much in Torinese politics.

07. Are you aware of the Flood Risk Management System developed by the authority?
No.

08. As a citizen of Turin, What would you like to suggest which can help the city deal with Urban Flooding and Urbanization?
I would suggest safe and clean riverbanks and stop destroying nature.

05 INTERVIEW

Name : Steven Corso
Occupation : Teacher
Age : 25
Residence : 6 years, Turin, Italy.

01. What Part of Turin do you live in?
I live in the Parella area of Turin.

02. How long you have been staying in Turin?
I came to Turin in 2016 from Biella. I was born in Biella.

03. How do you commute? Have you faced any difficulty in that?
I usually walk, use my bicycle and public transport.

04. What is your opinion about Urban growth in Turin?
I think the growth of the city is positive, although it has been progressing in years but slowly.

05. Are you satisfied with the Urban Development in Turin?
Yes! I am satisfied.

06. Have you ever been affected by Urban Flooding in Turin?
Yes! Once I was affected by the Urban flooding in Turin. This is disappointing because I go for a run near River Po and River Dora, and the area near the bank is so dirty.

07. Do you think authority is taking necessary measures to deal with Urban Flooding?
I think No! I am not satisfied with their work.

08. Are you aware of the Flood Risk Management System developed by the authority?
No! I am unaware of this. Although, I know that authority has shut down Murazzi Po Pubs and other services which are touristic near River Po to prevent flooding.

09. How Urban Flooding is affecting your life in Turin?
It affects my day-to-day life activity. Since I am a teacher at a school for disabled students.

10. As a citizen of Turin, What would you like to suggest which can help the city deal with Urban Flooding and Urbanization?
I would like to suggest regular cleaning of rives and drainage system.

06 INTERVIEW

Name : Elena Maritano
Occupation : HR
Age : 25
Residence : 5 years, Turin, Italy.

01. What Part of Turin do you live?
I live in Bargo San Paolo area of Torino.

02. How long have you been living in Turin or Cuneo Piedmont?
I was born in Saluzzo in the province of Cuneo and moved to Turin 5 years back.

03. How do you commute?
I use public transport.

04. What is your opinion about Urban growth in Turin?
Turin has developed a lot after FIAT. However, it somewhat ruined the aesthetics and architecture style of Turin. After this, the population growth has increased in Turin.

05. Are you satisfied with the Urban Development in Turin?
I am not completely satisfied. It could be better for sure. However, it is not possible to completely satisfy everyone with all the aspects of Urban planning and designing.

06. Have you ever been affected by Urban Flooding in Turin?
I saw two years back near Via LaLoggia behind Lingotto Mall, the area was filled with water and inhabitants had to throw their furniture out, also at my birthplace Saluzzo.

07. Do you think authority is taking necessary measures to deal with Urban Flooding?
Yes! I think they are trying to deal with it. However, at my birthplace, the story is different because it is surrounded by mountains so it is a bit hard to deal with the issue.

08. Are you aware of the Flood Risk Management System developed by the authority?
I think yes! They have plans, perhaps not that organized with some simple rules.

09. How Urban Flooding is affecting your life in Turin?
It is not affecting that much, although it is affecting my city Saluzzo.

10. As a citizen of Turin, What would you like to suggest which can help the city deal with Urban Flooding and Urbanization?
I would like to suggest cleaning the rivers more often, not once in a while, also look after for environment and include residents in the process as well.

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