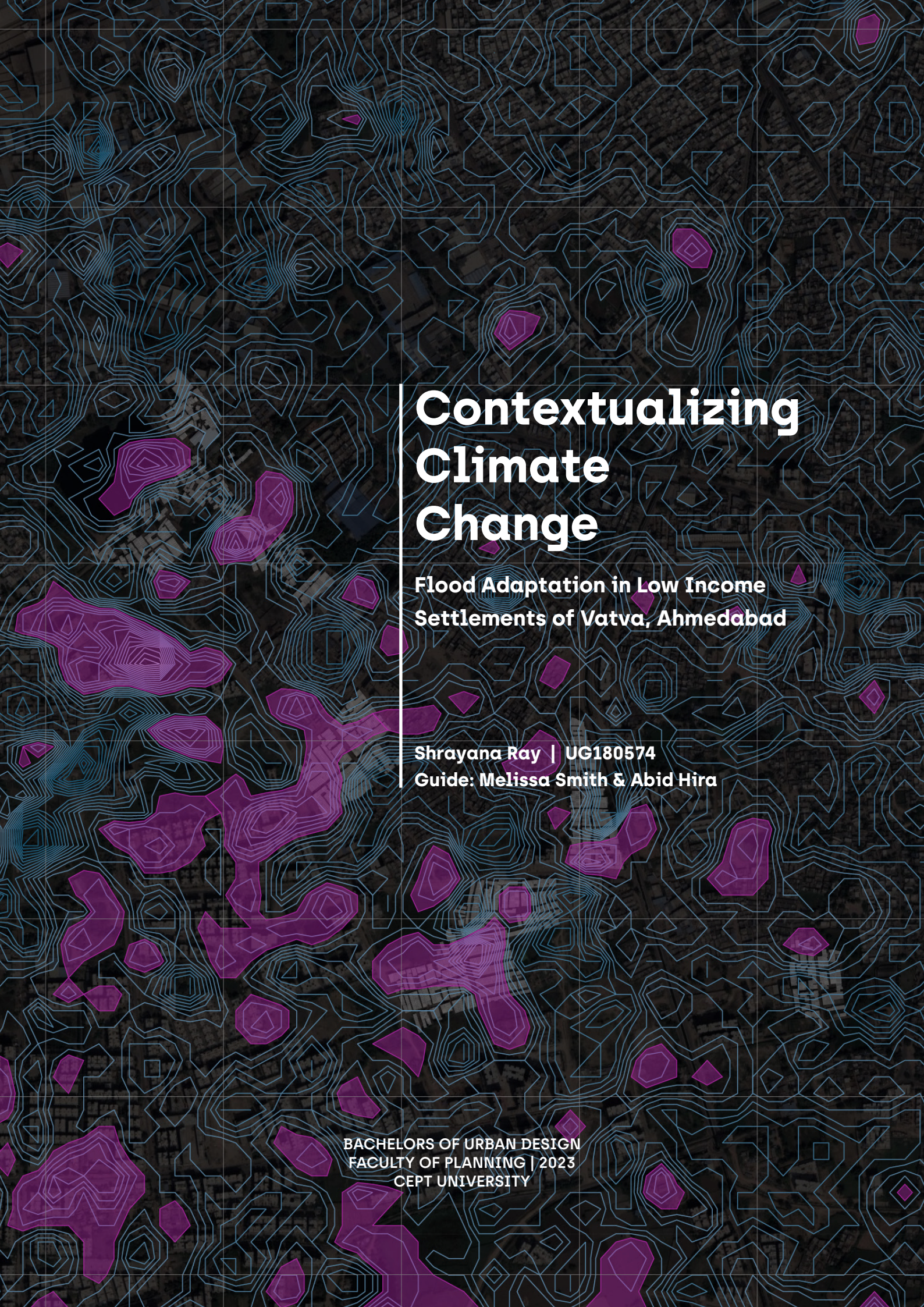

Contextualizing Climate Change

Flood Adaptation in Low Income Settlements of Vatva, Ahmedabad

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BACHELORS OF URBAN DESIGN
FACULTY OF PLANNING | 2023
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Contextualizing Climate Change :
Flood Adaptation in Low Income Settlements of Vatva, Ahmedabad

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2023

Ahmedabad, India

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Signature of Program Chair:

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Date: May 2023

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Abstract

The process of urbanization has created risks in relation to climatic variability, direct and indirect effects of climate change, as well as hazards. It is crucial to distinguish between these risks at a global level, but locally, responses to all environmental hazards and risks should be integrated. In case of Ahmedabad, a rapidly urbanizing city in India, four major climate change stressors namely; heat, water scarcity, flooding and water and vector borne diseases have been identified. People living in low-income settlements, especially in densely populated urban areas, are among the most vulnerable to the effects these stressors. This is an applied research which aims to investigate the existing flood adaptations in the low income settlements of Vatva, Ahmedabad; with the focus on understanding and evaluating the current practices and identifying the needs and gaps in the present scenario. A multistage sampling would be involved to zoom into the different levels of data collection, analysis and decision making. A total of six low income settlements would be studied so as to attain diverse perspectives to create a comparative study on the impacts of climate change. Semi structured interviews were conducted to determine that the specific climate stressor impacting widely in all the settlements is floods. Integrated assessment of both physical vulnerability as well as the socio-economic vulnerability is done to determine the most vulnerable groups and households. Household surveys were conducted to understand the overall dynamics of living conditions, the climate-related risks, the existing adaptation techniques to flood, and the coping mechanisms of the people. Furthermore, literature review and case studies are done to contextualize climate change, climate variability and the adaptation strategies used to cope with the floods globally. Based on the findings, this paper recommends suggestions on household level and communal adaptation strategies against floods for the settlements.

Keywords: climate change, stressors, vulnerability, flood, adaptation strategies

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1. Introduction and Background

1.1 Climate Change impact on the Urban Poor

Climate change is an extremely reported issue that has impacted people all around the world. The long-term shifts in temperature and weather patterns have resulted in an increase in extreme weather events, including heatwaves, storms, flooding, and droughts, contributing to climate variability (IPCC, 2018). Although climate variability has always transpired, but its frequency and intensity have largely been exacerbated due to climate change. India is a developing country that has a history of low per capita CO2 emissions yet it is urbanizing its way to match the target of the living standards that the developed countries have achieved. By 2050, it is projected that India will have added 416 million urban dwellers. (UN, 2018) This shift from rural to urban will result in land use changes, more energy demands, food production, and extreme consumption thereby stressing the increase in the effects of climate change. Projecting that climate change could be solved by the reduction of the emission of greenhouse gasses is inadequate and disconnected to the global crisis of increasing poverty or food insecurity. (Jaeger, Hasselmann, Leipold, Mangalagiu, & Tabara, 2012).

Populations with substantial economic and social challenges have a high vulnerability to climatic hazards even though their contribution to climate change is the least. Large amount of people live in low-income settlements with extremely poor living conditions, without

appropriate drainage, scarce water supply, inadequate sanitation, and lack of government support to withstand the impacts of climate change. The urban poor are the most vulnerable to the impacts of climate change and are least equipped to adapt to the changing conditions. Most of the disasters due to climate variability are recurring such that their rate of adaptation and their coping capacity is challenged. People living in the informal settlements which exposed to more frequently occurring low or moderate intensity of losses (such as floods due to heavy rain and poor streets and drainage infrastructure) suffer extensive risks of climate change. Thus, after coping from one disaster, another disaster hits the area before recovering fully such that it is a repeated cycle of disasters thereby, pushing them into even worse circumstances.

1.2 Climate Change overview of Ahmedabad

Ahmedabad is the largest city in Gujarat and is situated in a semi-arid region with a hot and dry climate. Ahmedabad receives rainfall from June through September, with a mean of 625 mm during the monsoon season, and an annual range of 95 to 235 mm. According to the Ahmedabad Heat Action Plan, the distribution of seasonal rainfall varies greatly. The number of rainy days in the district ranges from 5 to 14 days in July and August, and it gets more than 30 days of rainfall throughout the summer monsoon season. From the month of June and August, there has been a higher rainfall according to the data from 1951 to 2018.

Throughout the year, the highest mean temperature ranges from 30°C to 42°C, while the lowest mean temperature ranges from 10°C to 27°C. The summer months see a mean temperature between 35°C to 40°C, but the maximum temperatures of March, April, and May have shown an increasing trend in the past decade. There has also been a decrease in the mean percentages of cold days. The Ahmedabad Heat Action Plan projects future climate till 2090 using a multi-model mean (MMM) ensemble, predicting an increase in precipitation and rainy days. For medium emissions, there would be an 8% to 9% increase in precipitation and for higher emissions, an increase of 13% to 42% with a corresponding rise in temperature of 1.2°C to 2.4°C and 1.4°C to 4.5°C, respectively. This indicates that Ahmedabad's temperatures and precipitation are likely to increase in the future, leading to more frequent and intense climate disasters due to climate change.

Ahmedabad has four key climate stressors i.e. heat, flooding, water scarcity, and water and vector-borne diseases that have been identified through Global Resilience Partnership. The severity of climate stressors differs based on geographical location and socio-physical vulnerabilities. The impacts of these stressors will vary at the local neighborhood level, necessitating context specific responses with a holistic approach may work for addressing climate change, variability, and disasters.

1.3 Study Area: Vatva

Vatva is situated at the south zone of Ahmedabad. The land use in this area is predominantly residential, commercial, and industrial. In the 1940s and 1950s, as the Ahmedabad city's population and economy began to grow, industries started situating themselves at the rural parts of the Ahmedabad district. Under the Gujarat Industrial Development Act of 1962, the Vatva GIDC was established in the year of 1968. Soon people started migrating from different states of the country to this area searching for jobs related to industries. The AMC boundary expanded to Vatva GIDC area in 1986. The riots of 2002 led to an influx of migrants to this part of Ahmedabad, causing a surge in the population. This population growth led to the development of several commercial and residential projects in the area. In 2012, a new TP scheme was proposed for this locality, and since then, the area's development has been constant. Despite the development, Vatva still faces various socio-economic challenges. The area has a large number of low-income settlements that lack access to basic services and are vulnerable to the impacts of climate change.

SAATH Charitable Trust has been working on the Integrated Area Development plan of Vatva through a bottom up approach of progress implementation for the low income settlements. This research project would help them to achieve a detailed climate change area profiles for the sites. The DRP will entail the identification of strategies that will assist them in implementing the Integrated Area Development Plan effectively. Urban Resource Centre of SAATH Charitable Trust has been established at Vatva which is led and managed by communities. The Centre focuses on several critical sectors such as health, social infrastructure, local governance, identity documentation, gender sensitization, and awareness. The research study will focus on six low-income settlement sites, out of which five are located in Vatva, while the remaining one is situated in Narol. These areas were chosen on the basis of the socio-economic and physical vulnerability to climate change.

1.4 Site Overview

The six sites located within a maximum distance of 3.5 kilometres from each other offers an opportunity for comparative analysis.The close proximity of the sites facilitated data collection and comparisons, while also allowing for a better understanding of the area as a whole. An area leader has been appointed for each site by SAATH Charitable Trust who were also the key respondents for the semi structured interview as they were not only the residents but also had an in-depth overview of their areas. The following are the chosen sites:

1. Aziz Park
Site area : approx. 21,000 sqm
No. of households : 395 households

Ownership : private land
Average monthly household income : approx. 13,552.63 INR
The Kaircut Canal passes adjacently to the site which is highly polluted and people also tend to throw their garbage due to the irregularity in the garbage collection by AMC. People here are either daily wagers or vendors or unemployed. A lot of women earn irregular income through stonework on clothes. More than half of population are from Ahmedabad while the rest are migrants from Uttar Pradesh, Bihar, Maharashtra, and Karnataka seeking employment.

Fig 1: Map of Aziz park

2. Khwajanagar
Site area : approx. 47,000 sqm
No. of households : 1066 households
Ownership : Undefined - does not come under the town planning scheme
Average monthly household income : approx. 20,827.27 INR
Here most of the population has migrated from Uttar Pradesh in search of employment. The settlements has been primary built upon a water retention area therefore all the storm water of the locality tend to accumulate here thereby flooding the area.

3. New Baghe Kausar
Site area : approx. 25,000 sqm
No. of households : 570 households
Ownership : government land
Average monthly household income : approx. 14,966.67 INR
Here most of the population has migrated from Uttar Pradesh in search of employment.

Fig 2: Map of Khwajanagar

Fig 3: Map of New Baghe Kausar

4. Vanjara Vaas

Site area : approx. 57,455.43 sqm

No. of households : 735 households

Ownership : government land

Average monthly household income : approx. 14,966.67 INR

It is the only site situated in the Narol ward. It has Narol lake in its adjacent side and hence the whole settlement is built on the low lying area. Here most of the population are locals and rest of them have migrated from Uttar Pradesh in search of employment.

5. Chunara Vaas

Site area : approx. 13,000 sqm

No. of households : 177 households

Ownership : private land

Average monthly household income : approx. 12,736 INR

Most of the people are from Ahmedabad and others migrated from other districts of Gujarat.

6. Zia Masjid

Site area : approx. 9,500 sqm

No. of households : 216 households

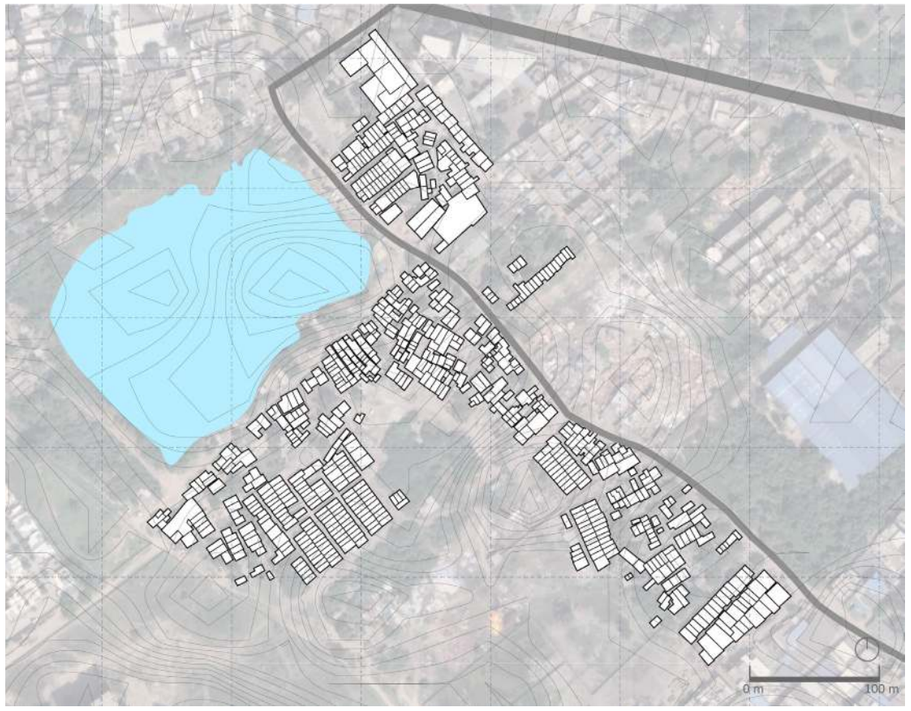


Fig 4: Map of Vanjaravaas

Ownership : private land
Average monthly household income : approx. 16,479.17 INR

Most of the built in this area has better conditions than other sites as people have already adapted to the waterlogging by increasing the plinth levels and constructing G+1 and G+2 houses. The population of the area is divided into people from Ahmedabad and also migrants who have come from Uttar Pradesh in search of better job opportunities.

Fig 5: Map of Chunaravaas

Fig 6: Map of Zia Masjid

1.5 Research Aim and Objective

The aim of the research is to understand the impacts of climate change and examine the current adaptations to flood in the low-income settlements of Vatva, Ahmedabad; with a focus on evaluating existing practices, identifying vulnerable groups and their needs, and proposing flood adaptation strategies.

The following are the four main objectives to be achieved through this research in a linear progressive flow:

1. To identify the specific climate stressor affecting the low income settlements of Vatva.

2. To identify the vulnerable groups and households to climate change across the different sites according to their adaptive capacity.

3. To analyse the existing flood adaptations that the vulnerable groups are using and their needs.

4. To provide recommendations for flood adaptation strategies.

2. Research Framework

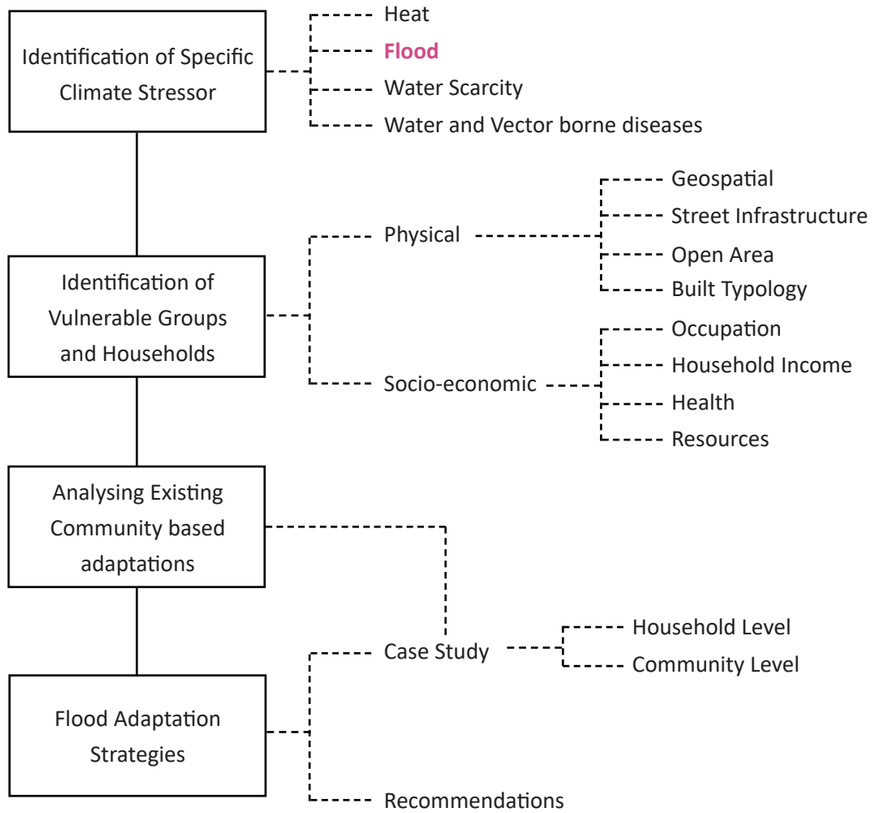
2.1 Methodology

The base of the research starts with literature review and data collection of weather and demography of the sites. First round of site visits were conducted for observation and to understand the living conditions of the people, the existing risks and hazards. The research methodology used semi-structured interviews to identify and isolate and finalize specific climate stressors affecting the population for further in-depth analysis. The research also examined individuals' coping mechanisms and adaptations to the identified stressor to gain an overview of the sites.

For the identification of the vulnerable groups and households, physical and socioeconomic vulnerability factors were mapped. In case of the physical vulnerability, GIS was used to obtain the topography and flow direction along with the water accumulation. Open spaces prone to waterlogging were identified. Street infrastructure such as drainage line mapping and manhole conditions were located through the data provided by SAATH Charitable Trust. Spatial typology study was conducted using photo documentation and Google Earth to identify and understand the vulnerability of different types of built structures across all sites. Household surveys were conducted based on the built typologies to map the socio-economic vulnerability of the sites and obtain data on existing flood adaptations used by vulnerable

groups, community and individual-level challenges, requirements, and actions taken for risk management. Further, to provide recommendations on the flood adaptation strategies, literature review and a set of case studies have been done to understand how low income settlement people living in the same climatic condition and flood risk areas are adapting to the climate stressors globally.

Considering the area, population size, and the vastness of the research topic, a multistage sampling approach was adopted. Identifying the specific climate stressor was the first level of sampling. This allowed for a more concentrated analysis and assured that the data gathered was relevant to the specific area of study. Conducting the household survey according to the typologies was the second level of sampling. Additionally, a range of 1:7 to 1:10 sample ratio of the number of surveys was taken to ensure that there is a homogenous collection of data from the population. In the second stage, stratified sampling was conducted such that the population of each sites were divided into different strata i.e. the built typologies and a proportionate number of households were selected from each stratum to ensure that the data collected was representative of the entire population. A total of 263 household surveys were conducted.



Areas	Surveys Conducted	Total number of households
Aziz Park	40	395
Khwajanagar	99	1066
New Baghe Kaushar	45	570
Vanzaravas	28	735
Chunaravas	27	177
Zia Masjid	24	216

Table 1: Surveys for each site

2.2 Scope and Limitation

This research holds significant importance as it lays down the fundamental groundwork for all forthcoming studies conducted by the SAATH Charitable Trust concerning the subject of climate change and community-based adaptations in the low-income settlements of Vatva. The outcomes of this research are pivotal in meeting the objectives of the Integrated Area Development Plan. It shall serve as a cornerstone in establishing an understanding of the challenges faced by the vulnerable communities to adapt to climate change and climate variability and also highlight the existing adaptation strategies and alarm the need for community level and household level development. This research holds particular significance as it provides a contextualized and applied study specific to Vatva. The case studies also present a compiled database for developing flood adaptation strategies for other regions with similar socio-economic and climatic conditions. Considering the vastness of the topic of climate change, it was only possible for this research to zoom into the flood adaptations at Vatva. There could be scope of research expected in the field of water scarcity and health for SAATH Charitable Trust in purpose of achieving a more holistic baseline of strategies which could rather be more efficient and cost effectiveDue to time constraints in the research project, only 2164 households out of 3164 households were mapped and identified. Therefore, the scope of this research and the sampling for household survey is limited to these households. Further research is required to obtain data on the unidentified households. The biggest limitation for this research project was the lack of accuracy of GIS data locations for the household surveys conducted through the 123Survey app by ArcGIS. Therefore, the household data collected from the areas are mapped in this paper as a representative of the whole site rather than just a household. This might also hold discrepancies in marking the locations of vulnerable houses.

3. Climate Change In Vatva

3.1 Climate change: Risks and Impacts

The semi structured interviews were conducted to understand the overall risks and impacts to climate change on the basis of each stressor.

2. Heat

Sites	Response/Impacts/Issues
Aziz Park	Coolers are the only available source of relief. They face health issues such as headache, low BP and rashes
Khwajanagar	Coolers are the only available source of relief.
New Baghe Kausar	People use fan and coolers during summer and look for shaded public spaces nearby if they don't have AC or cooler.
Vanjaravaas	Trees have been cut down therefore, there is no option to sit outdoors due to extreme heat thus, and people prefer staying indoors.
Chunara Vaas	Most people don't have AC or cooler, therefore, they prefer staying indoors or take shelter under tree during extreme heat.
Zia Masjid	In case of the houses with tin roof, the people attach white thermocol to the patra(roof) to decrease the heating.

Table 2: Impact of heat in Vatva

1. Water Scarcity

Sites	Water supply duration/ time	Water Quality	Issues
Aziz Park	2 hrs : 6am to 8am	Poor	During times of water infrastructure issue/ damage, water supply is lost for 2-3 days. The situation gets worse during summer. In time of scarcity, people buy water from private borewells. Certain households have installed water motors that further leads to uneven distribution.
Khwajanagar	2 hrs : 6am to 8am	Poor	If water is not provided in the morning, it's provided in the evening. Lot of households depend on private water supply and don't hold accountability on days when water is not supplied.
New Baghe Kausar	10 hrs: 6am to 4pm	Poor	During summer, the water flow is much less as compared to other seasons.
Vanjaravaas	6.30 to 7.30 or 8 am	Average	Water is not enough - insufficient flow.
Chunara Vaas	2 hours : 6am to 8am	Poor	Insufficient flow therefore people use motor.
Zia Masjid	1.5 hours daily for 15 days a month	Average	Insufficient water supply.

Table 3: Impacts of water scarcity in Vatva

4. Vector borne or water borne diseases

Sites	Response/Impacts/Issues
Aziz Park	During monsoon people suffer from water and vector borne diseases such as dengue, malaria, diarrhoea etc.
Khwajanagar	During monsoon people suffer from water and vector borne diseases such as dengue, malaria, etc., and this is the most pressing issue.
New Baghe Kausar	People here mostly suffer from mosquito borne disease, fever, cold and some have pre-existing health conditions.
Vanjaravaas	There is issue with garbage disposal especially during monsoon therefore diseases spread such as vector borne diseases, fever and cold.
Chunara Vaas	During monsoons, people suffer from vector-borne diseases such as dengue and malaria. The streets get muddy due to which the mosquitoes and flies increase. Fainting, nausea, and stomach-related issues are common in the area.
Zia Masjid	Mosquito borne diseases are more prevalent during monsoon. The AMC spray mosquito repellent smoke.

Table 4: Impacts of vector and water borne diseases in Vatva

3. Flood

Sites	Response/Impacts/Issues
Aziz Park	The houses are flooded during monsoons as they are below street level and lack proper infrastructure. The roads are water logged making it difficult to move around. When mobility is hampered, people lose access to resources, experience a hike in prices of everyday goods and daily labourers they lose their income. Houses with chula cannot cook during these periods and the water and food stored doesn't necessarily suffice. Forced to change their everyday and food habits.
Khwajanagar	The houses are flooded during monsoons as they are below street level and lack proper infrastructure. The roads are water logged making it difficult to move around. Latrine water overflows and fills up in the homes. The roads are water logged making it difficult to move around. When mobility is hampered, people lose access to resources, experience a hike in prices of everyday goods and daily labourers they lose their income. Forced to change their everyday and food habits. The G+1 home owners shift to the upper floors while some others temporarily or permanently shift from the settlement. Illnesses and injuries increase, and ambulances struggle to reach houses.
New Baghe Kausar	The streets get filled with water but the water doesn't enter the houses that much during the rainy season. Since there is no proper street infrastructure, during water logging, the people get pressure lines to push water to the gutter. It takes around 8-10 days for the waterlogging to subside. Vehicles can't enter inner streets, forcing people to wade for work.
Vanjaravaas	The water accumulates inside the homes in case of heavy rainfall. Complaints filed at AMC for proper road infrastructure, but no action taken. Difficulty to access resources during water logging At the edge of the lake, the runoff water fills and causes streets to flood. The dumped garbage on the streets float and enter the households. There is one person appointed to fix the local street gutter lines during rain.
Chunara Vaas	The houses are flooded during monsoon and the streets are waterlogged. The mud on the street causes injury to the pedestrians. There is no food or shop available inside the settlements.
Zia Masjid	Water from the bathroom gutter overflows and fills inside the houses as there is no street infrastructure for proper gutter lines. In the low level houses, flood water flows in. In such a case, there is no evacuation plan but the people shift their belongings to their neighbour's house.

Table 5: Impact of flood in Vatva

3.2 Stressor Identification

On the basis of the interviews, it was perceived that floods as a stressor affect the people most due to its subsequent effect on the built structural loss, livelihoods, health and occupation of the people. It should be addressed as a priority as the loss and damage incurred by the people is also difficult to repent as the income is very low. Floods were the one stressor which is a short term risk with a long term damage. According to the household surveys the people of these settlements prioritize heat and flood as the most critical stressor that they have been impacted by. **Therefore, this study focuses on impact and flood adaptations.**

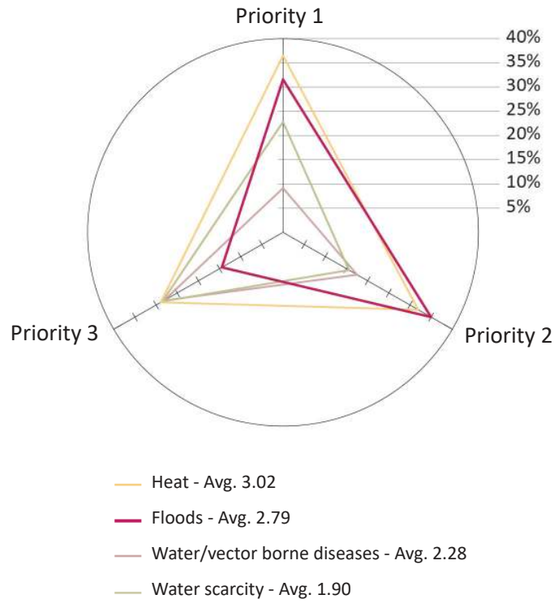


Fig 7: Order of Climate Change Stressor that affect people the most

4. Floods and Water Logging

4.1 Physical Vulnerability

The identification of the impact of floods on the low income settlements, necessitates the analysis of the amount of exposure that the people are experiencing. Physical vulnerability looks into the level of exposure and the sensitivity to the impacts of the hazards determined by physicality of the vulnerable groups. (Brooks, 2003) In case of the physical vulnerability identification, the analysis focuses more on the state of the system before the occurrence of flood. The data is mapped on the basis of household surveys, observation and the photo documentation conducted during the study. The physical vulnerability would give a key on how spatially a person is vulnerable to the risks of floods. It is categorised into three studies namely topography a geospatial, street infrastructure and built typology study.

4.1.1 Geospatial

This analysis maps out the physical vulnerability of the households according to their location. The first set of maps have been produced through GIS showing geospatial data for each site. The contours are generated which gives a sense of the location of low lying areas. Up to 40 meters of elevation, the flood water accumulate and during intense rainfall, the flood level could go higher.

Due to the presence of built, there is also water logging at the adjacent open spaces. The flow direction has been obtained through the accumulation data by processing the digital elevation model of each site. All these layers as an overlap enables us to analyze each site's condition. Fig. 8, Fig. 9, Fig. 10, Fig. 11, Fig. 12, Fig. 13, show the flood maps of the six sites.

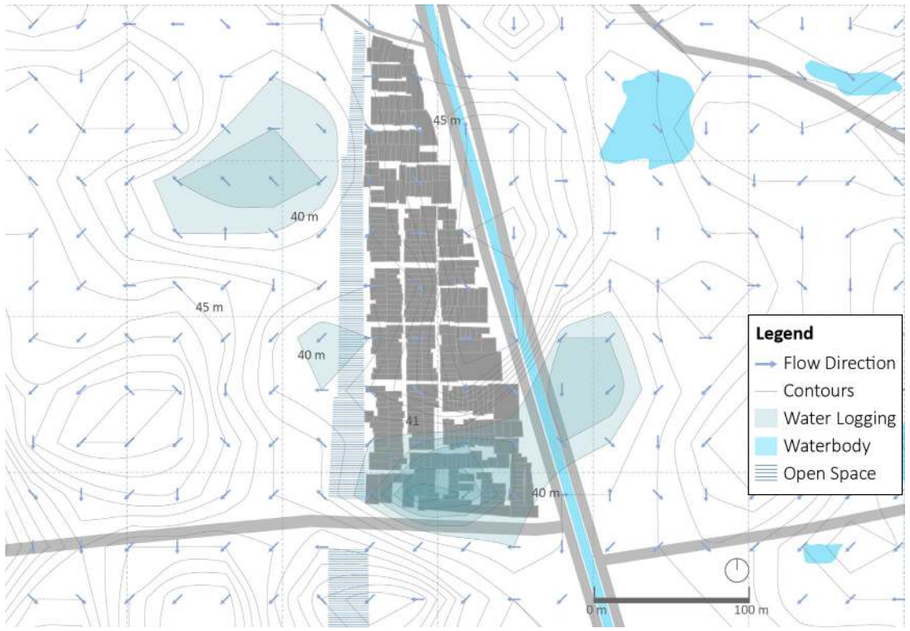


Fig 8: Flood map of Aziz Park

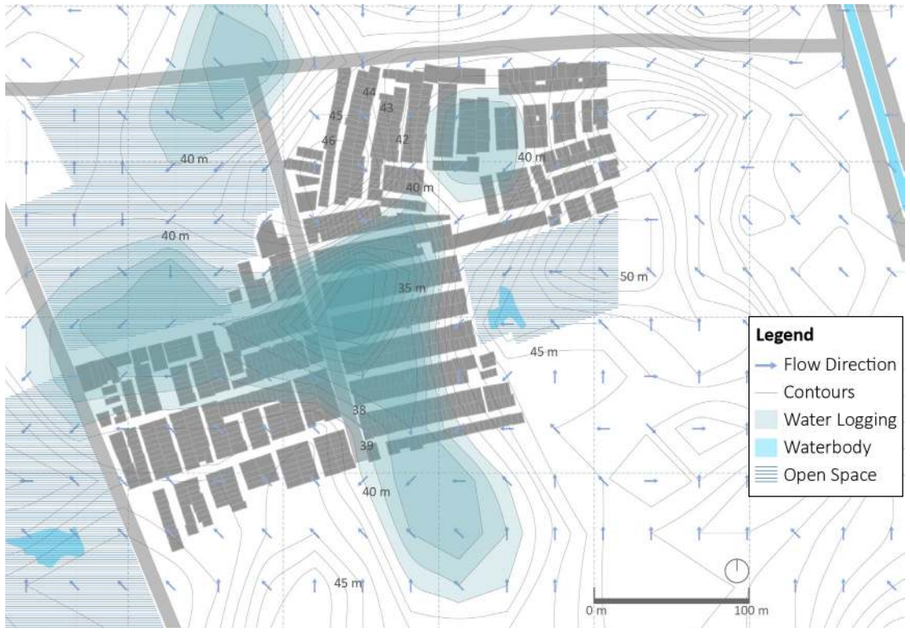


Fig 9: Flood map of Khwajanagar

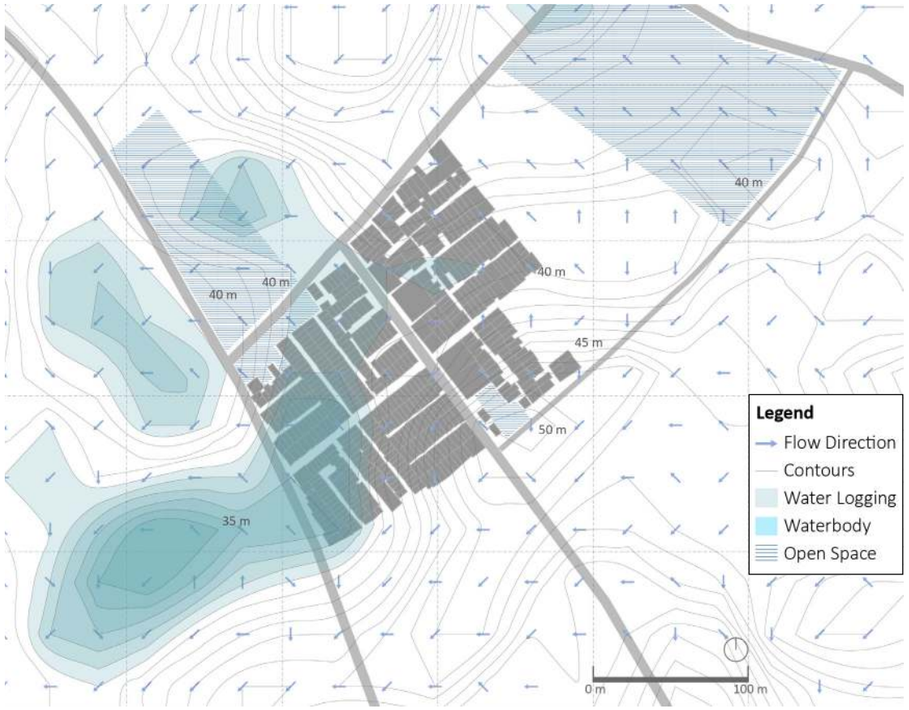


Fig 10: Flood map of New Baghe Kausar

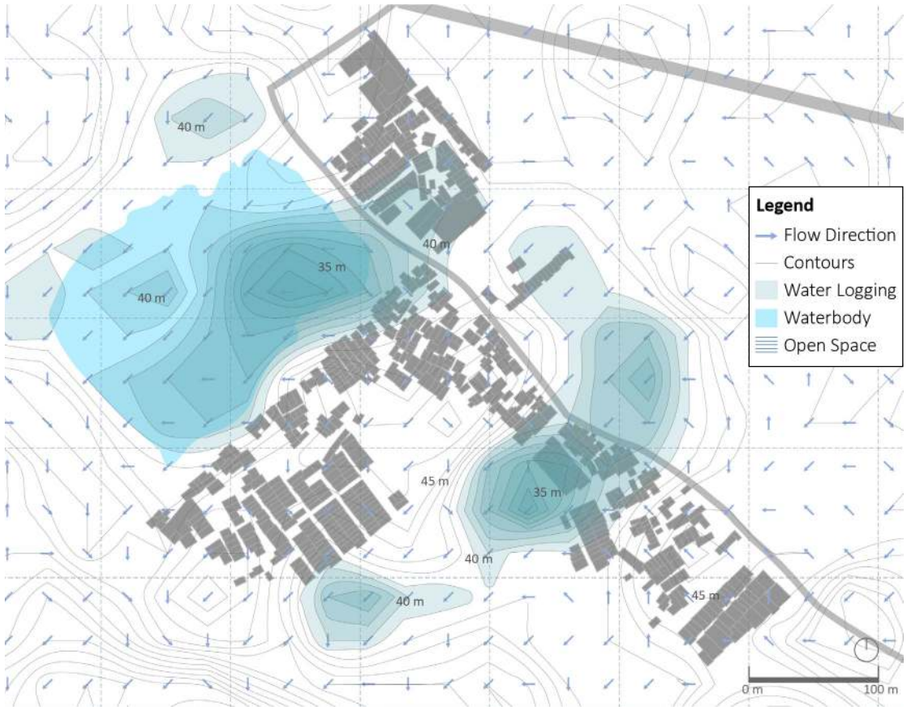


Fig 11: Flood map of Vanjaravaas

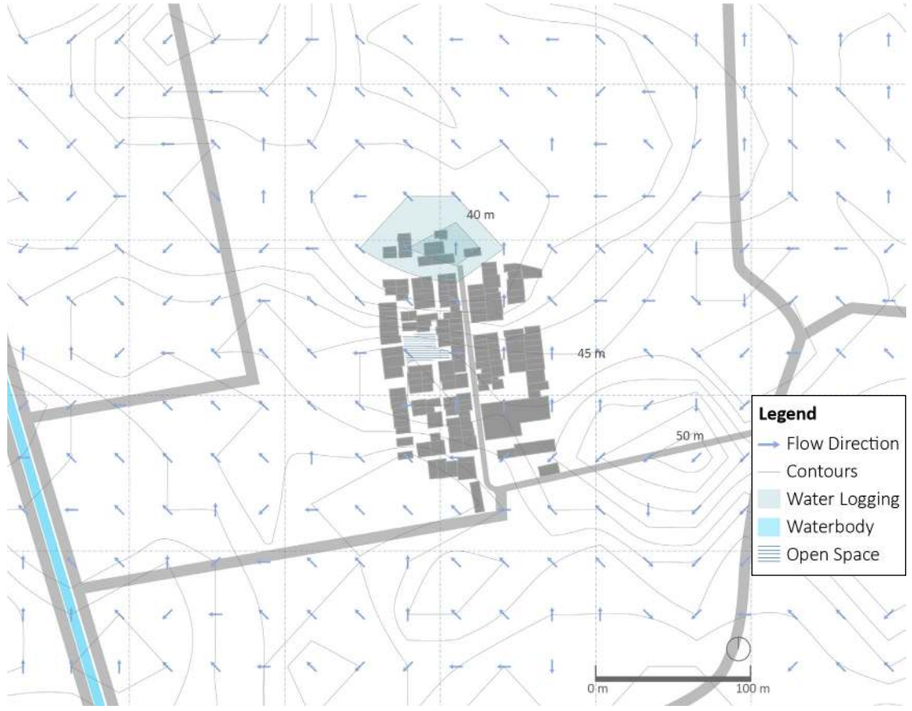


Fig 12: Flood map of Chunaravaas

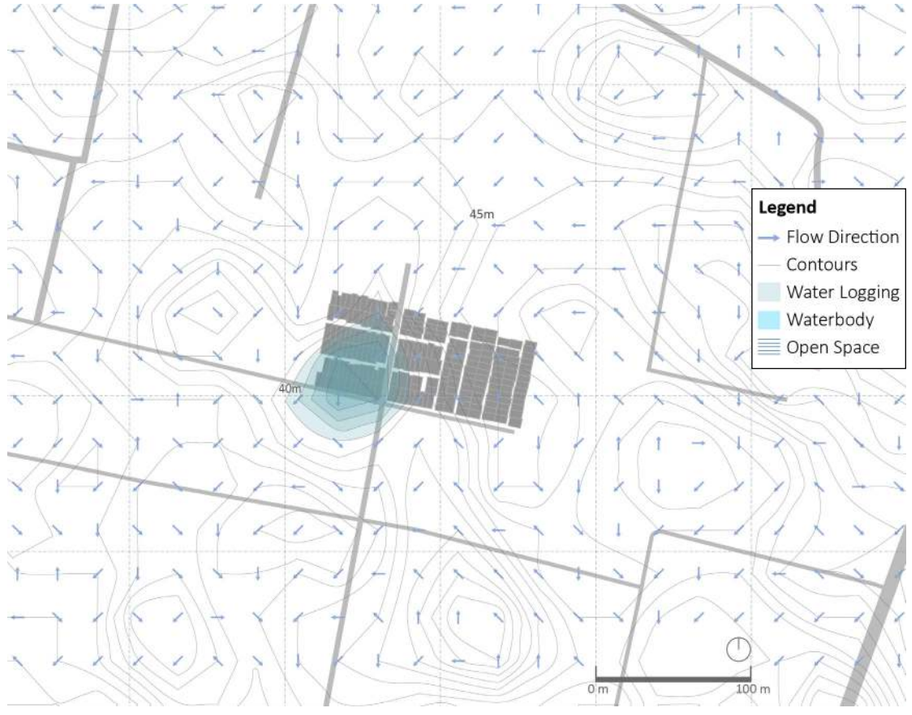


Fig 13: Flood map of Zia Masjid

The settlement's vulnerability has been marked accordingly and thus, the second set of maps have been generated highlighting the extremely vulnerable households at each site. Fig. 14, Fig. 15, Fig. 16, Fig. 17, Fig. 18, Fig. 19 show the vulnerable households of the six sites.

Fig 14: Vulnerable households of Aziz Park

Fig 16: Vulnerable households of New Baghe Kausar

Fig 18: Vulnerable households of Chunaravaas

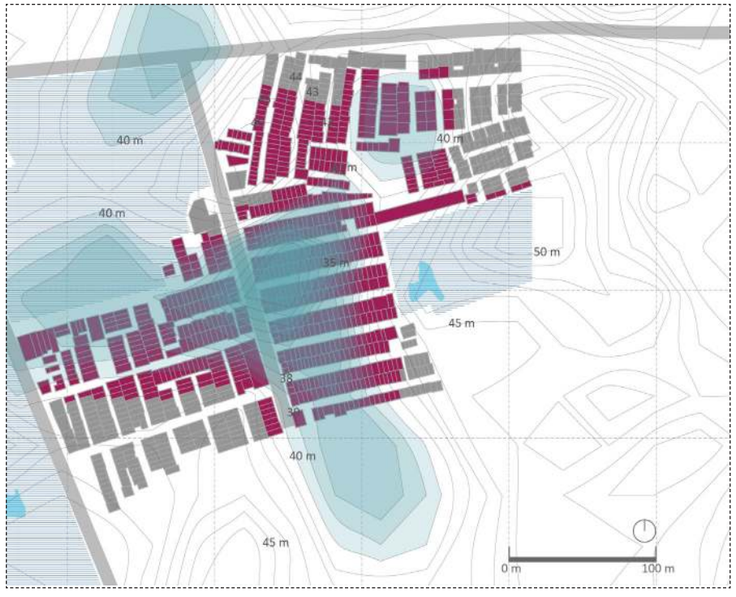


Fig 15: Vulnerable households of Khwajanagar

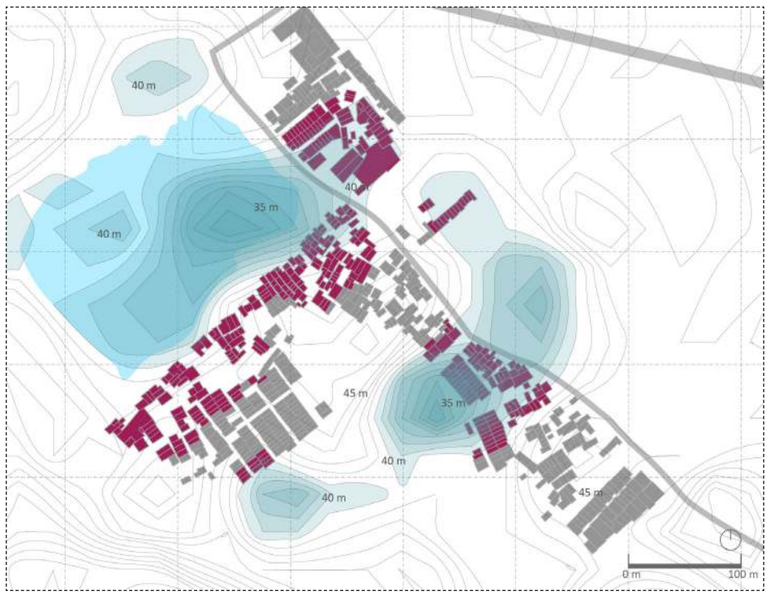


Fig 17: Vulnerable households of Vanjaravaas

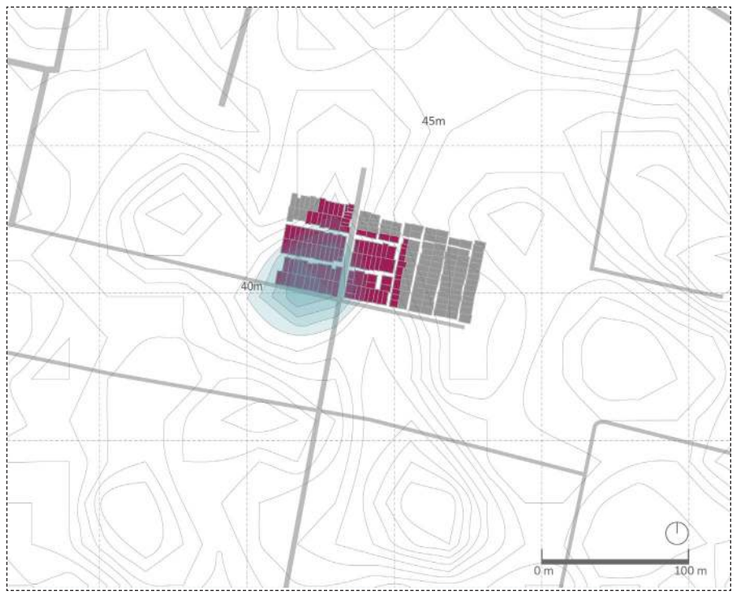


Fig 19: Vulnerable households of Zia Masjid

Legend

Contours
Water Logging
Waterbody
Open Space
Vulnerable Households

On ward level, the areas prone to waterlogging have been highlighted in Fig 19. It has been observed that all of the chosen sites are prone to waterlogging according to them being in a low lying areas. The pie charts have been generated according to surveys showing the maximum water level that the people experience during foods. These have been classified according to ankle level i.e. 10cm to 20cm, knee level i.e. 45cm to 55cm and waist level i.e. 85cm to 95cm.

In the following drawing, the size of pie charts is equivalent to the number of household surveys conducted in that specific areas. According to the chars, it is evident that chunara vaas has the highest amount of waist level water percentage. This could be because of the presence of low lying patch of land in the site. Additionally, vanjaravaas and khwajanagar have high responses of knee level water due to the site's presence in front of a lake and on existing water body respectively.

Fig 20: Flood Level Mapping of Vatva

4.1.2 Street Infrastructure

The maps in Fig 20,Fig 21, Fig 22, Fig 23, Fig 24, Fig 25 locate the drainage line and the condition of the manholes of all sites. It is evident from it that Zia Masjid is the most vulnerable site of all due to the large number of overflowing manholes. Chunara vaas and New baghe kausar are also vulnerable due to the manhole condition. This issue will hamper the drainage of the flood water and cause significant duration of water logging.

Fig 21: Infrastructure map of Aziz Park

Fig 23: Infrastructure map of New Baghe Kausar

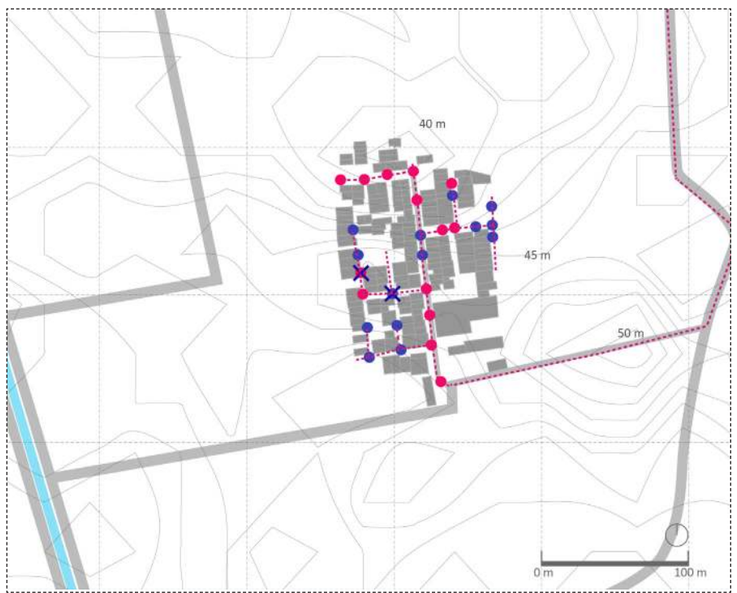


Fig 25: Infrastructure map of Chunaravaas

Fig 22: Infrastructure map of Khwajanagar

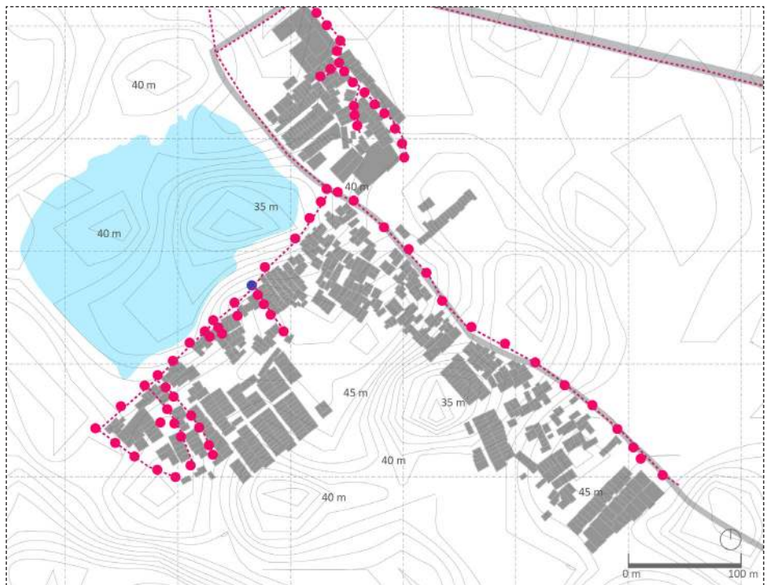


Fig 24: Infrastructure map of Vanjaravaas

Fig 26: Infrastructure map of Zia Masjid

Legend

Contours
Drainage Line
Closed Manhole
Overflowing Manhole
Open Manhole
Broken Manhole
Waterbody

4.1.3 Built Typology Study

The built typology study has been conducted for all the sites and several typology categories have been derived differentiating each on the basis of house elevation level, presence of plinth, roof material, built height, and toilet access. Since the sites are low income settlements, maximum houses i.e. 54.75% are semi pukka, 44.11% are pukka and 1.14% are kuccha houses. These are segregated into 3 types according to the building use i.e. residential, commercial and live-work (Fig 26). For the research, only residential typologies have been studied in-depth for understanding the flood-adaptations.

1. Residential

Typology	Level	Roof Material	Toilet Access	Jaali
R1 (G)	Below Street Level	Tin/G.I/ metal sheet	Outside	Present
R2 (G)	Below Street Level	Tin/G.I/ metal sheet	Adjacent	Present
R3.1 (G)	Above Street Level	Tin/G.I/ metal sheet	Inside	Present
R3.2 (G)	Below Street Level	Tin/G.I/ metal sheet	Inside	Present
R4 (G)	Above Street Level	Concrete	Inside	Present
R7.1 (G+1)	Above Street Level	Concrete	Inside	Absent
R7.2 (G+1)	On Street Level	Concrete	Inside	Present
R8 (G)	On Street Level	Plastic/G.I. Sheet	Outside	Absent
R9 (G+2)	Above Street Level	Concrete	Inside	Absent

Table 6: Residential typologies

2. Live Work

Typology	Level	Roof Material
LW1 (G)	Below Street Level	Tin/G.I/ metal sheet
LW2 (G)	Above Street Level	Concrete
LW3 (G+1)	Above Street Level	Concrete
LW4 (G+2)	Above Street Level	Concrete

Table 7: Live work typologies

3. Commercial

Typology	Level	Roof Material
C1 (G)	Above Street Level	Tin/G.I/ metal sheet
C2 (G)	Above Street Level	Concrete

Table 8: Commercial typologies

Fig 28, Fig 29, Fig 30, Fig 31, Fig 32, Fig 33 show the mapping of the identified built typologies of each site. The built typologies which are below street level and on street are the most vulnerable to flood. Additionally, the typologies with Tin/G.I/ metal sheet roof are vulnerable because of the leakage and damage incurred. Typologies with jaali as well as Tin/G.I/ metal sheet roof also have bricks over the roof for extra stability. All of the sites except Zia masjid have more G floor building height that G+1. Almost 69.2% households are prone to water entering the houses when the streets are waterlogged because 49.05% of houses are on street level whereas, 20.15% houses are below street level.

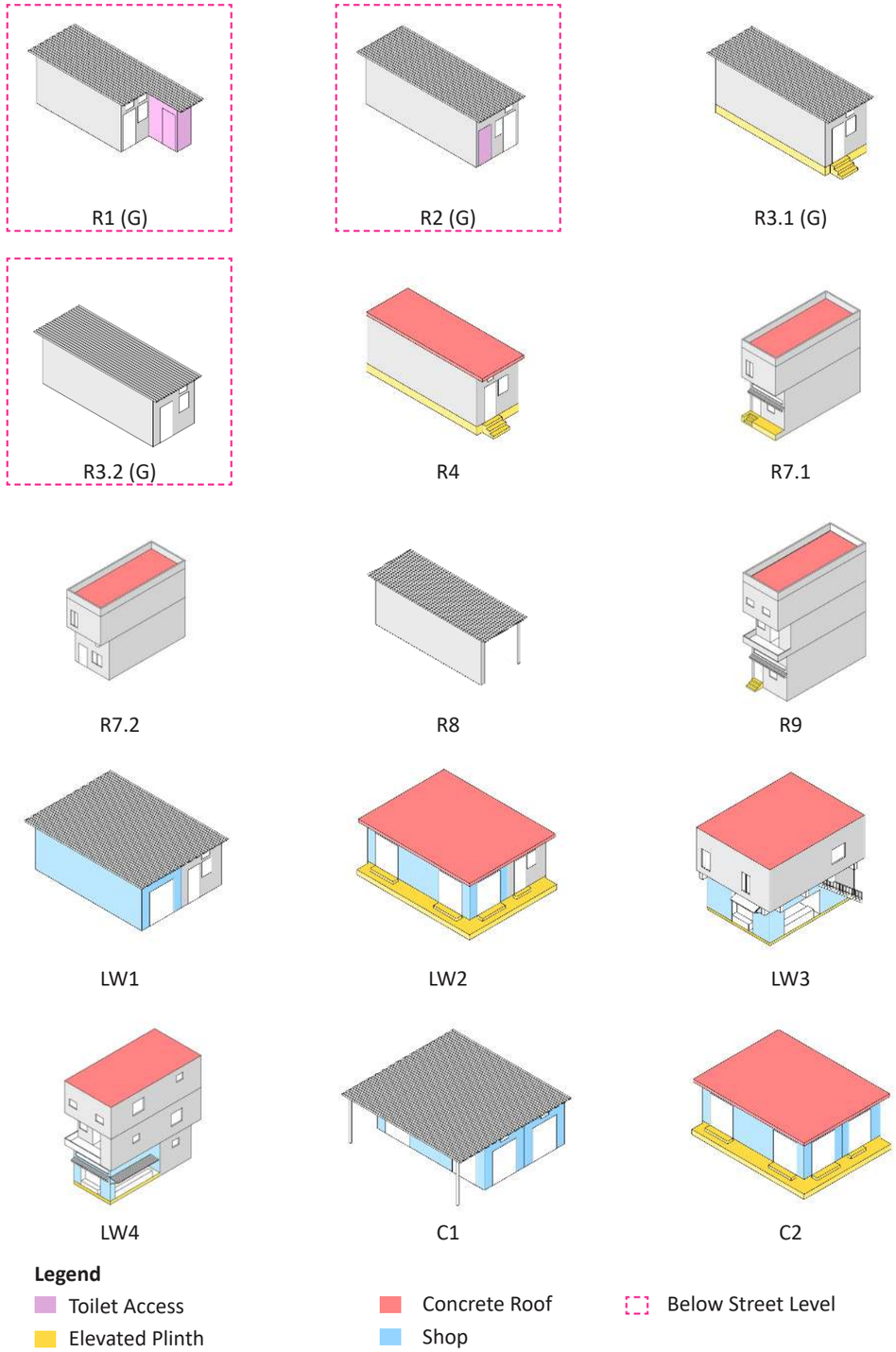


Fig 27: Built Typologies

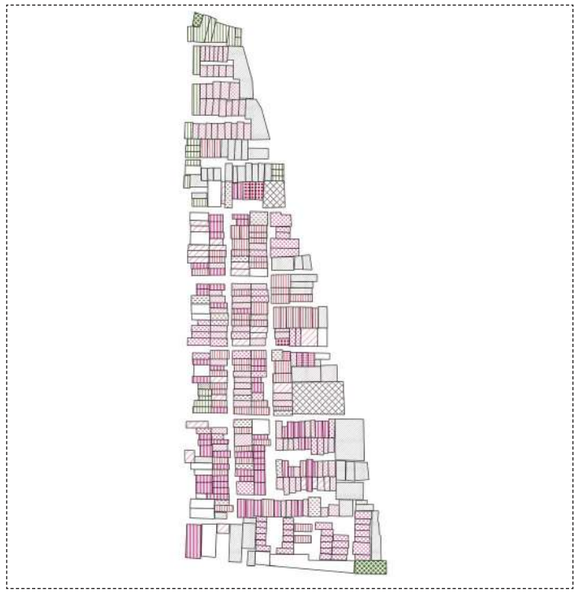


Fig 28: Typology map of Aziz Park

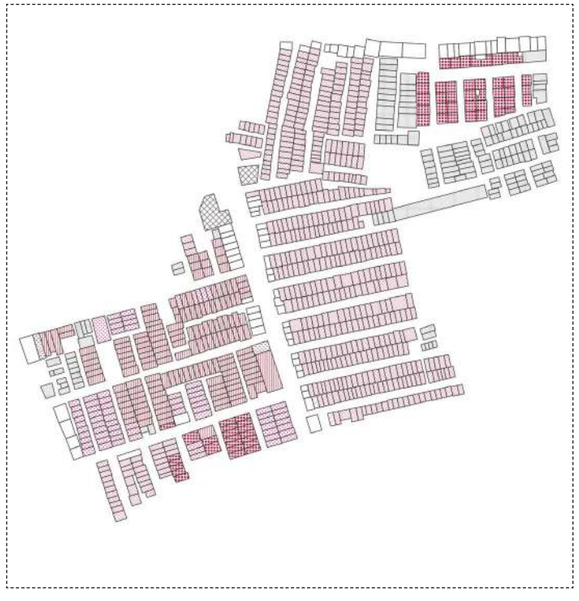


Fig 29: Typology map of Khwajanagar

Fig 30: Typology map of New Baghe Kausar

Fig 31: Typology map of Vanjaravaas

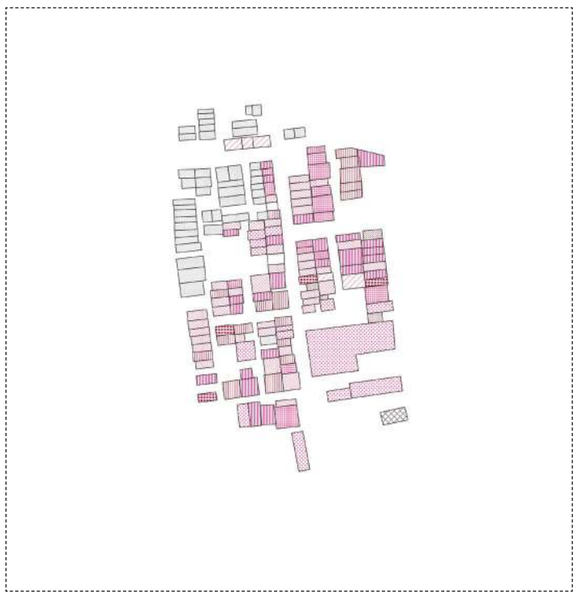


Fig 32: Typology map of Chunaravaas

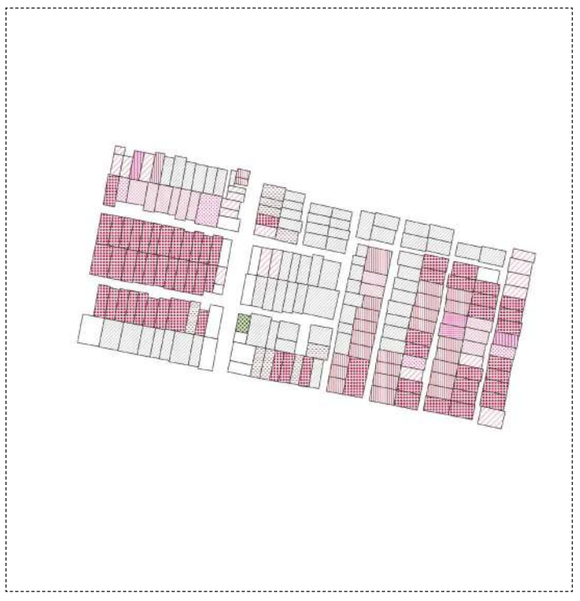


Fig 33: Typology map of Zia Masjid

Legend

Residential - G
- R1
- R2
- R3.1
- R3.2
- R4
- R8

Residential - G+1
- R7.1
- R7.2

Residential - G+2
- R9

Live work
- LW1
- LW2
- LW3
- LW4

Commercial
- C1
- C2

- Institutional/ Religious
- Unidentified

4.2 Socio-Economic Vulnerability

The socio-economic vulnerability categories determines the intensity of the hazard affecting the people based on their coping capacity. This is generally perceived as the ability of the system to adapt and cope with the hazards. This research analyses the occupation, income, work day loss, and health and resource access of the settlements. There is possibility for these factors could also determine hazards which are not even related to floods.

4.2.1 Occupation and Household Income

All of the sites are low income settlements and house large densities of people with common occupations as daily wage laborers, informal vendors, shopkeepers, auto drivers, tailors and embroiders. The average household income of each site has already been mention in the previous chapters of the paper. On accumulating data of all the sites, the average monthly income is 10,138.68 INR.

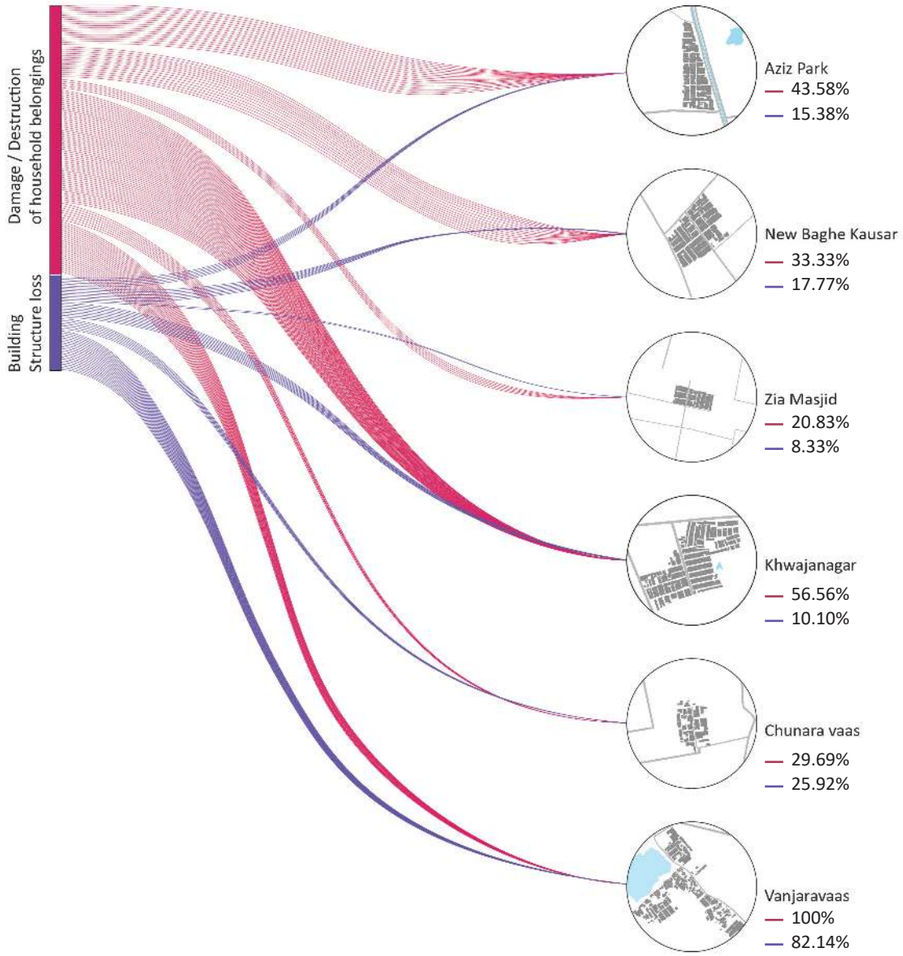


Fig 34: Impacts of flood

On the basis of the interviews, the household income is so low that there are no savings left for any expenses other than food and groceries. Additionally, almost half of the working population travels more than 40min minutes for work. 48.67% of the household survey respondents have migrated to the sites in search of employments yet a lot of the people are unemployed. During the flood and water logging, the streets are submerged and on an average, it take 7.7 days for the flood water to subside. This directly affects the income of the people. Almost 50.19% of people suffer economically from loss of work days during these times. In such a scenario, due to floods people also experience damage and even destruction of the household objects such as electric appliances, furniture, cutlery etc. Total 49.43% people face damage or destruction of household belongings (Fig 33) . Additionally, 21.67% people face housing structural loss of an average of 4080 INR. This situation makes the people economically extremely vulnerable during these times.

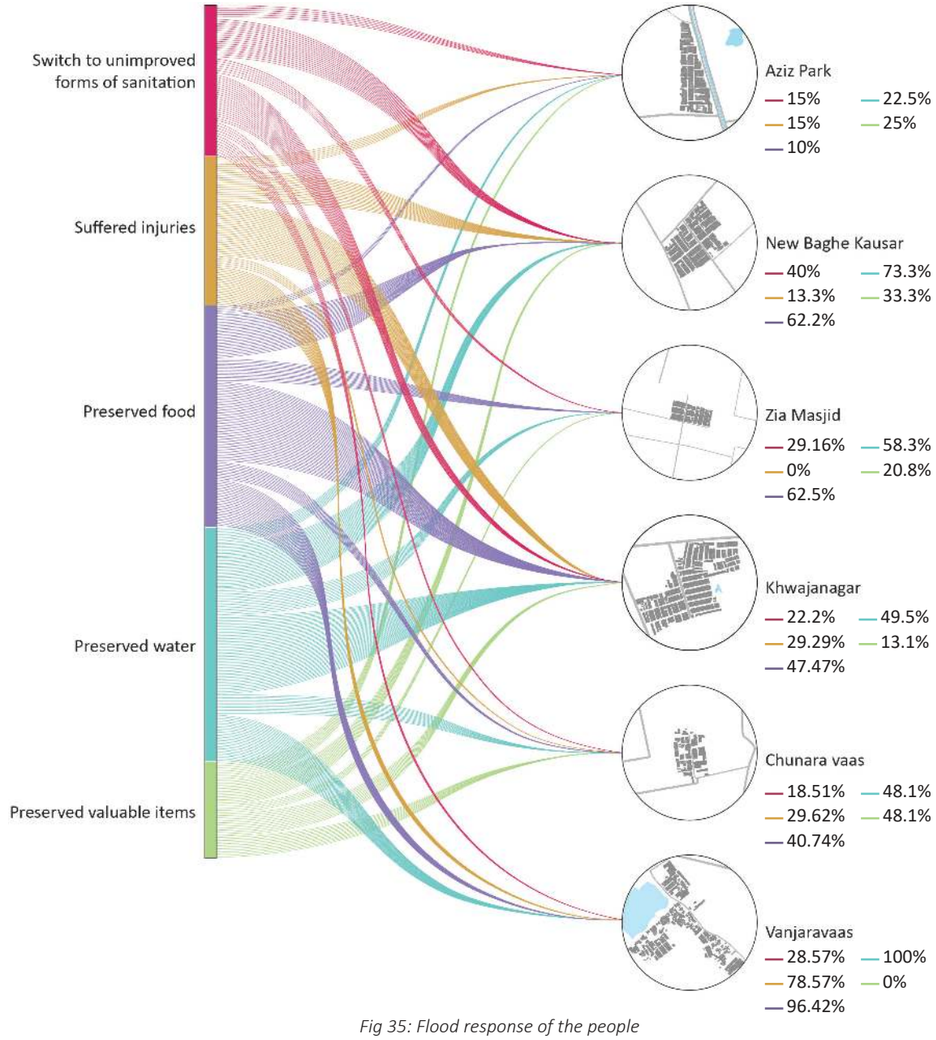


Fig 35: Flood response of the people

4.2.2 Health and Resources

At the time of floods, it is necessary for the people to get timely treatment as they are prone to water and vector borne diseases as well as injuries. Fig. 35 shows the different healthcare centres that people access and their distances from each site on the basis of household surveys. Receiving immediate treatment as well as the preparedness of the people defines the level of vulnerability of the people. 27.76% of the people were unable to seek necessary medical care during such hazards and 95.82% of people don't even receive any aid from the government or any local organization.
Fig 34 shows the flood response of the people due to the impacts of the hazard.

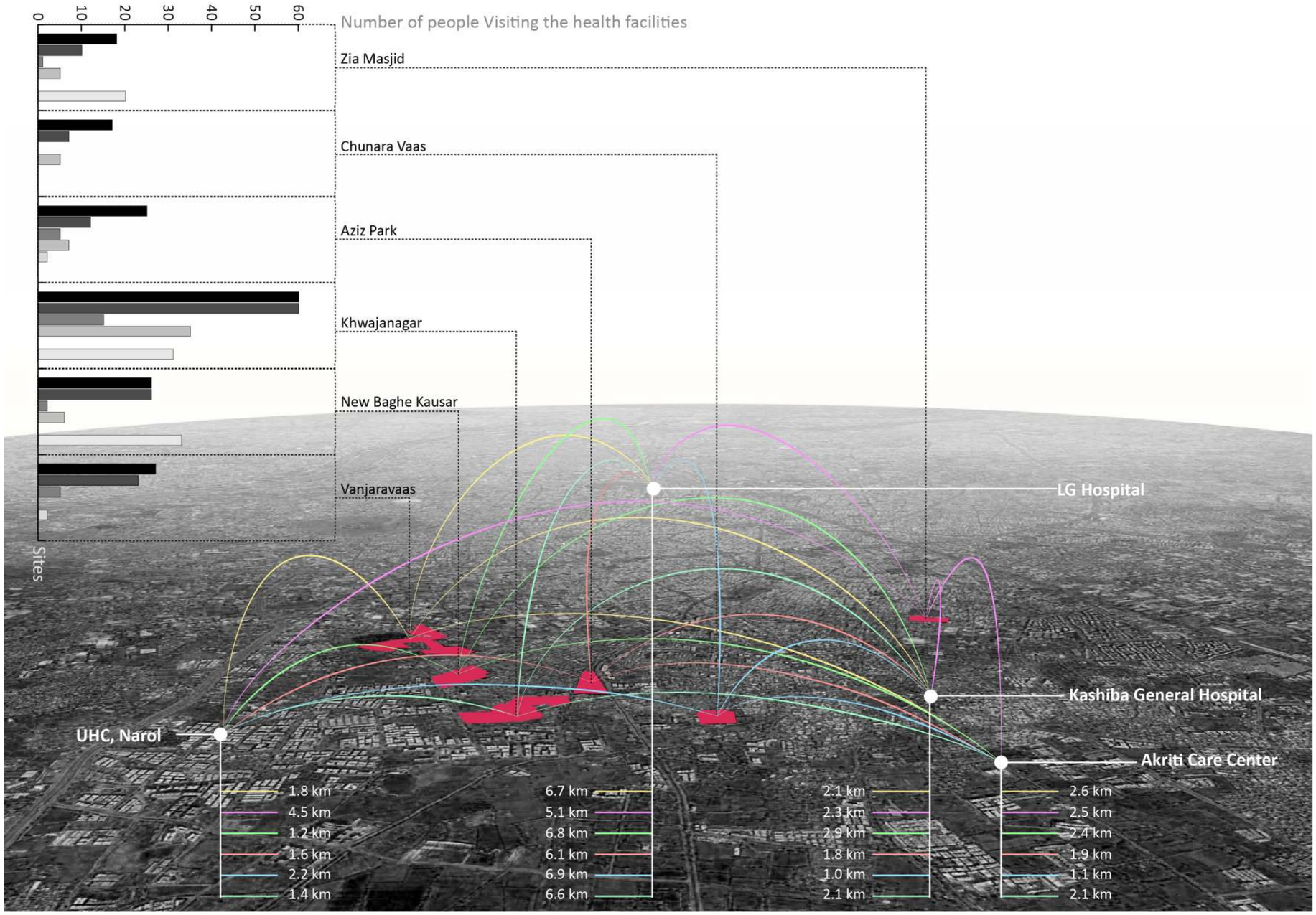


Fig 36: Healthcare Access

5. Adaptation

5.1 Community Based Adaptations

Community Based Adaptations (CBA) are integrated approaches that involve participatory decision making, disaster risk reduction and community development work (Dorsyth, 2009). This type of adaptation is a bottom up process to deal with the vulnerabilities to the risks and hazards due to the impacts of climate variability and climate change. It is in itself a community led process where the adaptation strategies could be implemented along with the help of an NGO in most of the scenarios. Community based adaptation to climate change appropriates itself on the priorities and needs of the community as well as builds upon their existing knowledge and ability to cope climate change (Haque, Dodman, & Hossain, 2014). Learning from the existing framework of informal makeshifts on the grounds of temporal damage control is the most efficient way to build upon the strategies and introduce newer ideas and empower the communities as well. Communities experiencing significant impacts resulting from short-term climate variability are likely to respond positively to start pursuing disaster risk reduction at the beginning (Christian Aid, 2009).

Adaptations should be looked into as a bigger umbrella where the primary goal to be achieved is resilience against climate change. Yet, it must also consider the existing livelihood scenario and work accordingly to give the communities a holistic benefit. CBA should also be

implemented such that along with it addressing the current risks of climate variability, it should cater to the future needs posed by climate change as well. The concept of CBA places a significant emphasis on the development of skills and knowledge at the grassroots level, through various training and capacity-building initiatives. These efforts aim to empower individuals and communities to take charge of their own growth and progress, while also fostering a culture of continuous learning and improvement.

There has been a surge in the availability of literature on community based adaptations in developing nations. This approach encompasses a range of strategies, from household-level to communal and institutional levels, to effectively facilitate a ripple effect of behavioral change and learning. Commencing with the implementation of such strategies at an individual household level, the positive impact of these measures should spread to the surrounding street and eventually, to the entire community. Such an integrated approach to adaptation can ensure that the wider population is equipped with the necessary knowledge and skills to confront climate change challenges head-on, and foster a more resilient and sustainable future for generations to come.

5.2 Current Adaptation strategies in Vatva

Community-based adaptation can provide effective approach to building resilience and reducing the vulnerability of low-income settlements in Vatva. The fact that some of the adaptations are skill based, the people could be trained accordingly. Since the process requires a high degree of user participation, the people would be kept informed on the status of financial flows status by government agencies (if any) or the NGO. Through careful observation and engagement with the communities in Vatva, it was discovered that many individuals were hesitant to provide any information during surveys owing to the ignorance and lack of development initiatives undertaken by the government or any organization, even after repeated complaints and concerns were raised. Therefore, in a way community based adaptations could be a viable approach to also convince people in restoring their trust onto the NGOs and CBOs which are interested in working for the welfare of the community.

The informal settlements located in Vatva exhibit a notable heterogeneity of vulnerable groups, with each group encountering diverse challenges that vary not just across various sites, but also within a single locality. As such, the adoption of adaptation strategies should be tailored to the specific needs of each group. Therefore, the types of adaptation strategies should vary according to the distinct needs of specific groups. On the contrary, certain groups of people while developing skills and working together on the different kind of strategies would ultimately develop a sense of community within themselves which is especially crucial during risk management at the time of floods. Hence, in designing and implementing intervention programs, it is crucial to consider the diversity of vulnerable groups within informal settlements, while fostering community-driven approaches that encourage the collective

development of adaptation strategies. The social and infrastructural challenges that impede the community's ability to cope with floods should be addressed as part of the overall strategy. By doing so, interventions can effectively tackle the multifaceted challenges of informal settlements, fostering long-term resilience and adaptive capacity. Community based adaptations have the prominent feature of adhering to the context of the scenario since it is a grassroot level approach. Keeping that in mind, while suggesting flood adaptation strategies for the sites, it is also necessary to look into the existing adaptations that are being done in the site to cope so as to build upon newer strategies. Furthermore, flood adaptation strategies taken up globally by the people living in low income settlements in similar climatic condition with yearly experience of flood adversities should be analyzed. By leveraging this dual approach, intervention programs can benefit from the local knowledge and experience while also incorporating successful strategies and techniques from similar settings. This can facilitate the implementation of flood adaptation strategies that not only address the unique needs of each community but also contribute to building a body of knowledge and best practices for informal settlement flood adaptation more broadly.

According to the household surveys, out of 263 responses it was found that only 33.08% households have implemented household level strategies or done any sort of structural modifications in their house to cope with the adversities of flood.

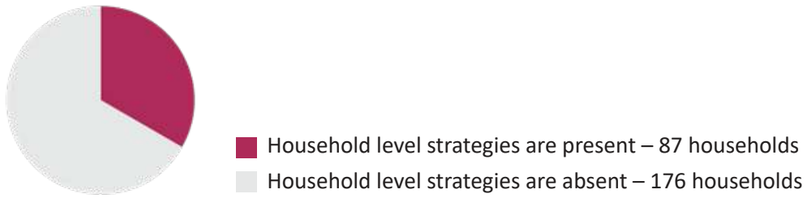


Fig 37: Household implementation of strategies

Out of the 33.08% people the following are the most common adaptation strategies and Fig 37 shows an example of how the flood adaptation strategies are implemented in one household :

1. Rebuilt their house on plinth and the height of the plinth varies from house to house due to the uneven street height and slope.

2. In order to prevent water from entering their homes, some people resort to the construction of temporary brick structures or stacking of stones. In certain cases, rags have been placed at the entrance, but water still manages to seep in.

3. Built low retention wall either in the entrance of the house or in the entrance of their bedrooms so that even if the water overflows inside the house, the inner room is protected. Also, in case of houses which are below street level, if the retention walls are built at the main entrance, it gets difficult for the kids or elderly to enter the house and end up getting injuries.

4. Some people have taken measures to elevate the fronts of their houses or courtyards, or even constructed otlas, in order to prevent water from entering the premises. Such spaces also serve as semi-public areas that encourage neighborhood interaction.

5. If the roofs are made of metal, people lay down panni on the roof. Panni is a water proof plastic fabric similar to tarpaulin sheets that protect the roof from leaking during heavy downpour.

6. People also replace the whole patra (roof) if the damage from the rain is more.

7. Application of M-seal on the roof is yet another way to avert damage and prevent leakage.

8. To prevent water from entering the house, mud is often stacked up to create a raised platform outside the house, thereby elevating the area and mitigating the risks of flooding. This is commonly referred to as making tekri.

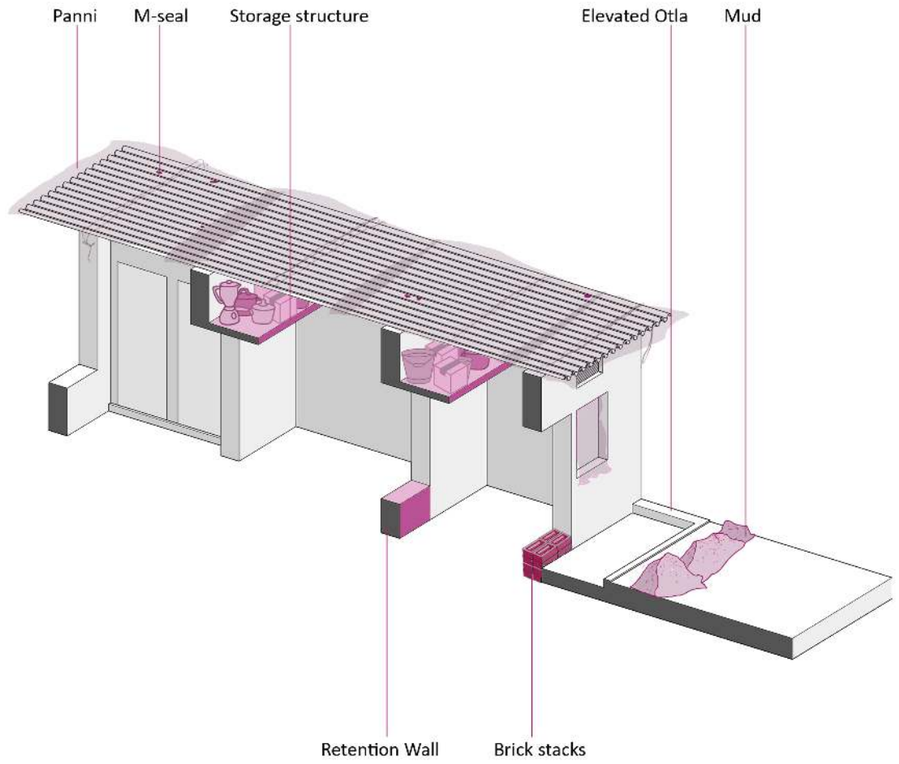


Fig 38: Household level flood adaptations

In the surveys, it was observed that the most of the houses which could afford redeveloping the household, they built their houses on plinths. This means that there has been a significant change in the household typologies over the years due to the adverse effects of floods.

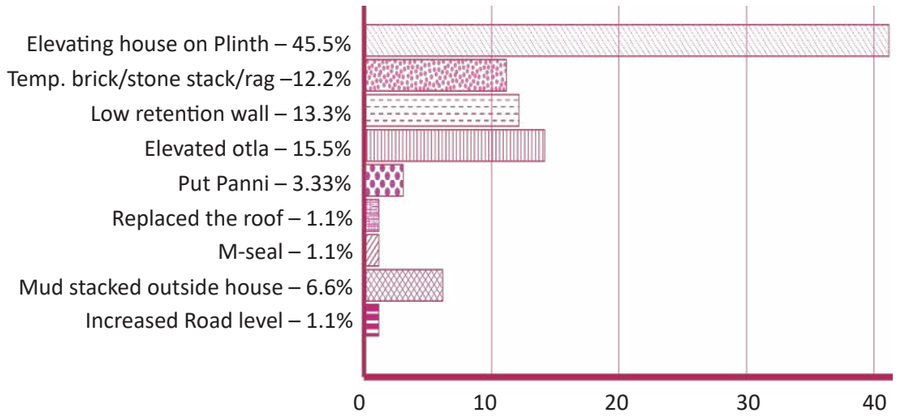


Fig 39: Household level srategies in use

This is an important thing to realize here that has there been better street infrastructure present, there would have been scope of using more of the temporal adaptation strategies instead of the home renovation which could cost people a lump sum amount of money in the low income settlements. Yet, people still require a set of strategies which are functional as well as cost effective.

5.3 Case Study

To propose flood adaptation strategies, a knowledge glossary is required for current practices in Vatva and globally in similar climatic conditions. The case study matrix in Appendix 1 illustrates flood adaptation methods used in low-income settlements in various developing countries, including those observed in Vatva, to identify common strategies. On the basis of that table, the strategies are segregated into household level and community level strategies. The following chart (Fig 40) shows the segregation:

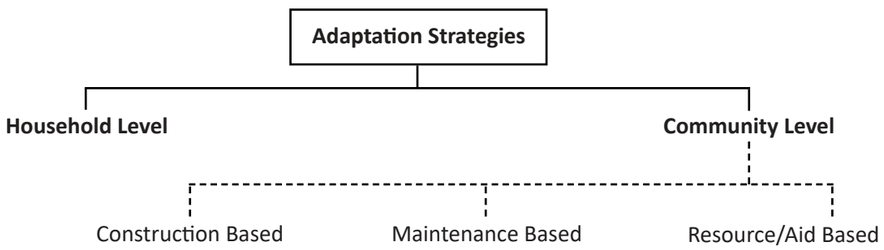


Fig 40: Segregation of Adaptation Strategies

To analyze the strategies, the following four factors are looked upon:

1. Ability to resist flood : Strategies are categorized based on their flood resistance abilities, with two main categories being preventive or reactive, depending on whether they aim to prevent or respond to flooding.

2. Accessibility : Cost analysis is required to identify the most cost-effective strategy that can persuade communities through affordable rates. This along with the strategy's applicability into the typologies would overall analyse the pertinence and generalizability of each strategy from its accessibility perspective.

3. Ease of Implementation: This determines whether the proposed strategy requires skills that needs to be taught to the people or could be easily implemented or if the strategy is a complex process which would require professional help and a body of people to enable the activity. Additionally, it will also include the ways of resource procurement to check whether the material required are easily available in the local market or not.

4. Longevity: To understand the durability of the strategy according to the cost to ensure the long term benefit.

5.3.1 Household Level Strategies

The household level strategies are the one's that could be implemented by the people on an individual level. The fig 41 depicts the different household level strategies and the locations of where they have been used around the world. Further, there strategies have been analysed to identify the one's which are the best suiltable for Vatva.

Fig 42 analyzes all the household level strategies on the basis of the different factors mentioned above. The bar graphs depit the costs incurred for developing the strategy and the line graphs show their longevity in years. The higher longevity of a strategy requires more frequent maintenance. The number of concentric circles show how many typologies in Vatva can adapt the specific typologies. Additionally, each of the strategy is categorised as high, medium or low according to their ease of implementation. These details of each strategy is also conveyed in the table 9 : household level strategy in Appendix 1.

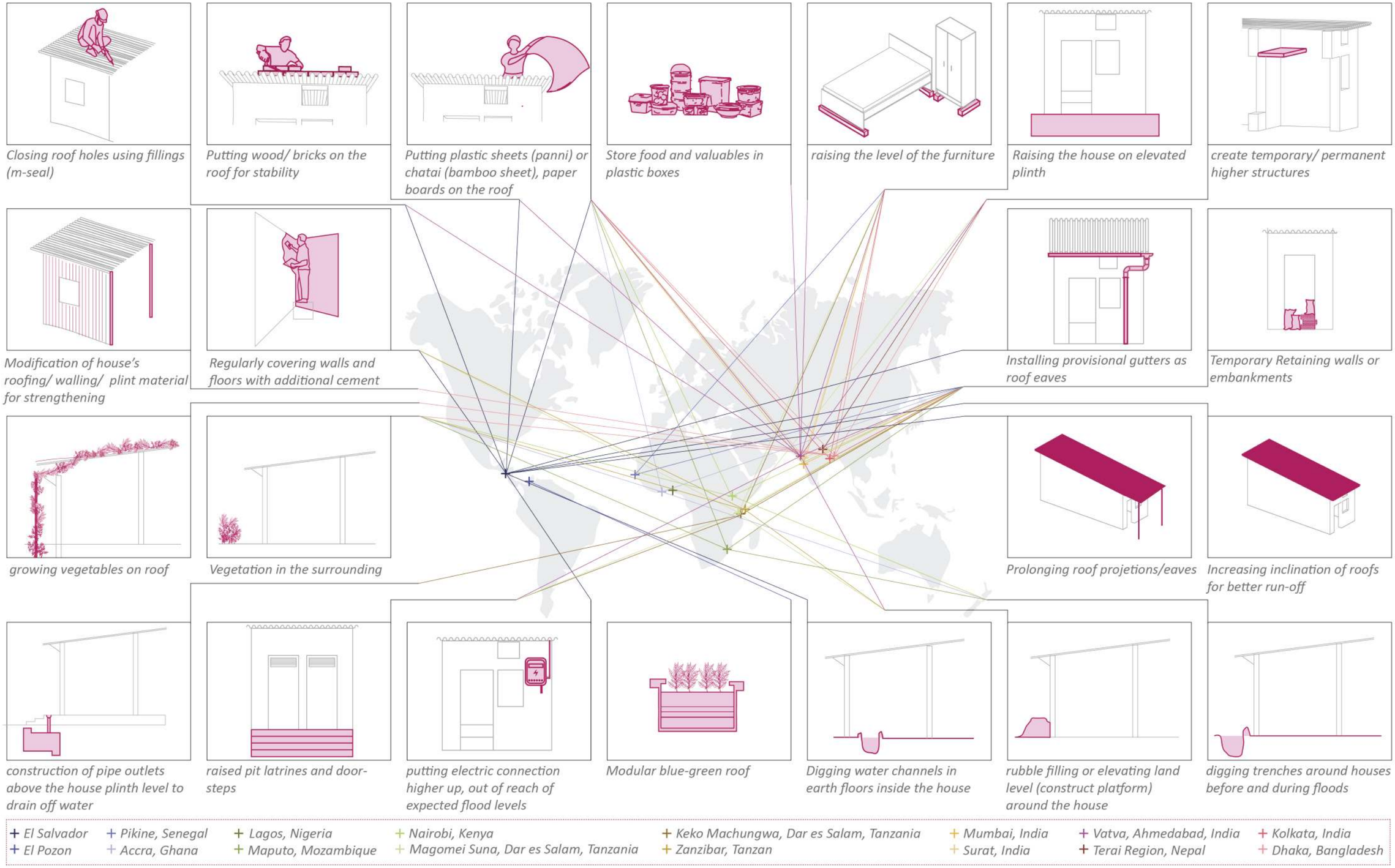


Fig 41: Household level Strategies

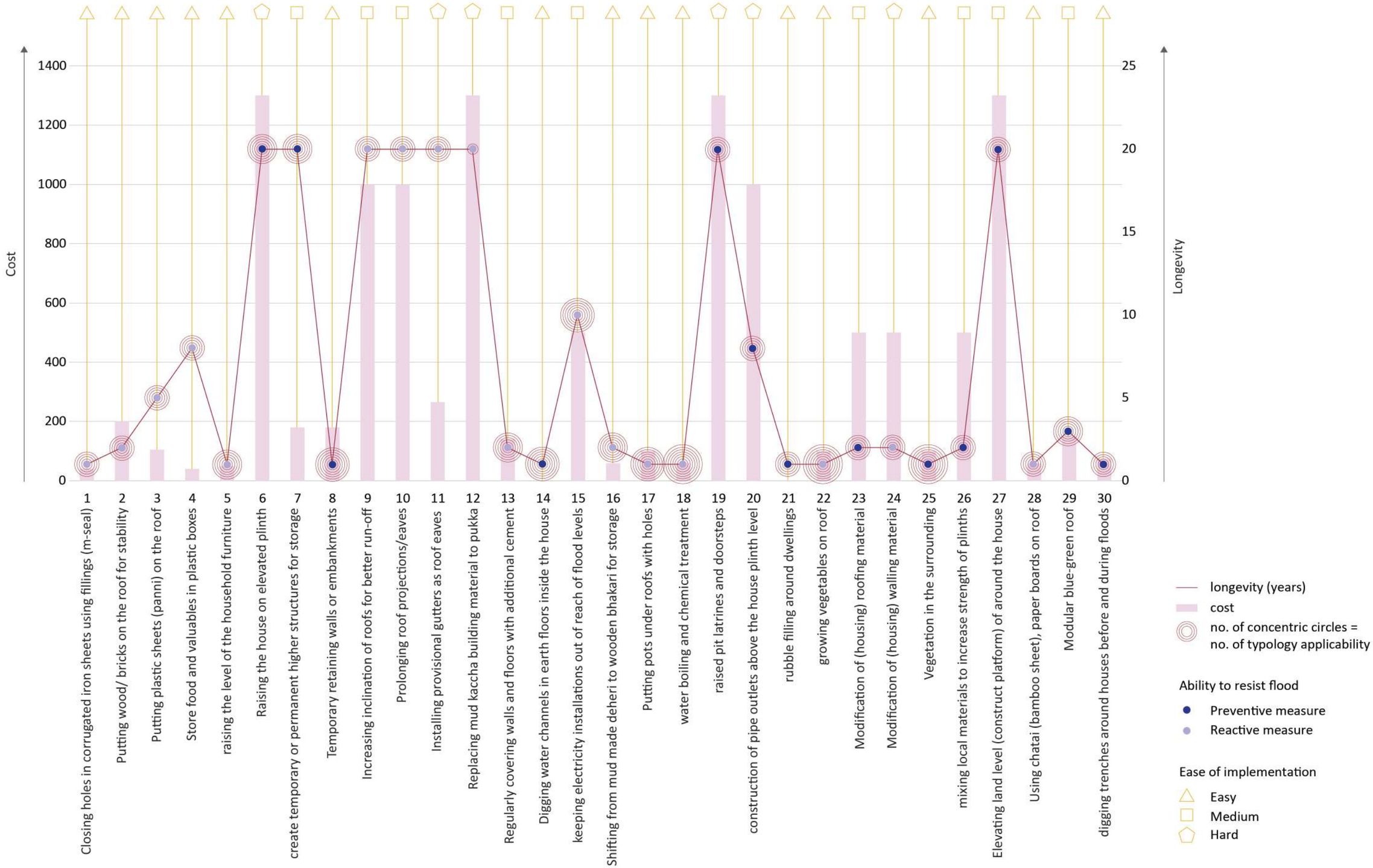


Fig 42: Household level Strategy analysis

5.3.2 Community Level Strategies

The community level strategies are the one's that could be implemented by the people as a community or through the support of the government and NGO. There are only a few which could be implemented by the people without any external skillset requirements. Therefore, the rest require hiring of labours, site supervisors, plumbers, electricians, masons etc.

Fig 43 contains the infrastructure construction based strategies which are located in the map according to places of interventions. The strategies have been analysed on the basis of cost (depicted by the bar graphs), longevity and ease of implementation. The ease of implementationis lesser for those strategies which could be implemented by the people on their own and do no require any external help.

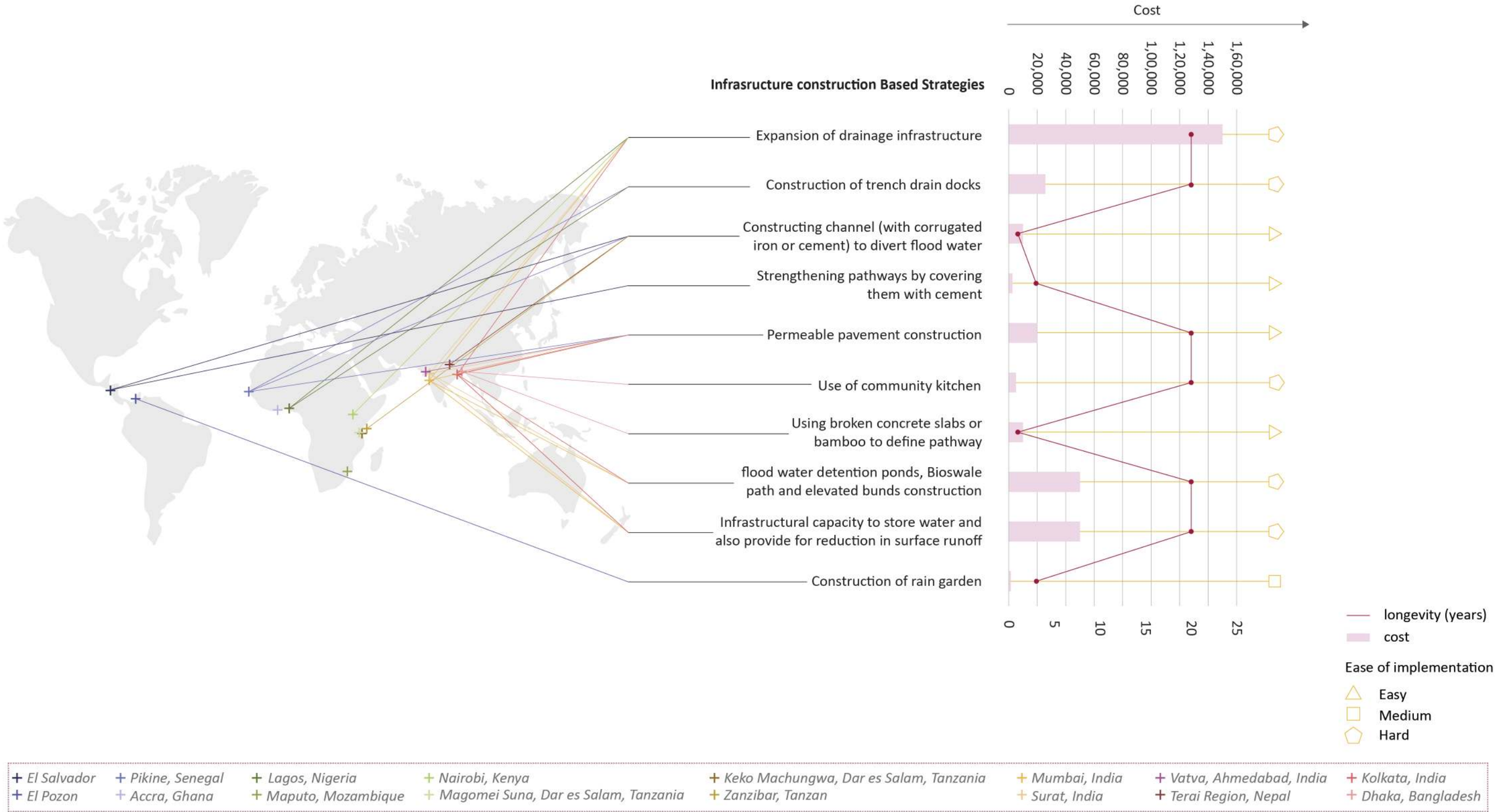


Fig 43: Community level Strategy analysis : Infrastructure Construction Based

Fig 44 contains the community level strategies which are maintenance based. These strategies should be implemented every year for the proper functioning of the existing infrastructure. Implementing these are a necessity and would reduce the severity of the floods to a massive level.

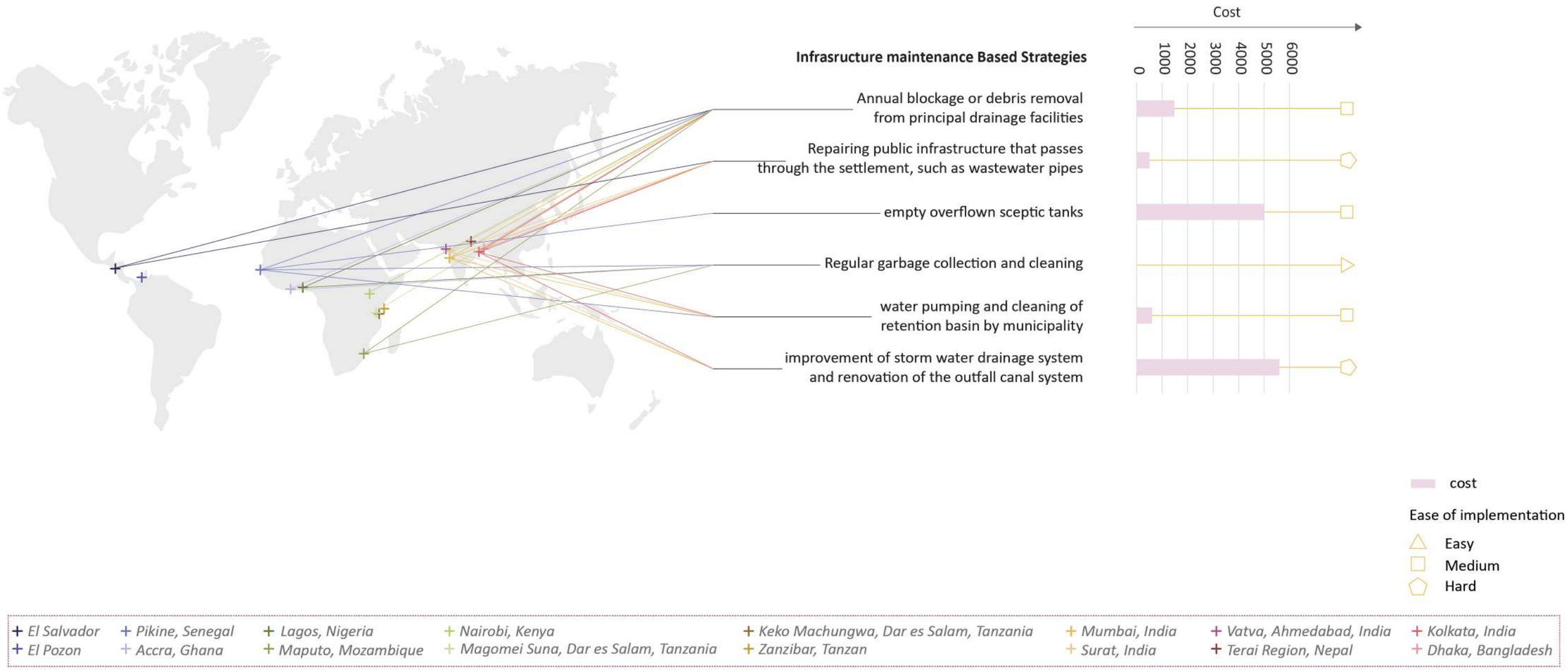


Fig 44: Community level Strategy analysis : Infrastructure Maintenance Based

Fig 45 contains the community level strategies which are resource provision based. These strategies mostly are dependent on the resources/ finance provided by the NGO or government organisations to prepare the communities to adapt to flood.

The detailed case study table of all the community based strategies have been compiled in table 10 : Community level strategies in Appendix 1.

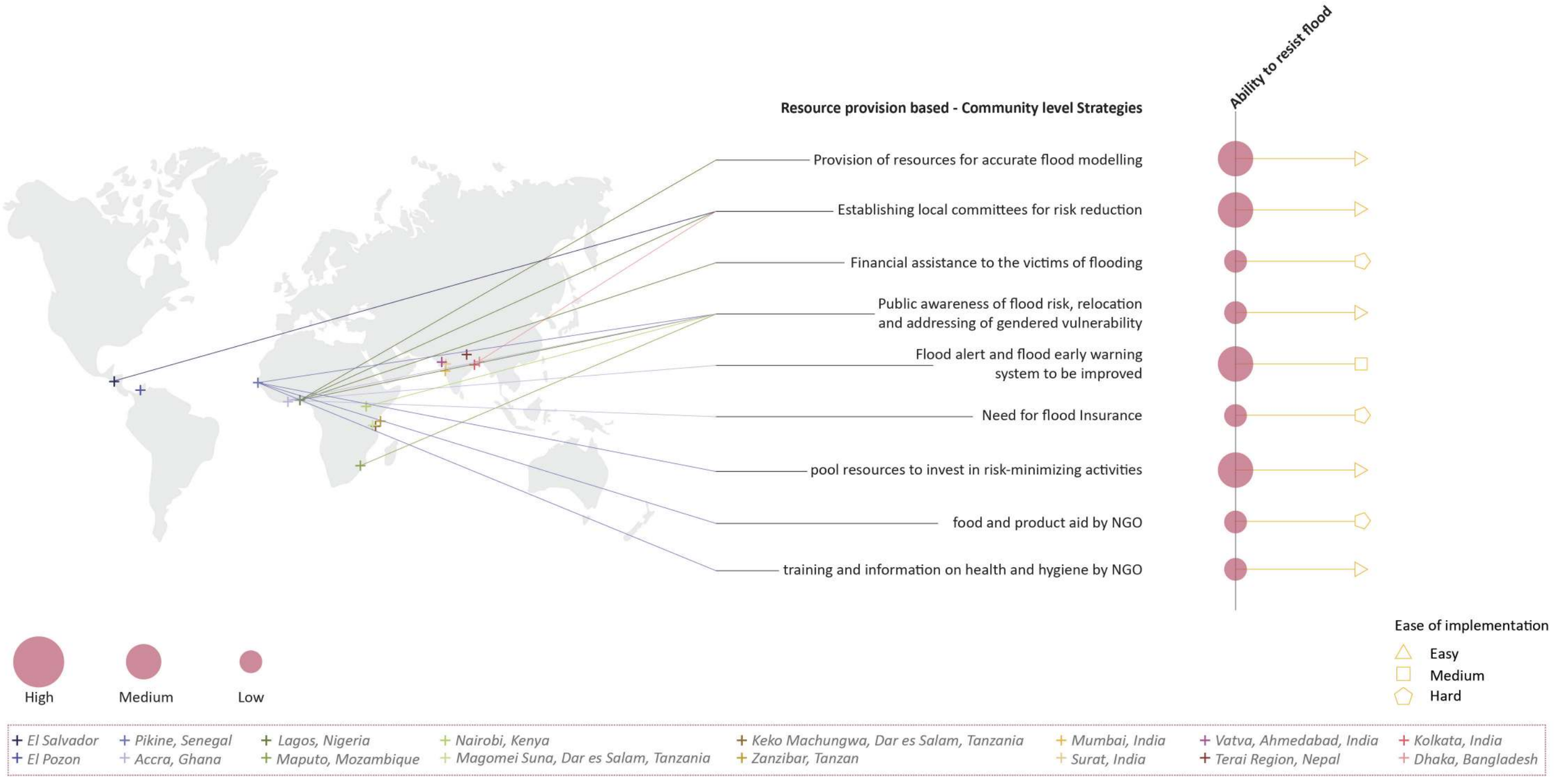


Fig 45: Community level Strategy analysis : Resource Provision Based

6. Approach and Recommendations

The development of flood adaptation strategies should be based on the idea of taking the advantage of the disaster rather than negating it. Therefore, even though strategies concerning the avoidance of water entering the houses or causing damage should be taken as priority, developing a system of productive design solutions to improve the quality of life of the settlements should be the broader objective. The research proposes the following as a way forward based on the case studies and the research framework:

1. On the basis of the household level strategy analysis, creating temporary retaining walls or embankments using cement bags, or car tyres or stacking bricks, digging water channels in the earth floor inside the house, and growing vegetation in the surrounding of the house are the strategies which are highly cost effective, usable in most of the residential typologies and are extremely easy to implement. These three strategies prove to be efficient if implemented together right before the floods and would be established within the cost of Rs. 300 - Rs. 400 for each household. The only drawack for these set of strategies are their longevity. They are to be implemented every year and are not permanent.

2. Strategies involving permanent structural changes in the house like raising the house on plinth or raising pit latrines and doorsteps or constructing platform around the house are the ones which are extremely expensive and requires skills to implement it and therefore should be redefined contextually such that it could be achieved in a cost effective and durable way.

3. One could club the blue green roof strategy along with the roof inclination and gutter devel-
opment together to achieve secondary strategies like growing vegetables/fruits and consuming them during the time of flood when the streets are waterlogged.

3. When faced with time constraints to implement large-scale communal strategies, it is advisable to prioritize cost-effective measures such as manually diverting water channels using corrugated iron or cement, using broken concrete for street paving, or pooling financial resources for pavement. These strategies can be swiftly executed by the households itself and have the potential to effectively mitigate urgent circumstances while minimizing costs.

5. For long term benefit, communal level strategies at streets should be developed by conglomerating a system of trench drain docks in front of the houses such that the water won't enter the houses, laying permeable pavement, inserting infrastructure for water filtration and a large scale common water storage. This will also ensure the availability of water for the communities during the time of scarcity. These strategies are relatively lower in cost as compared to the other strategies and have higher longevity as well.

6. Since the flood water currently accumulates at the open spaces and maidans, communal level strategies at these spaces along with the streets could inculcate a system of runoff water detention ponds or flood parks and bioswale paths. This could also include rain gardens at open spaces with smaller area. This combination of interventions would also act as a source of cooling and a place for gathering during extreme heat.

7. In case of the communal strategies, the awareness and response aspect of the flood risk management should be taken as a priority for the community as currently people have the feeling of panic and helplessness during the floods. Local committees for risk reduction and self-help groups could also be formed to support the people socially and financially. Such strategies would enable resource pooling and are quick and low cost.

8. Low cost resource provision based community level strategies such as flood modelling, establishment of local commitee for risk reduction, improvement of flood alert and early warning system and resource pooling should be implemented as priority since they are easy to implement and their ability to resist flood is also high. This requires high engagement of community as well as the NGO.

9. Institutional interventions of infrastructure expansion, regular repair, blockage removal and maintenance of the existing manholes and drainage system should be taken as a yearly measure and garbage collection and cleaning of streets should be taken as a daily measure to avoid adversities during hazard.

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Appendix 1 - Case Study

The case studies provide information on the practicality, effectiveness, and limitations of various household-level strategies for disaster risk reduction. They can help individuals and communities make informed decisions about which strategies are most suitable for their specific context and circumstances.

These case studies are based on research papers and studies done on the sites of low income settlements around the world which are prone to floods.

The table below comprises of the different household level strategies identified through case studies.

Household level Strategies	**Location and reference**	**Cost**	**Longevity**	**Typology applicable**	**Ease of Implementation**	
					Skill Requirement	**Procurement**
Closing holes in corrugated metal roof using fillings (m-seal)	Vatva, El Salvador	Rs. 40 for 100g	Upto 1-2 years	R1, R2, R3.1, R3.2	None – can be done by self	Could be bought at any hardware or stationary store
Putting wood/ bricks on the roof for stability	Vatva, El Salvador	Rs. 200	Upto 2-3 years	R1, R2, R3.1, R3.2	None – can be done by self	Materials from local wholeselles
Putting plastic sheets (panni) on the roof, on the inside walls or over the bed	Vatva, El Salvador, Dhaka, Mumbai, Kolkata, Surat, Nairobi, Accra, Maputo	Rs. 105	5-7 years if not exposed for long duration	R1, R2, R3.1, R3.2	None – can be done by self	Could be bought from local sources of hardware stores, plastic manufacturer or construction material supplier.
Store food and valuables in plastic boxes	Vatva	Rs. 40 per piece	8-10 years and then replaced	R1, R2, R3.1, R3.2	None – can be done by self	Could be bought from any store
Elevating the household furniture during waterlogging	Vatva, Pikine, Dhaka, Nairobi, Accra, Maputo	Rs. 50	Done only during monsoon	R1, R2, R3.2, R4, R7.2	None – can be done by self	Bricks or wooden planks could be gathered from construction material suppliers
Raising the house on elevated plinth	Vatva, Keko Machungwa, Magomeni Suna, Dhaka, Mumbai, Kolkata, Surat	Rs 1300 per sq.ft	More than 20 years with repair	R1, R2, R3.2, R4, R7.2	Masons, carpenters and labourers are required	Bricks, mortar or wooden planks could be gathered from construction material suppliers.
Modification of roofing material - Use of Dried coconut leaves or second-hand corrugated tins	Dhaka	Dependent on the amount and source of procurement	Upto 1-2 years	R1, R2, R3.2, R8	None – can be done by self or could even hire a daily wager	Materials could be obtained from scrap collectors
Modification of wall material - Use of jute sticks and bamboo frames, reinforced with dried cow dung plastering for increased strength	Dhaka	Dependent on the amount and source of procurement	2-3 years of not exposed to environment for long duration	R1, R2, R3.2, R8	None – can be done by self or could even hire a daily wager	Materials could be obtained from scrap collectors or self-procured
Vegetation in the surrounding	Dhaka, Zanzibar, Nairobi, Accra, Maputo	Within Rs. 100	Done seasonally	All the typologies	None – can be done by self	Materials could be obtained from local nurseries
adding ash, bran, and straw to strengthen the mud to construct plinth and walls	Dhaka	Dependent on the amount and source of procurement	2-3 years of not exposed to environment for long duration	R1, R2, R3.2, R8	None – can be done by self or could even hire a daily wager	Materials could be obtained from scrap collectors or self-procured
Elevating the ground level surrounding the dwelling (constructing a platform)	Vatva, Dhaka, Zanzibar	Rs 1300 per sq.ft	More than 20 years (might need repair)	R1, R2, R3.2, R8	Masons, carpenters and labourers are required	Bricks, mortar or wooden planks could be gathered from construction material suppliers.
Use of chatai (bamboo sheet? or paper boards to keep water from leaking through the roof.	Dhaka	Rs. 59 per piece	Done seasonally	R1, R2, R3.1, R3.2, R8	None – can be done by self	From local seller
Modular blue-green roof using egg container, coconut fibre, plywood panels, tarpaulin and plastic fruit box	EL Pozón, Cartagena de Indias	Rs. 150/unit	Upto 2-3 years and then replaced	R1, R2, R3.1, R3.2, R8	None – can be done by self, minor training required	Material could be bought on wholesale or from scap collectors

Table 9 : Household level strategy

Household level Strategies	Location and reference	Cost	Longevity	Typology applicable	Ease of Implementation	
					Skill Requirement	Procurement
construct temporary or permanent higher structures out of bricks or wood to store belongings	Vatva,Terai region, Magomeni Suna, Dhaka	Rs. 180/sq. ft	More than 20 years (if made of bricks)	R1, R2, R3.2, R4, R7.2	Masons, carpenters and labourers are required	Bricks, mortar or wooden planks could be gathered from construction material suppliers.
Retaining walls or embankments made from used car tyres, tree logs, bamboo, stones, bricks, or nylon bags packed with dirt and cement	Vatva, El Salvador, Keko Machungwa, Magomeni Suna. Pikine, Dhaka, Zanzibar, Mumbai, Kolkata, Surat, Nairobi, Accra, Maputo	Rs. 180/sq. ft	Done only during monsoon	R1, R2, R3.2, R4, R7.2, R8	Could hire labourers to do so or could be done by self	Materials could be obtained from either construction material suppliers or could also be taken from scrap collectors
Increasing roof inclination for better run-off	El Salvador	-	More than 20 years (might need frequent repair)	R1, R2, R3.1, R3.2	Carpenters, tin workers and laborers are required	Materials could be obtained from either construction material supplier
Increasing the length of roof projections/eaves	El Salvador	-	More than 20 years with repair	R1, R2, R3.1, R3.2	Carpenters, tin workers and laborers are required	Materials could be obtained from either construction material supplier
Installing provisional gutters as roof eaves	El Salvador	Rs. 265/m	More than 20 years (might need frequent repair)	R1, R2, R3.1, R3.2	Carpenters, tin workers, plumber and laborers are required	Materials could be obtained from either construction material supplier and hardware shops
Substituting mud walls with brick walls, wooden pillars with metal pillars, and corrugated iron with duralita.	El Salvador	-	More than 20 years (might need frequent repair)	R8	Masons, Carpenters, metal workers and laborers are required	Materials could be obtained from either construction material supplier
Regularly covering walls and floors with additional cement	El Salvador, Magomeni Suna, Zanzibar	Within Rs. 140	Upto 1-2 years	R1, R2, R3.1, R3.2, R8	None – can be done by self or could even hire a daily wager	Materials could be obtained from either construction material supplier
Digging water channels in earth floors inside the house	El Salvador	-	Done only during monsoon	R1, R2, R3.2, R4, R7.2, R8	None – can be done by self	None
covering wires and elevating electric connections above projected flood levels.	El Salvador	-	8-10 years and then replaced	R1, R2, R3.2, R4, R7.2, R8	Electrician required	Materials could be obtained from electrical suppliers and hardware store
Transferring grain storage from mud-made deheri to wooden bhakari	Terai region	Rs. 59	Upto 1-2 years	R1, R2, R3.2, R4, R7.2, R8	None – can be done by self	Wood can be obtained from local supplier
Putting pots under roofs with holes	Vatva, El Salvador	Within Rs 100	Done only during monsoon	R1, R2, R3.1, R3.2, R8	None – can be done by self	Could be bought from store
water boiling and chemical treatment	Vatva, Keko Machungwa, Magomeni Suna	Rs. 60/ litre	Dependent on consumption	All the typologies	None – can be done by self	Could be bought from store
elevated pit latrines and doorsteps	Vatva, Keko Machungwa, Magomeni Suna	Rs 1300 per sq.ft	More than 20 years with repair	R1, R2, R3.2, R8	Masons, plumbers, carpenters and laborers	Materials could be obtained from either construction material supplier
rubble filling around dwellings	Magomeni Suna	-	Done only during monsoon	R1, R2, R3.2, R8	None – can be done by self	Could be obtained from scrap collectors
installation of pipe outlets above the house plinth to drain water	Keko Machungwa	Dependent on the design	8-10 years and then to be replaced	R3.1, R4, R6, R7.1	Carpenters and plumber are required	Materials could be obtained from plumbing suppliers and hardware store
digging trenches around houses before and during floods	Nairobi, Accra, Maputo	Rs. 74.50/ Cu.m	Done seasonally	R1, R2, R3.2, R8	None – can be done by self or hire labourers	Materials could be obtained from construction material supplier
growing vegetables on roof to ensure food security and provide income	Dhaka	Within Rs.100-Rs. 200	Done seasonally	All the typologies	None – can be done by self	Materials could be obtained from local nurseries or self-obtained from grocery

Table 10 : Household level strategy

Community level Strategies	Location and reference	Cost	Longevity	Ease of Implementation	
				Skill Requirement	Procurement
Financial assistance to flood victims	Lagos	Dependent on the institution	Years of severe flood damage	None	Funding required
Awareness on food risk, relocation, and gendered vulnerability	Lagos, Pikine, Nairobi, Accra, Maputo	Dependent on the institution	Dependent on institutional schemes	None	Funding required
Upgrade of Flood alert & early warning system	Lagos	Dependent on the institution	-	-	Funding required
Need for flood Insurance	Lagos	Dependent on the institution	Dependent on institutional scheme	-	Dependent on institutional scheme
Constructing channel (with corrugated iron or cement) to divert flood water	Terai region, El Salvador, Pikine, Zanzibar	Rs. 997/ cu.m	Done seasonally	None – can be done by self or could even hire a daily wager	construction material supplier
Strengthening pathways by covering them with cement	El Salvador	Rs. 265 smt	Upto 2-3 years with repair work	Site supervisor or manager or contractor and labourers	construction material supplier
Repairing public infrastructure such as sewer pipes that run through the settlement	El Salvador, Dhaka, Mumbai, Kolkata, Surat	Minimum Rs.500 per joint	Yearly inspection and maintenance required	Site supervisor, engineers, plumbers, labourers	construction material supplier
pool resources for risk-minimizing activities	Pikine	Dependent on the institution	-	-	-
empty overflown sceptic tanks	Pikine	Minimum Rs.5000	Every year	Site supervisor, engineers, plumbers, labourers	Purchase from suppliers or manufacturers, government agencies
Regular garbage collection and cleaning	Pikine, Nairobi, Accra, Maputo	-	-	-	-
Permeable pavement construction	Vatva, Pikine, Dhaka, Mumbai, Kolkata, Surat	2000/rmt	More than 20 years with repairs	Site supervisor or manager or contractor and labourers	construction material supplier
food and product aid by NGO	Pikine	Dependent on the institution	-	-	Dependent on institutional scheme
Awareness on health & hygiene by NGO	Pikine	Dependent on the institution	-	Helth experts required	-
water pumping and retention basin cleaning by municipality	Pikine, Mumbai, Kolkata, Surat	Rs.600 per shift or 18.32 HP/ hr	Every year	Site supervisor, engineers, plumbers, labourers	Purchase from suppliers or manufacturers, government agencies
Use of community kitchen	Dhaka	Dependent on the institution	-	-	-
Using broken concrete slabs or bamboo to define pathway	Dhaka	Dependent on amount and source of procurement	Seasonally	None – could be done by self	construction material supplier
improvement of storm water drainage system and renovation of the outfall canal system	Mumbai, Kolkata, Surat	Min Rs.5600	Every year	Site supervisor or manager or contractor and labourers	construction material supplier
flood water detention ponds, Bioswale path and elevated bunds construction	Mumbai, Kolkata, Surat	Dependent on scale and design	More than 20 years	Site supervisor or manager or contractor and labourers	construction material supplier
Infrastructural capacity to store water and also provide for reduction in surface runoff	Mumbai, Kolkata, Surat	Dependent on scale and design	More than 20 years with maintenance	Site supervisor or manager or contractor and labourers	construction material supplier
expansion of drainage infrastructure	Lagos, Mumbai, Kolkata, Surat, Nairobi, Accra, Maputo	Min Rs.1,50,000	More than 20 years with maintenance	Requires engineers, construction manager, project manager, urban planner, pipefitters, plumbers, electricians, masons and labourers	Purchase from suppliers or manufacturers, government agencies
Annual blockage or debris removal from principal drainage facilities	Lagos, El Salvador, Magomeni Suna, Pikine, Dhaka, Mumbai, Kolkata, Surat, Nairobi, Accra, Maputo	Rs.1475.00 for 8hr	Should be done every year	Site supervisor, engineers, plumbers, labourers	Purchase from suppliers or manufacturers, government agencies
Construction of rain garden	EL Pozón, Cartagena de Indias	Rs. 150/unit	Upto 2-3 years and then replaced	None – can be done by self, minor training required	Material could be bought on wholesale or from scap collectors

Table 11 : Community level strategy

Community level Strategies	Location and reference	Cost	Longevity	Ease of Implementation	
				Skill Requirement	Procurement
Construction of trench drain docks	Lagos, Pikine	Rs. 2,575/ cu.m	More than 20 years (with regular repair)	Site supervisor, engineers, project manager, plumbers, labourers	Purchase from suppliers or manufacturers, government agencies
Provision of resources for accurate flood modelling	Lagos	Dependent on the institution	To be done for research purposes	GIS specialists, engineers, Data analysts	Funding required
Establishing local committees for risk reduction	Lagos, El Salvador, Dhaka	Dependent on the institution		None	Funding required

Table 12 : Community level strategy

The following are the case study overviews whose strategies are listed in the table:

1. Location: Lagos, Nigeria
Climate Region: tropical wet and dry climate
Research Method used: Secondary data sources: Online photographs, policies and Literature Review (Nkwunonwo, Whitworth, & Baily, 2016)
Site Background and context: Lagos is heavily populated low-lying coastal area in the south-western part of Nigeria. This place faces multiple challenges due to its high population density, including lack of space for human activities, overcrowding, slums, pollution, and illegal structures. Lagos floods are mainly the consequences of climate-change induced disproportionate rainfall.

2. Location: Terai region, Nepal
Climate Region: hot and humid subtropical monsoon climate
Research Method used: Primary data: household survey, semi-structured interviews, focus group discussions, key informant interview and observations. Secondary data: Topographical map, Arial photographs, Google Map and satellite image are mainly used as secondary data (Sharma, 2018)
Site Background and context: The Terai area of Nepal is a high-risk flood zone, with 80% of rainfall falling during the monsoon season, which lasts from June to September. High rainfall, soil erosion, flat terrain, debris flows, river channel migration, and human activities such as drainage system obstruction, deforestation, and poor planning and building practises all contribute to flooding. Low-income populations, such as landless and bonded labourers, are more vulnerable and tend to live near low-lying riverbank regions.

3. Location: El Salvador
Climate Region: tropical wet and dry climate
Research Method used: semi structured interview, walk through analyses, observation and literature review (Wamsler, 2007)
Site Background and context: El Salvador is extremely sensitive to the effects of climate change, such as increasing floods and landslides. According to the United Nations, the country is the most susceptible to climate change in Central America due to its vulnerability to natural catastrophes, high levels of poverty, and low capability to adapt to these consequences.
The growing urbanisation, which has resulted in the development of houses in high-risk regions such as floodplains and slopes, is one of the primary causes of floods in El Salvador.

4. Location : Keko Machungwa, Dar es Salaam, Tanzania
Climate Region: Tropical climate
Research Method used: literature review, mapping, aerial photos, household interviews (Sakijege, Lupala, & Sheuya, 2012)
Site Background and context: Keko Machungwa's research area is in the Temeke Municipality, around 3 km from the city core. Dar es Salaam, Tanzania's main commercial metropolis, is expected to have a population of four million people. Nearly 80% of the population (3.2 million) lives in 43 separate informal settlements with insufficient access to essential infrastructure services like as water supply, sewage, and stormwater drainage systems. When it rains, several of the villages are routinely hit by disastrous floods.

Fig 46: Pit Latrines and protective wall ; Source : Field work in Keko Machungwa, (Sakijege, Lupala, & Sheuya, 2012)

Fig 47: Sandbags; Source : Field work in Keko Machungwa, May 2009 (Sakijege, Lupala, & Sheuya, 2012)

5. Location: Magomeni Suna, Dar es Salaam, Tanzania
Climate Region: Tropical climate
Research Method used: household interviews, key informant interview, FGD (Regina, 2020)
Site Background and context: Magomeni Suna is a settlement in Kinondoni Municipality's

Magomeni Ward, around five kilometres from the city centre. Prior to 1998, the residents had experienced what they called "regular floods" throughout the rainy season, which were not strong enough to inflict substantial damage and were easily managed. However, the neighbourhood saw its first disastrous flood in 1998, caused by El Nio, which was followed by flash floods in 2011 and later in the years 2012 to 2015.

Fig 48: Pit latrine with raised foundation.
Source : (Regina, 2020)

Fig 49: Protection wall securing main entrance.
Source : (Regina, 2020)

6. Location: Pikine, Senegal
Climate Region: tropical savanna
Research Method used: grounded theory approach : observation, ethnographic approach (Schaer, 2015)
Site Background and context: This area's tropical savanna environment has grown more irregular, resulting in more extreme rainfall events that trigger floods. Pikine's population has also increased fast, resulting in an increase in impermeable surfaces like as concrete and asphalt, which exacerbates floods by preventing water from being absorbed into the ground. Furthermore, poor urban design, limited infrastructure, and informal settlements have added to the area's vulnerability to flooding.

7. Location: Dhaka, Bangladesh
Climate Region: Tropical monsoon climate
Research Method used: questionnaire survey, focus group discussions, transect walks (Huraera, Johnson, & Allen, 2010)
Site Background and context: Dhaka, Bangladesh's capital city, is one of the world's most densely inhabited cities and has been severely hit by flooding in recent years. Dhaka is located on the Brahmaputra River's floodplain, and growing urbanisation has resulted in a considerable decrease in green space, marshes, and water bodies, compounding the effects of flooding. Furthermore, the city's drainage system is insufficient, and the city's infrastructure, such as roads and buildings, is not built to withstand floods.

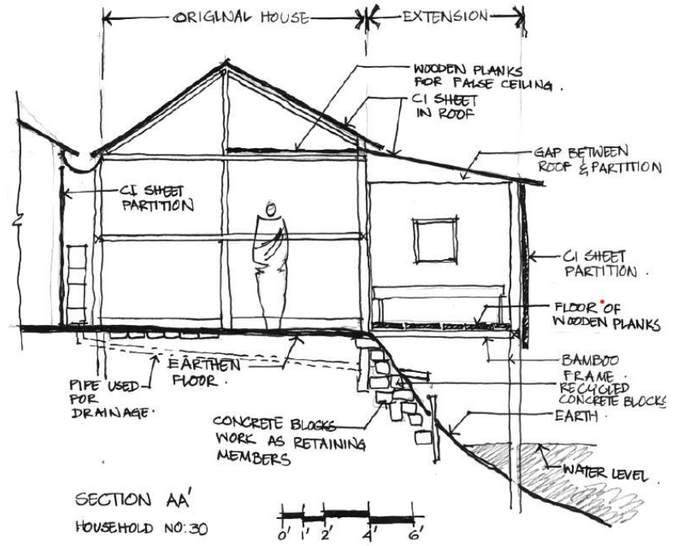

Fig 50 : Household cross section on the water edge
Source : Documented by Huraera Jabeen, (Huraera, Johnson, & Allen, 2010)

8. Location: Zanzibar, Tanzania
Climate Region: Tropical climate
Research Method used: grounded theory approach : observation, ethnographic approach (Nassor & Makame, 2021)
Site Background and context: The low-lying terrain of the region, along with the increased probability of catastrophic weather events, renders it especially prone to floods. Several flooding catastrophes have occurred on the island in recent years, resulting in fatalities, infrastructure damage, and community displacement. Climate change is also affecting the region's ecosystems, with rising sea temperatures causing coral bleaching and diminishing fish numbers, threatening the livelihoods of fishing tribes.

Fig 51: Sandbags wall. Source : (Nassor & Makame, 2021)

Fig 52: Vegetation barrier in the surrounding. Source : (Nassor & Makame, 2021)

Fig 53: Local Drainage System. Source : (Nassor & Makame, 2021)

Fig 54: Retention wall and stairs
Source : (Nassor & Makame, 2021)

Fig 55: wooden barrier
Source : (Nassor & Makame, 2021)

Fig 56: Strong cement wall
Source : (Nassor & Makame, 2021)

9. Location: Mumbai, Kolkata and Surat
Climate Region: Tropical climate/ tropical savanna climate
Research Method used: literature review (Goyal, 2021)
Site Background and context: Mumbai, Kolkata, and Surat are all Indian cities that are vulnerable to the effects of climate change, especially flooding. These cities are heavily inhabited and have grown fast in recent decades, putting additional strain on the natural environment and leaving little infrastructure to deal with catastrophic weather occurrences. All these cities have faced significant flooding and landslides, particularly during the monsoon season.

Fig 57: Construction of barrier wall
Source : (DNA web team, 2018)

Fig 58: Flood prevention by building bunds using sandbags
Source : (Das, 2020)

10. Location: EL Pozón, Cartagena de Indias, Colombia
Climate Region: tropical savanna climate
Research Method used: grounded theory approach : observation, ethnographic approach (Veloza, Dadati, Giordano, & Savio, 2022)
Site Background and context: The rainy season, which lasts from May to November, can bring heavy rain and thunderstorms, causing floods in low-lying places like El Pozón. Flooding has been more frequent and intense in the area in recent years, causing substantial damage to houses and infrastructure. Climate change is predicted to intensify these effects, showing that sea-level rise will grow and extreme weather events will become more frequent.

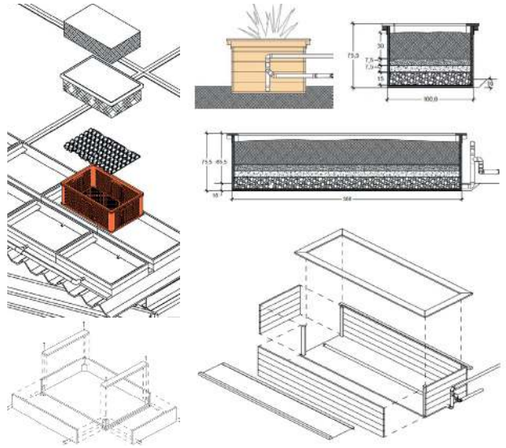

Fig 59: Blue green roof module and rain garden unit
Source : (Veloza, Dadati, Giordano, & Savio, 2022)

Fig 60: Blue green roof module prototype
Source : (Veloza, Dadati, Giordano, & Savio, 2022)

11. Location: Nairobi, Kenya; Accra, Ghana; Maputo, Mozambique
Climate Region: Tropical Savanna Climate
Research Method used: grounded theory approach : observation, ethnographic approach (Reed, 2013)
Site Background and context: These cities are vastly affected by the impacts of climate change and there has been an increase in the loss due to floods because of poor urban planning as well as infrastructure.

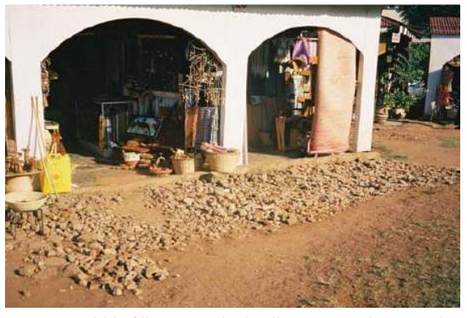

Fig 61: Rubble filling outside dwelling, Kampala, Uganda
Source:(Reed, 2013)

Fig 62: Removing silt from drainage channel, Kampala, Uganda Source:(Reed, 2013)

Fig 63: Silt clearance from drains
Source:(Reed, 2013)

Fig 64: Sandbag protection, Kampala, Uganda Source: (Reed, 2013)

Appendix 2 - Survey Questionnaire

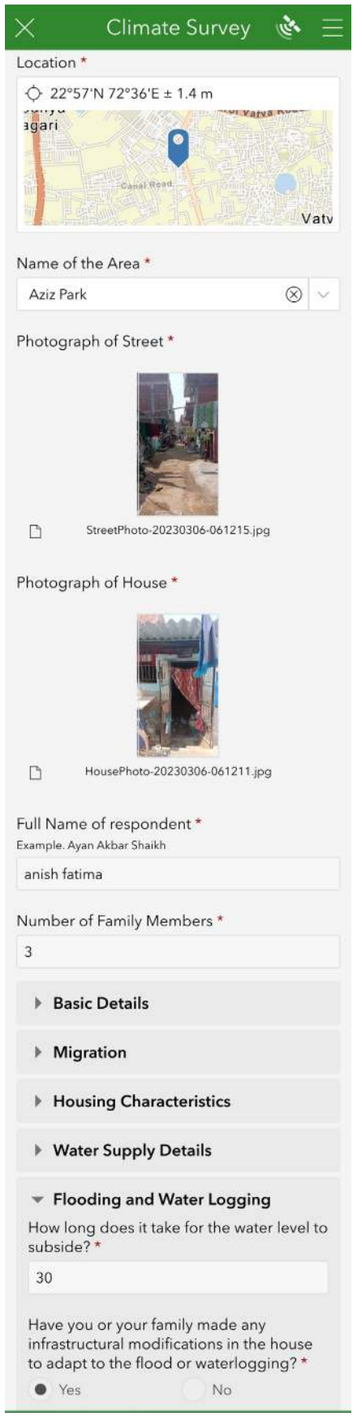

Fig 65: ArcGIS Survey 123 mobile app interface

The household surveys were conducted by using ArcGIS Survey123.

Fig 66: ArcGIS Survey 123 mobile app interface- flood and health

The following are the list of household survey questions :

Household Details

Name of respondent		
Location		
Place of origin		
How long have you lived here?		
Reason for moving here (if applicable)		
Occupation of the members		
Annual family income		
Ownership	Own	Rent
Image of the house		
Image of the street		

Housing Characteristics

Does your house have the following	Pani ni barni (water jar)	Yes	No	
	Water Pump	Yes	No	
	Landline	Yes	No	
	Cooler	Yes	No	
	AC	Yes	No	
	Internet Connection	Yes	No	
What type of stove do you use for cooking?		LPG/ Cooking gas stove		
		Piped Gas		
		Traditional fuel stove		
		Others (specify):		
Do you have an exhaust fan/chimney in the kitchen?		Yes	No	
Toilet Access		Individual	Shared	Pay & Use	None

Fig 67: Household Survey Questionnaire

Does your house have the following	Pani ni barni (water jar)	Yes	No
	Water Pump	Yes	No
	Landline	Yes	No
	Cooler	Yes	No
	AC	Yes	No
	Internet Connection	Yes	No
What type of stove do you use for cooking?		LPG/ Cooking gas stove	
		Piped Gas	
		Traditional fuel stove	
		Others (specify):	
Do you have a door-to-door waste collection service?		Yes	No

Water Scarcity

How frequently do you face water scarcity in your neighborhood?	Daily	Weekly	Monthly
Have you had to purchase water from external sources during periods of scarcity?	Yes		No
	From:		
Has the quality of drinking water ever been compromised?	Yes		No
How has water scarcity affected the health and hygiene of you and your community?			
Have you had to make changes to your daily water usage due to water scarcity?	Yes		No
	How?		
Do you have any water storage facilities at home or in your community?	Yes		No
What are your needs and concerns regarding the scarcity of water?			

Fig 68: Household Survey Questionnaire

Flooding and water logging

How often do you experience floods here?	Every year	Once in 2 yrs	Once in 5 yrs
How long does it take for the water level to subside?			
Have you or anyone in your family faced the loss of work days due to flood/water logging?	Yes		No
If yes, then how many days were you not able to go to work?			
Has flood water ever entered your house?	Yes		No
If yes, then what happens to your belongings inside the house?			
Have you or your family made any home modifications in the house to adapt to the flood or waterlogging?	Yes		No
If yes, describe.			
What are your concerns and needs?			
As a community what changes have been implemented to avoid adverse effects during the flood or waterlogging?			
Have you experienced power cut during such a situation?	Yes		No
Did you face any housing structure loss during the flood/water logging?	Yes		No
If yes, then how much cost did it incur?			
Have you had to evacuate during a flood?	Yes		No
If yes, then where?			
Do you receive any support from the government or local organizations during these times? (eg. evacuation plans, food supply, etc.)	Yes		No
	Specify:		
Have you received any financial assistance to recover from flood damage?	Yes		No
If yes, how much?			

Fig 69: Household Survey Questionnaire

Heat

What time of the day do you mostly feel hot while living indoors?	Morning	Afternoon	Evening	Night
When do you face heat-related health issues?	Only during Summers		All year round	
How have your daily activities been affected due to the rising temperatures in the summer?				
What measures and home modifications do you take to cope with extreme heat?				
If you have AC/cooler then how often do you use it during the summer?				
Do you use an AC/ cooler during winter?	Yes		No	
Has extreme heat impacted your source of income or employment opportunity in any way? If yes, please describe its effects on your household.	Yes		No	
Are there any available sources of shade or cooling in your community during a heat wave? If yes, describe where it is and how it is used.	Yes		No	

Health

What kind of diseases are more common in your household?	Heat exhaustion- sweating, dizziness, headache	
	Skin diseases and rashes	
	Respiratory- TB, Asthma, Pneumonia	
	Stomach related issues	
	Vector-borne - malaria, dengue	
	Water-borne - Diarrhea, Cholera, Typhoid	
What are the steps you take to protect yourself and your home from mosquitoes?		
Are there any community-level programs or efforts in place to control the spread of these diseases? If yes, what are they?	Yes	No
Where do you seek treatment in case of illness?	Urban Health Centre	

Fig 70: Household Survey Questionnaire

	Government Hospital		
	Private Hospital		
	Local clinic		
	Home remedies		
How far is the nearest health care facility?	5-10 mins	20-30 mins	More than 40 mins
Have you received any education or information on how to prevent the spread of such diseases?	Yes	No	
Are there any challenges or barriers in the community that prevent the effective control of the spread of vector-borne diseases?			

Disaster Response

Select the extreme weather events/ disasters you have experienced in this settlement	Flood	
	Heat Wave	
	Water Scarcity	
	Dust Storms	
	Infrastructure failure	
	Increased/ frequent air pollution, smoke	
	Water and vector-borne diseases	
	Cyclone/ Lightning events	
Did you receive any advance notice or warning?	Yes	No
Which hazard?		
Was the early warning helpful information?	Yes	No
What was your source of the early warning system?	Television	
	Internet	
	Community	
	Other:	

Fig 71: Household Survey Questionnaire

Did you take any of the following measures?	Preserve drinking water		Yes	
			No	
	Preserve food		Yes	
			No	
	Preserve valuable items (eg. jewelry, household appliances, utensils, etc.)		Yes	
			No	
	Preserve medicines		Yes	
			No	
As a result of the event, did you experience any of the following:	Injury		Yes	No
	Illness		Yes	No
	Dwelling/ Assets	Destroyed	Yes	No
		Damaged	Yes	No
	Loss/ decrease in income		Yes	No
As a result of the event, did you experience any of the following consequences:	Had to switch to an unimproved form of sanitation		Yes	No
	Was unable to seek necessary medical care		Yes	No
	Had to switch to unclean cooking/heating/lighting fuel for more than two weeks		Yes	No
Were you involved in any committees or groups where you felt you could influence responses to rebuild after these events?			Yes	No
If yes, specify:				

Order the following climate issues from most to least priority	Water Scarcity
	Flood
	Water and vector-borne diseases
	Heat stress

Fig 72: Household Survey Questionnaire

Appendix 3 - Literature review

The literature review has been divided into the following four main domains of study:
1. Global Perspective on Climate Change and Vulnerability
2. Climate change impacts on the Urban Poor of South Asia
3. Community Based Adaptations to Climate Change
4. Case Studies : Adaptation and Strategies to Waterlogging and floods

DOMAIN 1 : Global Perspective on Climate Change and Vulnerability

1. Jaeger, C. C., Hasselmann, K., Leipold, G., Mangalagiu, D., & Tabara, J. (2012). Reframing the problem of Climate Change . Oxon: Earthscan.
This book argues that the traditional framing of climate change as a problem to be solved by reducing greenhouse gas emissions is inadequate and create blockages in climate change policies. This issue cannot be disconnected from the global problems like poverty or food security. The book mentions CCIA and the number of factors with uncertainity which arise due to unpredictability. It highlights the role of development NGOs in climate change adaptations in both long term development and emergency response work. The book provides an overview of the current state of climate science and economics, and explores the potential implications of different policy options along wth new generation of climate scenarios.

2. *Bicknell, J., Dodman, D., & Satterthwaite, D. (2009). Adapting Cities to Climate Change. Oxon: Earthscan.*
This book provides an understanding of the potential for adaptation and constraints of climate change in the urban areas of low to middle-income nations. It claims that the process that shapes urbanization creates risk factors for climate variability but sometimes the hazards could be unrelated to Climate change. Therefore there is a need for adaptation as an integrated response to all environmental hazards and risks. The authors introduce terms such as “concatenated hazards” and “natech events” which are prevalent in Indian Urban contexts related to climate change. The second part of the book examines the cases of global cities and their vulnerability to climate change and hazards. The third part of the book looks at the development strategies, policy, and governance issues that hold potential for development to adapt and mitigate climate change risks.

3. *Birkmann, J., Jamshed, A., McMillan, M. J., Feldmeyer, D., Totin, E., Solecki, W., . . . Alegría, A. (2022). Understanding human vulnerability to climate change: A global perspective on index validation for adaptation planning. Science of the Total Environment, 1-18.*
The authors compare the different vulnerability index or “internal validation methods” and “external validation methods” to assess their effectiveness of how the vulnerability matrix can be used at the times of disaster and extreme events. This assessment is based on how relevant the vulnerability indicators are. The article effectively differentiates the WRI (World Risk Index) and the INFORM index and point out the blind spots and limitations of these global indicators. Additionally, the article states the dependency of vulnerability onto the systemic barriers such as the socioecological system and the level of preparedness. Moreover, this article has aided in the identification of the aspects for determining the vulnerable groups/households in this research paper.

4. *Downing, T. E., Patwardhan, A., Mukhala, E., Stephen, L., Winograd, M., & Ziervogel, G. (2005). Vulnerability assessment for climate adaptation. In Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures (p. Chapter 3). IPCC.*
This chapter proposes a system of vulnerability assesment framework for climate change distinguishing them in terms of context and scale of analysis. It suggests that a framework should consist a two step analysis where one needs to access spatial indicators as well as identify the targeted vulnerable groups to prioritise the adaptation policy. This paper is overall helpful as a reference to adapt then level of indicators during the study in accordance to places, institutions and people knows as the units of analysis. Aditionally, this paper also presents the multi level vulnerability assessment in the the case of floods in Kenya.

5.*Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework. Tyndall Centre Working Paper No. 38 (pp. 1-20). Tyndall Centre for Climate Change Research and Centre for Social and Economic Research on the Global Environment (CSERGE).*
This paper aims to present a conceptual framework to study vulnerability and adaptation to the impacts of climate change and climate variability. It differentiates vulnerability into “biophysical vulnerability” and “social vulnerability” and their relationship with the apaptive capacity and the actual adaptation that is adressed. The paper also talks about the IPCC definitions of vulnerability and their consistencies.

DOMAIN 2 : Climate Change Impacts on the Urban Poor of South Asia

1. *Marolla, C. (2013, May). Climate Change Impacts on Health: The Urban Poor in the World's Megacities. Master's thesis, Harvard Division of Continuing Education.*
This thesis by Cesar Marolla examines the impact of climate change on the health risks and vulnerability to threats towards the urban poor which are caused due to the rapid and unplanned expansion of megacities. The author conducts a literature review on climate change and its effects on the environment, food security, diseases and endemics globally. The author also talks about the risk management frameworks, preventive methods for health risks for the potential future impacts of the climate change. The thesis concludes with recommendations for strategic approaches for cities to reduce GHG emission, adaptation and risk reduction costs and mentions the “Hestia Project” to suggest the use of bottom up methods to understand climate change and its projections.

2. *Amjad, K. (2019, October). Climate Change Impacts on Urban Poor: A Study on Slum People in Dhaka City. doi:0.9790/0837-2409104075*
This study is based on a qualitative as well as quantative research conducted at the slums of Dhaka. The urban poor are particularly vulnerable to the effects of climate change due to their limited access to resources and their concentration in low-lying, flood-prone areas. It finds that the major impact of climate change are damaging of shelter and othe household assets, water crisis and diseases due the problem of sanitation. The climate change also affects the income of the slum dwellers due to the unavailability of work. They take shelter on the roads or even nearby school and cope up with their losses by taking loans or use savings and even cut off their daily meal as they have extremely limited assets. The author provides recommendations at the end of the paper regarding development policies and programs to support the urban poor.

3. *Khosla, R., & Bhardwaj, A. (2019). Urban India and Climate change. In N. K. Dubash, India in a warming world (pp. 459-476). Oxford University Press.*
This chapter, written by R. Khosla and A. Bhardwaj, examines the impact of climate change on urban areas in India and how urbanization contributes to climate change in the forms of future energy demands, population growth, land use change, and industrialization. The authors also look at the role of government policies and private sector initiatives in addressing the impacts of climate change in Indian cities. They conclude by suggesting considerations by which climate actions can be mainstreamed in urban areas by three objectives namely structural changes and lock-in, multiple objective-based planning, and institutionalizing climate responses.

DOMAIN 3 : Community Based Adaptations to Climate Change

1. *Bicknell, J., Dodman, D., & Satterthwaite, D. (2009). Adapting Cities to Climate Change. Oxon: Earthscan.*
This book provides an understanding of the potential for adaptation and constraints of climate change in the urban areas of low to middle-income nations. It claims that the process that shapes urbanization creates risk factors for climate variability but sometimes the hazards could be unrelated to Climate change. Therefore there is a need for adaptation as an integrated response to all environmental hazards and risks. The authors introduce terms such as “concatenated hazards” and “natech events” which are prevalent in Indian Urban contexts related to climate change. The second part of the book examines the cases of global cities and their vulnerability to climate change and hazards. The third part of the book looks at the development strategies, policy, and governance issues that hold potential for development to adapt and mitigate climate change risks.

2. *Haque, A. N., Dodman, D., & Hossain, M. (2014). Individual, communal and institutional responses to climate change by low-income households in Khulna, Bangladesh. Environment and Urbanization, 112–129.*
This paper examines the relationship of adaptations to climate change in the context of the poverty stricken households of Khulna city. The study was drawn out of a quantitative dataset based on 550 household interviews and qualitative research on observations and focus group discussions to identify vulnerabilities. The domains of climate related hazard responses are devided into socioeconomic and built environment which are then categorised as communal, institutional and individual. The paper also provides a literature review on exploring the potentials and limits for CBA in Bangladesh. The study concludes that long term meaningful resilience is required to support the households and community through effective ways of influencing urban governance to highlights the need for increased support on the impacts of climate change on vulnerable populations.

3. *Archer, D., Almansi, F., DiGregorio, M., Roberts, D., Sharma, D., & Syam, D. (2014). Moving towards inclusive urban adaptation: approaches to integrating community-based adaptation to climate change at city and national scale. Climate and Development, 6(4), 345-356. doi:-DOI: 10.1080/17565529.2014.918868*
The ability for community-based adaptation (CBA) to climate change in metropolitan settings is discussed in this article. The authors argue that CBA is frequently disregarded in urban adaptation efforts, and that increased emphasis on CBA is required to achieve more inclusive and sustainable urban development. The article uses case studies from cities in India, Indonesia, and the Philippines to illustrate effective CBA initiatives, and it proposes that such projects should be expanded up and integrated into national and local policy. The authors conclude that CBA can help cities adapt to climate change in a more effective and fair way, and that further research and investment in CBA is needed.

4. *Fegade, A. (2012). To Establish Cause Effect Relationship between Flow In Kharicut Canal (Vatva – GIDC) And Groundwater In Its Vicinity Through Modeling. International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA) 2012. International Journal of Computer Applications.*
This paper examines the relationship between canal flow and groundwater levels in the Kharicut Canal located at Vatva GIDC area, using a modelling approach by collecting water from the tube wells of the area. It introduces the canal as an extension from the Khari River which is known to have no water release since 2011. Therefore the water that is there in the canal is polluted and has percolated through the walls of the canal causing a possibility to contaminate the ground water. The study concludes that the bore-well water exceed the permissible limit for TDS. The model developed in the study could be used as a tool for future research and management decisions.