International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 8 Issue 12 ǁ 2020 ǁ PP. 29-35

Planning Challenges and Implications of Sponge City Concept in Managing Urban Floods in Kerala

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Abstract
The expeditious development of social economy, uncontrolled expansion of urbanization and increased urban population are magnifying risks of major disasters in urban areas. Flooding in urban areas causes large damage at infrastructures and environment. Sponge City Concept, which was successfully implemented in China to overcome the above problems. The study was also expected to provide a deeper thinking to solve the water logging and water scarcity of the State Kerala in sustainable and green manner. Prolonged, governments implemented grey solutions such as dams and levees to mitigate flood risk. However, with adverse impacts of floods growing, interest in a more integrated approach to urban flood risk management is growing as well. Kerala is facing severe floods during 2018 and 2019. It may cause large impacts to the economy and it affects the infrastructures badly. A sponge city is a city that acts as a sponge with an urban environment planned and constructed to soak up almost every raindrop and capture that water for reuse. The concept is being developed to make use of „blue" and „green" spaces in the urban environment for storm water management and control. In this paper we are presenting a rational approach to conducting a rapid assessment to improve the livability and sustainability of cities. The implementation of Sponge City is the best solution for these problems.

Keywords: *Urban flooding, Sponge city concept, Flooding in Kerala*

Date of Submission: 01-12-2020 Date of acceptance: 15-12-2020

I. INTRODUCTION

The expeditious development of social economy, uncontrolled expansion of urbanization and increased urban population are magnifying risks of major disasters in urban settings around the world. Flooding in urban areas causes large damage at infrastructures and at environment. The main problems are associated with water logging, water resources and the aquatic environment, for example, a heavy rain in a city inevitably leads to water logging, which leads to a great threat to the livelihood, property and transportation facilities. This study briefly introduces the opportunities of Sponge City, which was successfully implemented in China to overcome the above problems. The study was also expected to provide a deeper thinking to solve the water logging and water scarcity of the State in sustainable and green manner.

Prolonged, governments implemented hard engineering or grey solutions such as dams and levees to mitigate flood risk. Even so, with ruinous effect of floods enlarging, interest in a more integrated approach to urban flood risk management is flourishing. This paper is to study the urban flood management in Kerala and the sponge city concept as a solution for urban flooding. A sponge city is a type of city which acts as a sponge with an urban environment organized and constructed to absorb almost every raindrop and capture that water for reuse. *"The Sponge City has the capacity to mainstream urban water management into the urban planning policies and designs. It should have the appropriate planning and legal frameworks and tools in place to implement, maintain and adapt the infrastructure systems to collect, store and treat (excess) rainwater. In addition, a "sponge city" will not only be able to deal with "too much water", but also reuse rain water to help to mitigate the impacts of "too little" and "too dirty" water"*

The concept is being developed to make use of "blue" and "green" spaces in the urban environment for storm water management and control. The concept and its related recommendation and practices will provide numerous opportunities to integrate ideas from Eco hydrology, climate change impact evaluation and planning, and consideration of prolonged social and environmental aspects, within the urban land-use planning process. In this paper we are presenting a rational approach to conducting a rapid assessment to improve the liveability and sustainability of cities. Our neighboring country China has successfully implemented this technology.

II. SPONGE CITY CONCEPT

The S*ponge City* designate a particular type of city that does not behave as an impermeable surface not allowing any water to filter through the ground, but, more like a sponge, actually absorbs the rain water, which is then naturally filtered by the soil and allowed to reach into the wells. This helps to extract the water from the ground through urban wells. This water can be used for the city and for the domestic water supply.

This integrated concept solved the current China's specific issues.

i. Possessing a good "elasticity and resilience" on response to environmental change and natural disasters, etc.
ii. Solving the problems of urban waterlog and environment deterioration
iii. Managing, protecting and utilizing drinking water source, wastewater, ecological water, rainwater and underground water, etc.
iv. Taking fully consideration of water resources, water environment, water safety, water ecology and water culture
v. Mitigating the heat island effect, the essence of Sponge City belongs to the integrated solutions of urban water resources and environment

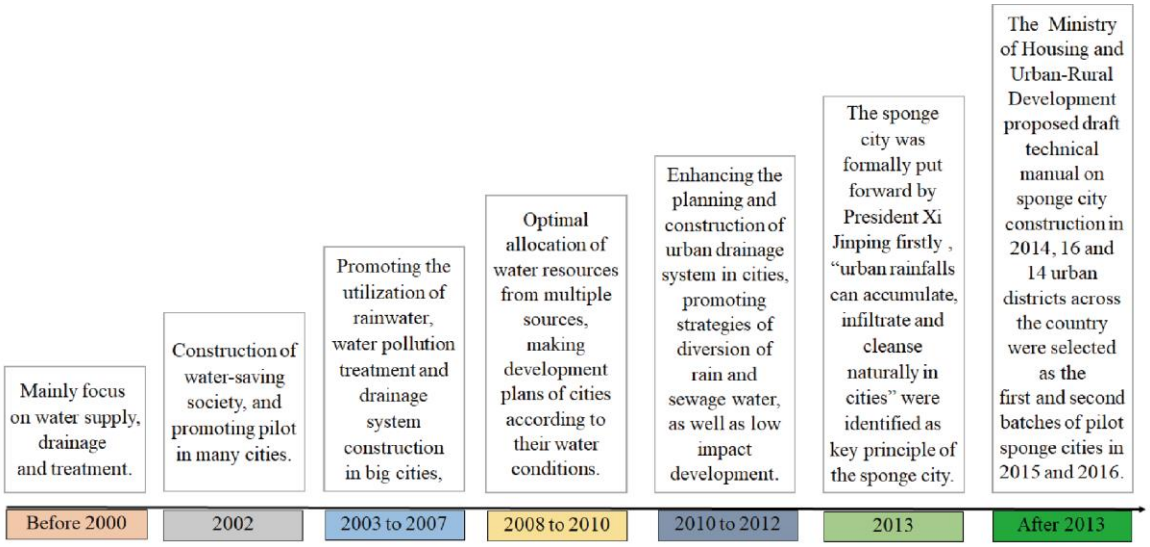

Figure 1: Timeline of the development of Chinese urban water management policies

A sponge city needs to be abundant with spaces that allow water to seep through them. Rather than impermeable concrete, the city needs more:

i. Adjacent open green spaces, interconnected waterways, channels and ponds across neighborhoods that can naturally detain and filter water as well as foster urban ecosystems, boost bio-diversity and create cultural and recreational opportunities.
ii. Green roofs that can hold on rainwater and naturally filters it before it is released into the ground.
iii. Porous design interventions across the city, including construction of bio-swales and bio-retention systems to detain run-off and allow for groundwater infiltration; porous roads and pavements that can safely accommodate vehicles and pedestrians flow while allowing water to be absorbed and recharge groundwater; drainage systems that percolate the water into the ground.
iv. Water savings and recycling, including extending water recycling particularly of grey water at the building block level, incentivizing consumers to save water through increased tariffs for increase in consumption and improved smart monitoring systems to find the leakages and inefficient use of water.

2.1 BENEFITS OF A SPONGE CITY

There is a large number of benefits associated with the implementation of sponge cities. Absorbed the rainwater naturally and can be stored and used for irrigation and domestic use. In China, the country plans for 80 percent of its urban cities to harvest and reuse 70 percent of rainwater. If there is a sudden rainstorm, rain water can overcharge a city's drainage infrastructures. Overflowed stormwater get mixed up with the sewerage flow, thus polluting drinking water and recreational spaces. The incorporation of green roofs and lots of green spaces with plants as well as grasses, also helps to filter the water and increase the groundwater recharge and refresh the air from pollutants. Cities are often warmer than their suburbs. This is partly due to the expanded use of concrete that absorb and re-radiate the sun's energy. Global warming effect is aggravating by the release of CO_2 from heated buildings as well as vehicles. All this come up with a phenomenon known as the urban heat island effect. Through their incorporation of

natural features, sponge city designs help to reduce this excess heat. Increase greenspaces is a highly effective method of improving a city's microclimate. Sponge cities also help to reduce global warming through their use of eco-friendly materials. The reduction in the amount of stone and concrete used in urban infrastructure, leads to reduction in the emission CO2 from cement. Cement accounts for roughly 8 percent of all man-made greenhouse gas emissions, and any reduction is welcome. Grass swales, artificial ponds, wetlands and rain gardens provide an aesthetic appearance and calming effect of urban development.

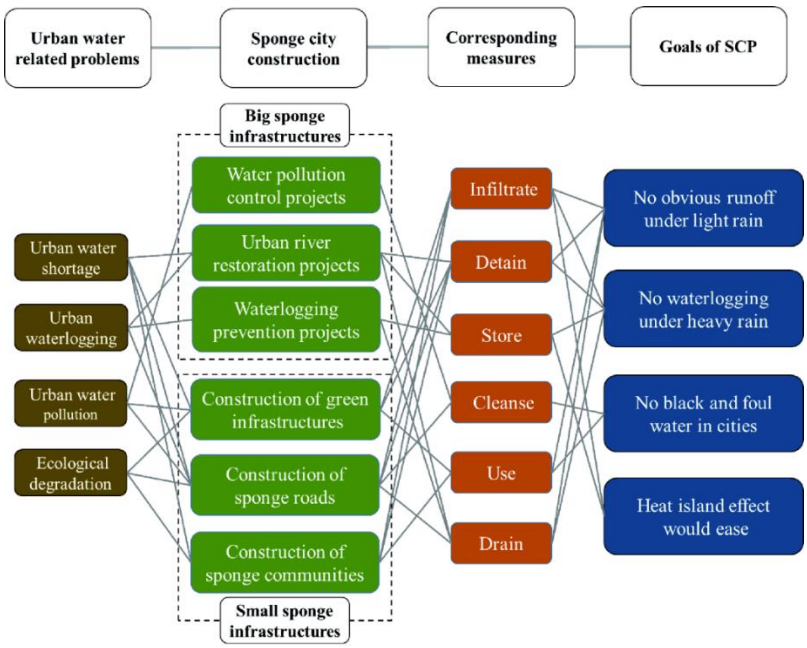

Figure 2: Implementation of Sponge City Program in China

III. LITERATURE REVIEW

Literature has been reviewed to understand methodology of Sponge city construction for mitigating flood risk and developing strategies for managing urban floods in Kerala.

A. Analysis of sponge city construction uses nature-based solutions for integrated urban flood management –in the case of Shenzhen City, China

China is among the most highly exposed countries to flooding risks, with more an estimated 67 percent of the national population located in flood-prone areas. Rapid urbanization and economic growth are driving increasing exposure to urban flood risks, which are expected to worsen under future climate change. In 2014, China introduced the sponge city approach to improve integrated urban water management, address surface-water flooding, attenuate peak run-off, improve purification of urban runoff, and enhance water conservation. The Sponge City approach combines traditional structural engineering approaches with innovative nonstructural measures, leveraging both grey and green infrastructure and the application of nature based interventions. China aims to have 80 percent of urban areas across the country sponge like by 2030. Located at the Southern coast of China and bordering Hong Kong, Shenzhen is selected as one of the 30 Sponge City pilots in 2016. During the last 40 years, Shenzhen's population and economy have experienced rapid growth, increasing the potential exposure to urban flood risks. Shenzhen has applied the Sponge City approach across a number of different projects, with significant achievements with a range of multidimensional benefits, including flood reduction, increased climate resilience, improved social wellbeing, ecological restoration and better biodiversity outcomes, and improvements in water quality, among others. China's experience with integrated approaches to urban flood mitigation has direct relevance to Kerala and other States in India that are routinely impacted by floods and in search of sustainable solutions for flood management that can deliver on the promise of improved urban environments. This paper reviews the concept, implementation and outcomes of China's Sponge City Initiative using Shenzhen city as an example. China suffers from serious urban flooding issues that have caused severe social economic consequences. Rapid urbanization and future climate change are expected to aggravate such challenges. China initiated its Sponge City Program in 2014 and identified 30 pilot cities in the subsequent years. The Sponge City approach combines both structural and non-structural measures that leverages both grey and grey infrastructure to improve integrated urban water management, address surface-water flooding, attenuate peak

run-off, improve purification of stormwater runoff, and buildup water conservation. The Sponge City has realized a broader range of benefits in multiple dimensions, including flood reduction, water quality improvements, increased urban green space, increased urban biodiversity, as well as contributing to social linkage and people's wellbeing, among others.

B. Identify the strategies of Sponge City Construction Planning- in the case of Pingxiang, Jiangxi Province, China

Nowadays, urbanization in China will maintain a rapid development speed. After the downpour, the phenomenon of "sea views" is common. The main reason is that the urban drainage system cannot afford the excessive flow of water in a short period of time, but the most fundamental reason is that the artificial impermeable construction changes the water storage and drainage function. "Sponge city construction" came into being to solve these water related issues. By analyses and studies the sponge city construction in Pingxiang City and the techniques adopted and the methods used for the site investigation and data's to be collected to understand the ideas of sponge city construction in Pinxiang city. Sponge city refers to the new construction and development mode of cities to cope with urban water accumulation, waterlogging and other problems, which has a special regulation function on precipitation. It can dissolve the tense relationship between urban ecological environment and water resources fundamentally. This low-impact development mode can effectively reduce the non-point source pollution of rainwater, improve the utilization efficiency of rainwater, improve the water shortage problem of cities, make the ecological balance reach a higher level, change the traditional state of rainwater drainage and impoundment, make the city develop better, make full use of resources, and build a new city with beautiful environment and harmonious coexistence between man and nature. Precipitation of the cities in the south of China is generally more than that in the north, and the total amount of rain in Pingxiang is larger than that in most cities in the south.

People's harm to nature will always be retaliated by nature, and urban residents and rulers are troubled by the problem of heavy rainstorms and urban water accumulation. Therefore, it is put on the agenda to find a new direction for urban development, improve urban water accumulation and water shortage in dry season. After the approval of the application of sponge cities for pilot cities, the preferred areas for flood disasters in old urban areas should be renovated, and then experimental transformation should be carried out in new districts and administrative districts of cities. Pingxiang sponge city construction has achieved good results, which can provide relevant cities with experience and learning methods. But many practices cannot adapt to the present unchanged, with the progress of society and the development of the times to improve and further improve. At present, there are still many small and medium-sized cities in our country facing the problem of urban waterlogging, these cities can learn from the experience of the reconstruction of the city, and plan their own construction road, economic development to a certain extent, people pay attention to the quality of life and ecological environment, and the construction of sponge city can meet people's mentality of upgrading and improving the status.

IV. KERALA CONTEXT

Urban flooding in Kerala has been studied in detailed to find the causes and the possibilities of transforming the Cities in Kerala to Sponge city. Also developing strategies for the implementation of this concept in urban flood vulnerable areas in Kerala.

4.1 URBAN FLOODING IN KERALA

Floods happen in varying locations and at varying magnitudes giving them markedly different effects on the environment. Flood hazard comprises many aspects that include structural and erosion damage, contamination of food and water, disruption of socioeconomic activity including transport and communication, as well as loss of life and property. Urban floods as the name implies take place in urban areas especially in towns located on flat and low-lying terrain especially where drainages are not available or poorly built or have been blocked by disposed municipal waste and eroded soil materials. Conversion of natural terrain to paved and tarred roads increases runoff two to six times more than would normally occur. The impact of flooding is driven by a combination of natural and human induced factors. The rapid growth leads to poorly planned urbanization making urban populations increasingly vulnerable to floods. The damages of urban flooding are more intense and costlier and difficult to manage.

4.1.1 Population growth in urban areas

As per 2011 Provisional Population Figures, Rural Population in Kerala is 17,455,506. Out of this 8,403,706 are males and 9,051,800 are females whereas urban population in this state is 15,932,171. Out of this, 7,617,584 are males and 8,314,587 are females. The decadal decline of rural population was –25.96%, whereas the urban population has grown by 92.72%. The huge growth of urban population of 92 per cent in 10 years could be attributed to manifold increase in the number of towns from 159 to 520 during the period. Ernakulam district,

with the state's fast-growing business hub Kochi as headquarters, is the most urbanized area in the state. The upland Wayand in north Kerala, on the other hand, is the least urbanized district.

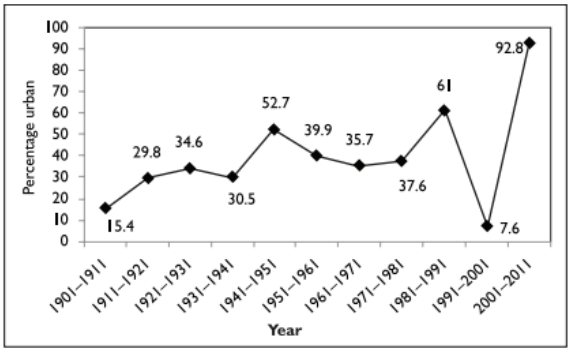

Figure 3. Decadal Urban Population Growth Rate, Kerala 1901–2011

4.1.2 Urbanization in Kerala

Urbanization in Kerala shows marked peculiarities. Generally, increase in urban population growth rate is the result of over-concentration in the existing cities, especially in the million-plus urban agglomerations. However, in Kerala, the main reason for urban population growth is the increase in the number of urban areas as well as urbanization of the peripheral areas of existing major urban centers. Kerala is very unique in settlement pattern also. In most of its parts, it is a continuous spread of habitation without much open lands or fields separating habitations. So the settlement pattern itself gives an image of urbanization. Moreover, the infrastructural facilities available to the population in general do not vary much between rural and urban, especially in the case of access to educational and health care facilities.

4.1.3 Issues in planning & development of urban areas

i. **Urban Drainage:** Urban Drainage is an important parameter in urban development. Conversion of low lying paddy fields, water bodies, ponds etc. indiscriminately, has resulted in surface drainage problems in many an urban area. Due to this, during cloud-bursts and heavy monsoons, floods occur causing damage to men and materials. Kerala is having lack of drainages and most of them are in bad condition. The canal fails to carry the rainwater to sea outlets due to the deposition of silt a debris. Land zoning and new land developments will be viewed with regard to urban drainage aspects and the required measures will be strictly enforced.

ii. **Solid waste management:** Waste management has come to be a serious issue in Kerala. The main problem was that the state did not have a successful model for waste management. Waste management is an essential service to be provided by the municipal and local government authorities at the local and state levels cite. But the failure of planners and administrators to foresee the emerging threats, lack of training to (NGO)'s, (CBO)'s Residents Welfare Associations and women Association in solid waste management in Kerala, absence of appropriate technology are the reasons for the problem assuming such explosive dimensions. Steadily increasing population of the state has a direct bearing on the amount of waste generated. The solution to the massive problems lies in decentralization of waste treatment.

iii. **Sewerage System:** The urban local bodies in the state, barring a small extent in the municipal corporations of Thiruvananthapuram and Kochi, do not have planned sewage disposal system. Government will promote setting up of underground sewerage system and liquid waste treatment plants with private sector participation. High density areas of Corporations and major Municipalities will be given priority in setting up of underground sewerage system whereas provision of in site sanitation will be encouraged in low income areas. Most of the sewerage system failed to reach the treatment plants and the poured into the rivers directly. Due to the improper condition of sewerage system the waste water get mixed up with the stormwater and get polluted.

iv. **Landuse changes:** The main reason why the floods in Kerala were devastating is deforestation that has taken place in the Western Ghats along with quarrying for stones and minerals as is evident from the graph below. The wetlands and the floodplains of rivers have also been encroached on. All these have together increased the runoff and also decreased the water holding capacity of the hills and the plains. The Vembanad Lake, which is a protected Ramsar site, into which several rivers drain has been encroached on and its capacity to hold water has been drastically reduced because of the huge urbanization that has taken place around it. Consequently, it did not have the capacity to hold the huge runoff coming into it and overflowed and submerged the urban areas around it.

4.2 OBSERVATIONS ON THE KERALA WATER SYSTEMS AFTER FLOOD

The rivers observed have clearly delineated main channels. The embankments are steep and stable to a degree. It seems the rivers are stable within their bed. The full bank capacity of the rivers is, based on discussion and observation, in the order of a 1 in 10 to 25-year maximum discharge depending on the local topography. Flooding occurs with any higher river discharges. People seem to live with limited flooding, live with water, but were not prepared for an extreme flood as occurred in 1924 and 2018. This observation is relevant in planning for future flood mitigating measures with the objective of lowering the flood levels along the principles of "Room for the River". Regular flooding occurs in the low areas around the backwaters and lower river reaches. Apart from the flood discharge inflow from the rivers the reason for flooding is in particular the poor discharge capacities or blockage of discharge at the sea outlets (Azhis and Pozhis).The drainage channel system of the Kuttanad area including the main drain into which the four main rivers drain into the Kuttanad wetlands have poor maintenance and have to some extent silted up thus reducing their drainage discharge capacities towards the Thottappally Spillway which itself has a limited capacity of reportedly 380 m3/s. Manmade interventions along the coast such as creating small harbours by building out breakwaters have detrimental effects on the natural coast line.

Kerala has a well-established hydrometric network but it is not fully operational and reliable. The quality of the data can, reportedly, not always be guaranteed. Reliable topographical, hydrometric and bathymetric data are a pre-requisite for proper planning and designing of water resources development interventions as well as for the operational management of the infrastructure such as flood forecasting and preparation of dam operation protocols.

V. ANALYSIS AND FINDINGS

From the literature study, it can be seen that sponge city concept is an integrated natural based solution for urban flood management. The concept not only solves the water related issues, it tries to make the city from "grey" to "green". Concept includes structural and non- structural measures to solve the social, economic and environmental issues due to urban flooding. From the case studies, we can understand that Shenzhen and Pinxiang cities in China successfully implemented the sponge city concept and achieve better results. These two cities continuously facing water logging and water related issues. By adopting these techniques, they can control the impacts due to flooding to a large extent. Kerala is having large precipitation annually than China. Ecological characteristics in Kerala is completely not same as China but have some similarities. From the study we can conclude that flooding occurs mainly due to the improper and unsustainable way of planning in the urban areas. Both places, the maintenance and operation of physical infrastructure is in bad condition. Also, encroachment of build-up areas in the ecologically sensitive regions is one of the reason for urban flooding. Kerala faced a severe flood during 2018 due to heavy precipitation. The water opened from the dams overflowed the rivers and lakes, it may cause heavy flooding. Also, the overflowed water doesn't infiltrate and it immobile in the drainages because of the waste deposited in the drainages.

i. The well-balanced hydrological system focuses on the balance between water use, flood control and the ecological environment in the basin. Healthy water-cycle cities are mainly realized by constructing or transforming green rainwater infrastructure, rain city and rain village. China's Sponge City intuitively expresses the drainage, absorption and reuse of rainwater through nature
ii. Goal of the „Sponge-City "is to buffer rainwater at its place of origin. "Green elements" just as swales, tree-drains, green roofs and facades help to evaporate, store and infiltrate the rainwater, which strongly reduces the outflow.
iii. Sponge City" may not be, or should not be, a profitable investment for private investors.
iv. Governmental involvement is dominant in planning, financing and construction as "Sponge City"
v. To implement sponge cities successfully, an appropriate definition of goals and adequate research to understand this new approach (along with sufficient knowledge) is very crucial
vi. Shenzhen and Pinxiang cities successfully implemented sponge cities. Thus they achieve a greater results and make a sustainable green city.
vii. People live with limited flooding but were not prepared for the extreme floods of 1924 and 2018. This is particularly relevant in planning for future flood mitigation and lowering flood levels along the principles of 'Room for the River'.
viii. Regular flooding occurs in the low areas around the backwaters and lower river reaches. Apart from flood discharge inflow from rivers, flooding is caused by poor discharge capacities in the canals or blockage of discharge at the sea outlets
ix. River is flowing in its full capacity and they bring heavy sediment load from the catchments, these coupled with inadequate carrying capacity of the rivers are responsible for drainage congestion, causing floods and erosion of river banks

x. Improper maintenance and operation of drainage and sewage is one of the main reason for waterlogging in urban areas
xi. Sewage and stormwater get mixed due to the inefficient infrastructure.
xii. Deforestation of hill areas causes sudden rising of water as cutting of trees reduces the water carrying/storing capacity of the ground.
xiii. Haphazard construction on hills, failure of embankments to check water flow when heavy rainfall occurs, aggravates the flood problem.
xiv. Changing the course of river in the name of development should be avoided strictly because it will only a damage stored for the future
xv. Participatory planning at every stage should be practiced towards floods mitigation where center and state works in coherence

VI. CONCLUSION

The study was an attempt to appraise the planning challenges and the implication of sponge city concept in managing urban floods in Kerala. This was done through analyzing the planning aspects using the literature study and case studies. Urban planning parameters are selected for formulating strategies that include identifying the mitigation measures for urban flooding, adopting the methodologies for evaluating the values associated with urban flood management, integrating the solutions can provide significant benefits beyond flood management and developing the agreed financial and policy mechanisms and models for realizing the values associated with Nature-based Solutions for Integrated Urban Flood Management.

One of the objectives was to study the concept and elements of sponge city and its role in urban flood management. This has been achieved through literature review in which need for sponge city and its benefits has been studied. Also learned about the sponge city implemented in China through different case studies.

Another objective was to study the flooding in Kerala, its causes & impacts and the resilience programs in Kerala to mitigate the flooding. This can be achieved by studying various reports related flooding in Kerala and reports of resilience program conferences held in Kerala. Flood vulnerable areas in Kerala has been identified by generating GIS maps and from the study we can conclude that low lying areas in Kerala faced severe flood due to overflow of rivers when the dams opened. Also, understand that most of the physical infrastructures were in bad condition, it may cause the waterlogging in urban areas. Encroachment of hazardous development is one of the reason for flooding. Based on the analysis of sponge city concept and flooding in Kerala and China, this study sorted out the planning strategies and guidelines for policies to reducing the flood vulnerability of river basins in Kerala.

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