Climate Change Vulnerability of the Urban Poor in Dhaka City: A Case Study of the Korail Slum

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STATEMENT OF AUTHENTICITY OF MATERIAL

This thesis contains no material which has been accepted for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis.

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ABSTRACT

Bangladesh is a developing coastal county in south Asia that face high climatic risks due to its geographical location in the coastal region. The capital city Dhaka in Bangladesh is the country's major economic center and it has a high contribution to the country's GDP. Considering the city's economic prospects, the poor from the rural region and the climatic migrants experiencing adverse climatic impacts (losses) at different parts of the country are migrating to this city. High migration has caused the high population density, infrastructural challenges and unplanned growth of this megacity. The migrated poor facing the city's infrastructural challenges and lack of affordable housing provision find their accommodation in the urban slums and informal settlements. Dhaka city contains the highest share of the slum population among all the urban areas in the country. Climate change has impacted the megacity Dhaka with temperature increase, heatwaves, change in rainfall's pattern and frequent urban flooding. The urban poor living in the slums due to their low adaptation capacity and high sensitivity to the climate change impacts in the city is the most vulnerable urban group. There is a lack of empirical research studies to understand the extent of vulnerability of the urban poor in Dhaka in different parameters. Such knowledge about the grassroots vulnerability extents would help to develop sustainable and inclusive climate policies in this developing country. This research addressed the research gap through the parametrical study of the vulnerability extent of the urban poor in Dhaka following the three dimensions of vulnerability framework as exposure, sensitivity and adaptive capacity. The study adopted a case study based method in the Korail slum which is the largest slum in Dhaka city. Formulating a climate risk matrix, the study analyzed the climatic problems, stresses and the poor's perceived risk levels for the studies area. Developing a Climate Vulnerability Index (CVI) within the scale of 0 (low) to 1(high) this research found that the surveyed urban poor group has a high level of climate vulnerability (0.956) in the urban context. It also embodied the high climate vulnerability extents of the urban poor in the studied community in the dimensions of sensitivity (0.711), and exposure (0.613) but low adaptive capacity (0.416). This study also analyzed the recent climate policies like NAPA (2005), BCCSAP (2009) and city development plans (Dhaka Structure Plan, 2016-2035) for their inclusive responsiveness to address/reduce the urban poor's climate vulnerability. It found that the national climate policies, action plans, and city development structure plan lack coordination, adequate policy instruments and directions for reducing urban poor's climate vulnerability. Based on the understanding from the grassroots climate vulnerability, assessment of policies and relevant empirical researches this study also developed sets of recommendations to reduce the climate vulnerability of the urban poor group. The recommended measures highlighted the strategies like the poor's affordable housing supply, improvement of tenure security, urban decentralization, skill development, adaptation training, poor's inclusion in the policies, etc. The researched insight from this study and the recommendations would pave the way for the future inclusive climate policy formation, necessary adjustments, and sustainable climate responsive urban developments.

Keywords: Climate change impacts, Vulnerability framework, Climate Vulnerability Index, Dhaka city, Urban poor, Korail slum, Climate policies.

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LIST OF ABBREVIATIONS

BCCSAP - Bangladesh Climate Change Strategy and Action Plan

DCC - Dhaka City Corporation

DMDP - Dhaka Metropolitan Development Plan

DWASA - Dhaka Water Supply and Sewerage Authority

GoB – Government of Bangladesh

IPCC - Intergovernmental Panel on Climate Change

MOEF - Ministry of Environment and Forest

NAPA - National Adaptation Program of Action

NGO - Non-Governmental Organisation

RAJUK - Rajdhani Unnyan Kartipakkha (Capital City Development Authority, Bangladesh)

UNFCCC - United Nations Framework Convention on Climate Change

Units

MLD - Millions of liters per day

lpcd - Litre per capita per day

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1. INTRODUCTION

1.1. Context

"*...hazards and disasters were not a result of physical events alone, but were also greatly influenced by the social, economic, and cultural conditions that contributed to hazardous exposures and the ability to plan for and manage them.*"

(Ford and Smit 2004, p. 392)

Climate change is a global phenomenon occurring due to the emission of greenhouse gasses and global warming. IPCC's fourth assessment report has defined climate change as any sort of change in the climatic condition over the times that may be occurred by natural variation or activities of human beings (IPCC 2007a, p. 6). Climate change bears a diversified impact on human settlements around the world at different scale and at different dimensions. The population in the cities is rising globally, 55% of the world's population reside in the urban areas and by 2050, the proportion of the world's urban population will be 68% (United Nations 2018a). Increasing the urban heat island effect, rising sea level, urban flooding, and increased frequency of natural disasters impact the people's lives in the cities, so, the cities in the world need adaptation measures to enhance resilience to cope with climatic impacts. Due to geographical location, the cities in the coastal countries are in the climate change disaster risk-prone areas. The coastal countries having low income or developing status are in the most vulnerable state for the climate impact risks (McGranahan, Balk & Anderson 2007; Nicholls 1995). IPCC's fourth assessment report in its 'summary for policymakers' has reported the poor communities as the most vulnerable due to the risk of climate change as they have the least adaptation capacity and high risk to access resources like water and food (IPCC 2007b, p. 12). Specifically, the informal urban poor in the megacities of the developing coastal countries where the population is increasing creating infrastructural challenges and inequality are the most vulnerable communities in the cities due to climate change (Ahmed, S. A., Diffenbaugh & Hertel 2009). They suffer the impacts severely due to their low means of subsistence in the city and inadequate adaptability options. There is a trend of research about how the adaptation measures can be developed for resilient urban development reducing inequality and incorporating the adaptation measures for the urban poor in the formalized climate disaster strategies [eg: in Mozambique (Broto, Boyd & Ensor 2015); in Ecuador, India, and South Africa (Anguelovski, Chu & Carmin 2014), in Nigeria (Adelekan 2010)]. This research attempted to study the grassroots urban poor's climate vulnerability in the megacity Dhaka in the developing coastal country Bangladesh. Based on the vulnerability assessments, it studied the responsiveness of the national climate policies and city development strategic plans to understand the urban poor's inclusion in the adaptation planning. The study also developed recommendations for promoting inclusive climate policies and resilient urban development considering the urban poor.

Bangladesh is a South Asian country, a delta with over 700 rivers flowing to the sea Bay of Bengal. Being a riverine delta and due to the proximity to the sea, the country suffers adversely from the climate change impacts, disasters, risks and stresses (figure 1). The capital city Dhaka contributes 36% to the country's GDP (2013-14) and provides 31.8% of the country's total employment as it is the most important and largest economic center of the country (RAJUK 2016, p. 136). The people from rural areas are migrating to the city in search

of better income opportunities and better livelihood opportunities. Climate change impacts add also the climate-migrants who congregate in this city from the coastal regions or other parts of the country in search of a job, livelihood and safe shelter after facing climate-induced losses (cyclones, salt-water intrusion in agricultural land, drought, riverbank erosion, etc). With high population density (43,578 people per sq. KM) Dhaka city is facing infrastructural challenges and unplanned growth (BBS 2014, p. 28). Rapid, unplanned urbanization and growth have gradually filled up the city's low-lying areas, water bodies and natural water drainage systems with build-up areas (Hassan & Southworth 2017, p. 14). So, after rainfall, the city experiences urban flooding and the lack of green spaces in the city also increases the temperature. Meteorological data analysis shows the temperature in Dhaka is increasing by 0.11℃ per year (from March to November) with high statistical significance (Rabbani, Rahman & Islam 2011, p. 5). The rainfall pattern has also changed which includes a decrease in rainfall frequency but an increase in the intensity. Projection reports, the 24-hour rainfall will increase by 16% by 2050 (than 2004) which would increase climate change-induced sufferings in this dense megacity (Dasgupta et al. 2015).

The rural poor and also the poor coastal people facing losses due to climatic impacts (climate migrants) congregate in Dhaka city with hope for economic potential and a better life, but they suffer from the climatic impacts in the city. The poor migrants due to the high cost of accommodation in the city make their accommodation in the informal slums and illegal squatter settlements near the rail tracks, vacant land near water bodies, lowlands, etc (Jahan 2012, p. 190; Ishtiaque & Mahmud 2017, p. 25). The urban poor find their livelihood options through informal jobs/activities in the city. 80% of the low-income labors are involved in informal activities in the city like rickshaw pulling, housemaid, waste picking, bus helper, street hawkers, garments industry worker (garments sector has a high contribution to the national economy), etc (Hossain 2005, p. 48; RAJUK 2016, p. 39). The 65% of the Dhaka city's employment is informal and 37.4% of the city's people live in the informal settlements (RAJUK 2016, p. 38; Angeles et al. 2009, p. 8). There are 3.4 million low income, urban poor people in the city living in over 4000 slums (RAJUK 2016, p. 119). The informal squatter and slum settlements lack the civic services and facilities which increases the climate impact risks for the poor. Lack of drainage system, water supply, climate protective houses, sanitation provision, waste disposal systems, capacity building initiatives increases the climate impact risks in the slums. Due to the low adaptation capacities, poor and informal nature of settlements and lack of inclusive civic amenities the urban poor are the most vulnerable groups in the capital city Dhaka for climatic impacts. The urban poor are contributing by service delivery to the city (e.g.: rickshaws providing transportation facility, housemaid, etc), maybe in informal ways but their social right in the urban development policy is often ignored or inadequate due to the embedded informality and inequality in this dense city (figure-02). The theoretical background for the urban poor's 'right to the city' is also linked to the context of the changing climatic condition and their climate vulnerabilities. This research tried to address a research gap to parametrically understand the climate vulnerability extents of the urban poor in different dimensions (and major components) of vulnerability framework. This research also studied the responsiveness of the national level climate policies and the city level structure plans for reducing the urban poor's vulnerability and formulated relevant recommendations.

1.2. Problem Identification

The capital city Dhaka being Bangladesh's major economic center contains the largest share (36%) of the country's total urban population (RAJUK 2016, p. 136). This city contains the highest share of the slum population among all the city corporations of the country (Angeles et al. 2009, p. 8). So, the climatic impact vulnerability studies on the urban poor of this megacity may contain high significance for the country considering its rapid urbanization and future resilient urban development. Climate change has its impacts on all urban people but the urban poor who are residing in the city's informal slums have the highest risk of vulnerability due to their low adaptive capacity. The urban heat waves increase the temperature during hot days and urban flooding impacts the social, health, physical, economic dimensions of the urban poor's living conditions. As the slum settlements are considered informal, contextually, there is a lack of proper/inclusive water services, sewerage systems, drainage systems, waste management, and other civic amenities (Baker 2012). To cope with the changing climatic condition, the urban poor in slums take different adaptation measures in their private household level (eg: making flood pediments, raising houses and furniture, use of creepers and trees to make the house cool during hot days, savings for disaster adaptation, etc) and in neighborhood-level (collective drainage system, water supply etc) (Jabeen, Johnson & Allen 2010). CBOs and NGOs are working at a scale for the urban slum's neighborhood-level adaptation measures (awareness, building social capital like training, provision of microcredit for repairing houses, etc). But low tenure security of the urban slum settlements and the national climate policy's negligence about the urban poor reduce their interests and scopes for climate-resilient development for the urban poor (Banks, Roy & Hulme 2011, pp. 493–494; Ahmed, I. 2014, p. 751).

UNFCCC guides the least developed countries (LDCs) to determine their priorities that are important for better climate-adaptive developments through the prevailing adaptation assessments (Haque, Grafakos & Huijsman 2012, p. 200). It directed the LDCs to formulate country-specific National Adaptation Program of Actions (NAPA) according to the local assessments, priorities and urgent adaptation options (Ibid). The Bangladesh Government has taken the National Adaptation Program of Action (NAPA) and Bangladesh Climate Strategy and Action Plan (BCCPSAP) but the resilience and the living condition of the urban poor have not been considered adequately in the strategic action planning (Ahmed, I. 2014, pp. 751–752; Araos, Ford, Berrang-Ford, Biesbroek & Moser 2017, p. 8). The local government and policies lack coordinations to assess the vulnerabilities and adaptation capacities for the most vulnerable urban poor groups. The National Disaster Management Bureau (DMB) and most NGOs are focussing on the rural areas for disaster-related strategies (Ahmed, I. 2014, pp. 751–752). The limited engagements of the government and NGOs and the urban poor communities are present to promulgate necessary adaptation strategies in the urban slum areas (Ibid). The capital city development master plan (Dhaka structure plan 2016-2035) addresses climatic impacts in Dhaka but it lacks the coordination and implementation tools for the climate action plans (Araos et al. 2017, pp. 8–9). It also lacks policy implementation tools/measures in reference to the urban poor settlement's climate resilience development (significantly, 37% of the city's people live in slums).

To improve climate impact resilience in the urban slums it is necessary to understand the urban poor's vulnerability condition (extents) at the grassroots level and likewise taking adaptation measures. Empirical knowledge from researches shall be integrated into practical

climate policy formation. The research trend on the slums in Dhaka city lacks the effort to understand the poor's climate vulnerability in any measurable parametric framework using a single scale or index. Literature reviews presented that some of past researches were focused on the descriptive overview of the slum's poor conditions, some researches only considered the urban flood and some researches had a broader focus on the whole city's people without specificity for the vulnerability of the urban poor. Addressing such a research gap by developing a climate vulnerability index for a particular slum would reveal and compare the vulnerable dimensions in the urban poor settlement. In a developing country like Bangladesh, such grassroots vulnerability assessment would help to develop inclusive climate policies or other climate resilience strategies for mobilizing limited resources effectively and alleviating the urban poor's climate impact risks.

Bangladesh: A South-Asian Country
Capital: Dhaka

Figure 1: Location of Bangladesh in the world map and location of the capital city Dhaka. Source: Based on CIA[1] and The Dhaka Tribune[2].

[1] CIA: www.cia.gov/library/publications/the-world-factbook/goes/print bg.html
[2] The Dhaka Tribune: www.dhakatribune.com/uncatagorised/2014/06/26/bangladesh

2. LITERATURE REVIEW

2.1. Dhaka City and Urban Poor Settlements

Dhaka, the capital city of the developing country Bangladesh having the population of 19.5 million (2018) is one of the world's most populous city and this megacity (city having more than 8 million population) has a population projection of 28 million by 2030 (United Nations 2018b, p. 17). The city has a population density of 43,578 per square kilometer (2011) and it has a yearly population increase rate of 3.96% (from 2001 to 2011) (BBS 2014, p. 28; RAJUK 2016, p. 37). The population growth rate is composed of the natural increase rate of 1.7% and the city's urban migration rate of (3.69% - 1.7%) 2.49% (RAJUK 2016, p. 37). So, migration is responsible for 63% growth of the total urban population in this city (Ibid). People from the rural parts of the country are coming to the city for different pull and push factors of migration. Jahan (2012, p. 188) has discussed that urbanization's better income opportunity, the hope of better life, good amenities, search for better livelihood comprise the main pull factors while environmental loss, poverty, landlessness, unemployment, lack of opportunities act as the push factors for internal migration in Bangladesh. The migrated poor in the Dhaka city being helpless, find their accommodation in the slums and squatter settlements as there is a lack of affordable housing options in the city (Ibid, p. 189) for the poor.

In Dhaka city, there is an increasing growth of informal slum settlements over the years. Figure 2 shows that in Dhaka there were just above 2000 slums in 1991 which had become more than doubled to 4966 slums in 2009 (by 18 years) (Nahiduzzaman 2012, p. 56). Angeles et al (2009, p. 8) have mapped the slums in the Dhaka Metropolitan City area and demonstrated that Dhaka city contains the highest slum living population among all the city corporations of the country, which is 3.4 million people or 37.4% of the whole city's population (figure 3, table 1). Banks et al (2011, pp. 494–495) discussed that the urban poor people living in the slum lack tenure security and also contain the high vulnerability to climate change impacts in the megacity Dhaka.

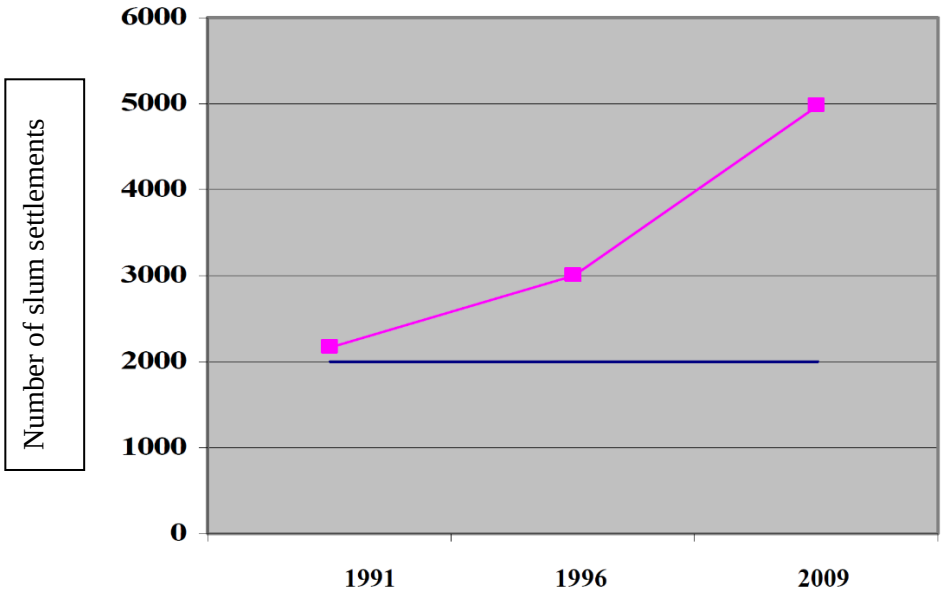


Figure 2: The increasing trend of the slum settlements in Dhaka city (1991- 2009).
Source: (Nahiduzzaman 2012, p. 56).

Table 1: The urban slum's characteristics among the city corporations in Bangladesh.

City	a	b	c	d	e	f	g	h	i	j
Dhaka Metropolitan Area	4,966	9,136,182	3,420,521	**5,715,661**	**1.67**	37.4	29,857	220,246	**19,677**	**0.089**
Chittagong	1,814	4,133,014	1,465,028	**2,667,986**	**1.82**	35.4	23,299	255,100	**15,543**	**0.061**
Khulna	520	966,837	188,442	**778,395**	**4.13**	19.5	20,346	132,988	**16,884**	**0.127**
Rajshahi	641	489,514	156,793	**332,721**	**2.12**	32.0	9,544	67,236	**6,796**	**0.101**
Barisal	351	365,059	109,705	**255,354**	**2.33**	30.1	7,152	133,730	**5,084**	**0.038**
Sylhet	756	356,440	97,676	**258,764**	**2.65**	27.4	12,961	154,741	**9,630**	**0.062**

a) Number of slum communities
b) Overall 2005 population (estimate)
c) Slum population
d) Non-slum population
e) Ratio of non-slum to slum population
f) Slum population as a percent of city population
g) Overall population density (persons per Km^2)
h) Slum population density (persons per Km^2)
i) Non-slum population density (persons per Km^2)
j) Ratio of non-slum to slum population density

Source: (Angeles et al. 2009, p. 8).

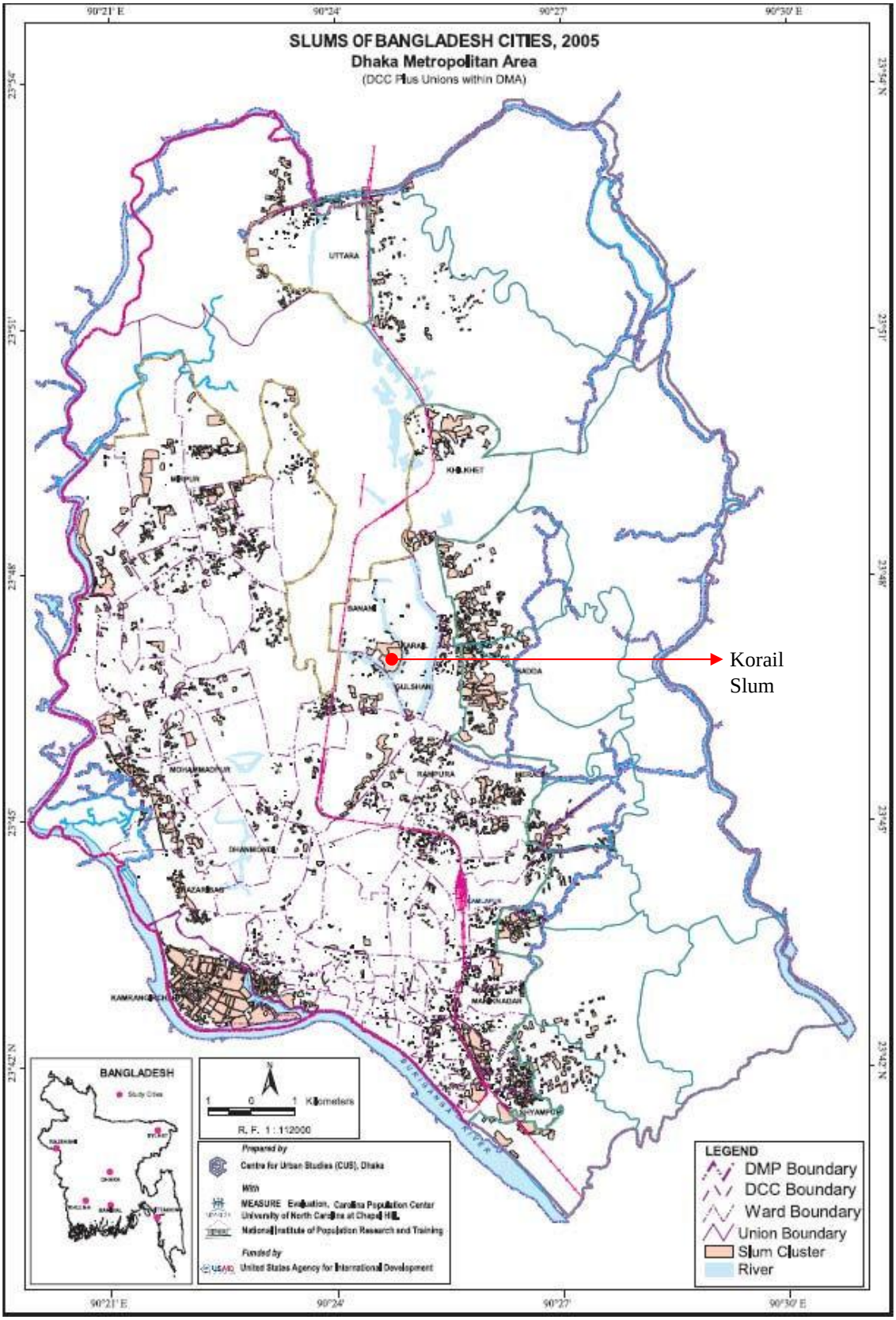


Figure 3: Dhaka city Slum map.

Source: (Angeles et al. 2009, p. 6).

2.2. Climate Change in the Megacity Dhaka

Global climate change impact has affected Dhaka city's local Urban environment, infrastructure, and living conditions. World Bank (2000, p. 11) reported that due to global climate change impact, the temperature in Bangladesh would increase by 0.7℃ during the monsoon season and 1.3℃ during the winter season by the year 2030. It predicted that by 2050, the temperature would increase by 1.1℃ in monsoon and 1.8℃ in winter (Ibid). The temperature's increasing trend was also found to be reflected in the Dhaka city's temperature. Rabbani, Rahman & Islam (2011, p. 5) have analyzed the yearly average temperature's changing trend with the 30 years meteorological data (from 1980 to 2009) which shows that the city's yearly temperature from the month of March to November has an increasing trend (figure 4). The study found that in recent years (2005 to 2009) the average temperature from March to November had increased at a rate of 0.11℃ per year signifying high statistical confidence value (R^2=0.9548) (figure 5). It also reported the increasing frequency of heatwaves in the city owing to the increasing trends in temperature. The heatwaves and temperature increase have negative impacts on human health and the economic productivity of the poor laborers (Ibid, pp. 5–6).

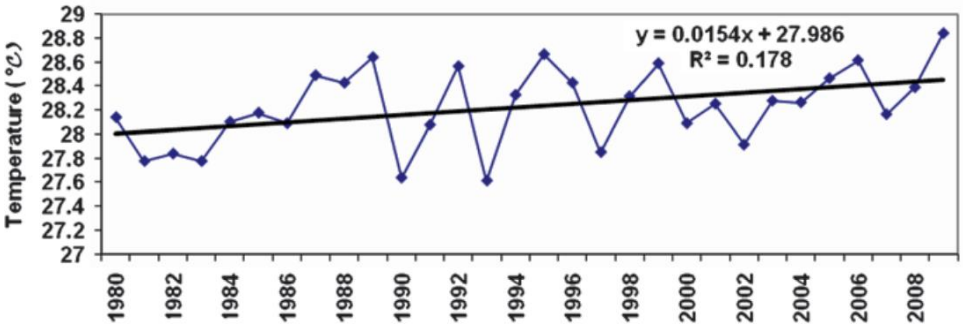


Figure 4: Trends in average temperature change from March to November in 30 years (1980-2009).

Source: (Rabbani, Rahman & Islam 2011, p. 5)

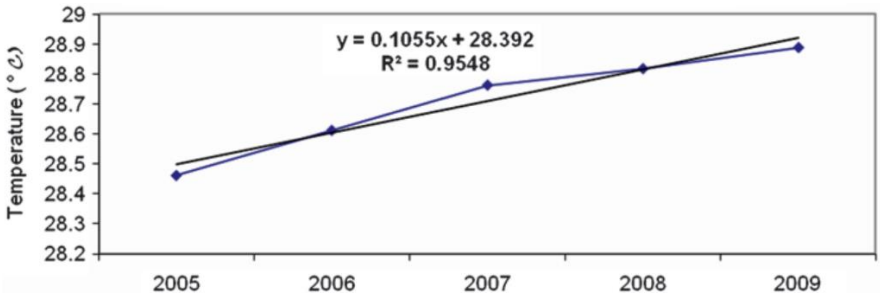


Figure 5: Trends in average temperature change from March to November in recent years (2005-2009)

Source: (Rabbani, Rahman & Islam 2011, p. 5).

A World Bank (2000, p. 11) study reported that the precipitation in Bangladesh would increase during the monsoon season but follow a decrease at other seasons. It predicted, by 2050, the 24-hour precipitation would increase by 16% than the base value of 2004 and 70% rainfall would occur during the monsoon season (June-August) (Dasgupta et al. 2015, pp. 199–200).

Alam and Rabbani (2007, pp. 87, 89) have analyzed Dhaka's rainfall data from 1971 to 2005 which shows that the number of days without rain has increased. Ahammed, Hewa & Argue (2014, pp. 179–180) have analyzed the rainfall data of 57 years (from 1957 to 2009) of Dhaka city that shows, the annual rainfall has a yearly increasing trend of 4.54 mm. But in recent times (from 2000 to 2009) the annual rainfall pattern has an increasing trend of 55.90 mm per year (figure 6). The study has also formulated a rainfall forecast from 2010 to 2066 which (with a very high statistical significance, R^2= 0.97) predicts that the frequency of the estimated annual rainfall will adopt a decreasing trend, but the extreme rainfall will have an increasing trend (figure 7).

Such analytical result may signify two things that the city's rainfall's frequency has decreased aggravating the adverse effects of temperature increase, heatwaves and droughts while the intensity of rainfall has increased causing occasional heavy rainfall and urban flooding. Due to the city's increasing population, urbanization and unplanned growth, the previous low-lying areas, canals, and natural watery areas have been transformed to build-up areas, so, with light rainfall, the city gets flooded very quickly (Dewan & Yamaguchi 2009). The resilience of the city's infrastructure and urban life in the changing climatic context is very vulnerable.

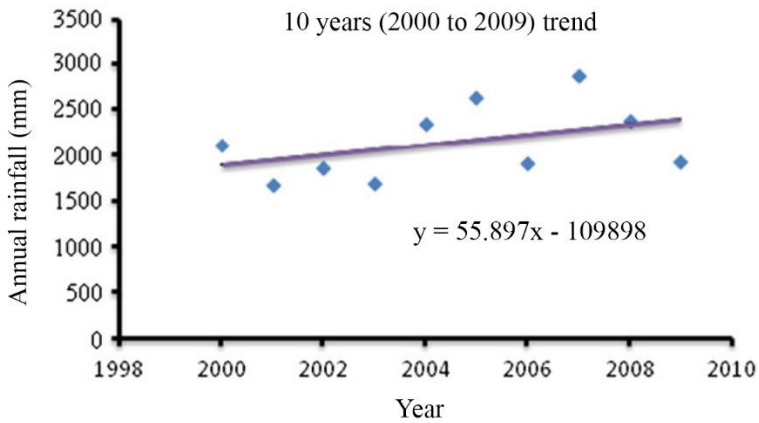


Figure 6: Annual rainfall trend in Dhaka city in recent years (from 2000 to 2009).
Source: (Ahammed, Hewa & Argue 2014, p. 179).

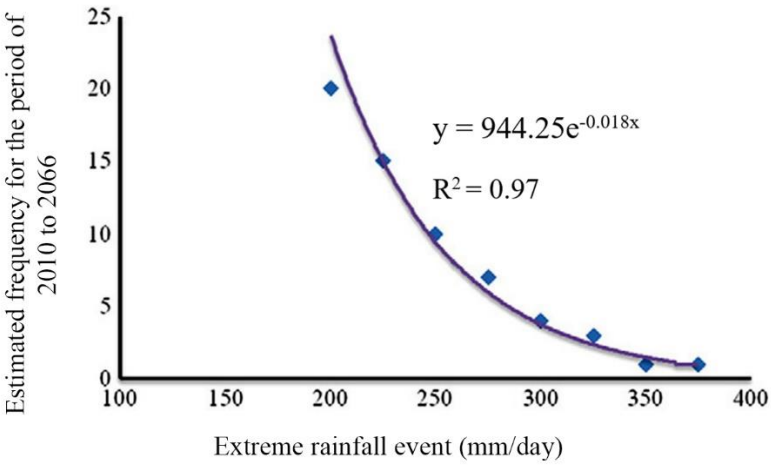


Figure 7: Forecast for rainfall pattern change in Dhaka city (from 2010 to 2066).
Source: (Ahammed, Hewa & Argue 2014, p. 181).

2.3. Description of the Case Study: *Korail* Slum, Dhaka

Korail slum is located in the central part of Dhaka city, (latitude 23°46'36.7752" N and longitude 90°24'25.2720" E) under administrative ward 9 and 10 of Dhaka City Corporation area and it is the largest slum community in this megacity (figure 8) (Jabeen, Johnson & Allen 2010, p. 419; Biplob, Sarker & Sarker 2011, p. 20). This slum was developed during the late 1980s at the vacant high ground near the water body (lake) at the Gulshan and Mohakhali areas which were the city's high class residential and industrial areas. Over time the slum community expanded along the bank of the waterbody and accumulated over 1,00,000 population covering over 90 acres of land (Jabeen, Johnson & Allen 2010, p. 419). Presently, the Korail slum is enclosed at the east and south by the 'Gulshan Lake' (water body) which is the natural water reservoir for the surrounding areas and the other sides (west and north) sides are close to the high class residential or commercial areas of Gulshan and Mohakhali. Such location of the slum alongside the waterbody naturally creates a vulnerable condition for the poor's precarious settlement and they frequently suffer from climate-induced hazards like flood, waterlogging, heavy rainfall, and heatwaves. Due to the proximity of the slum community to the high-class communities, the poor slum dwellers for their income generation get involved in the informal service delivery to those high-class communities such as rickshaw pulling, household helping (maids), petty businesses, street hawking, etc (Ibid).

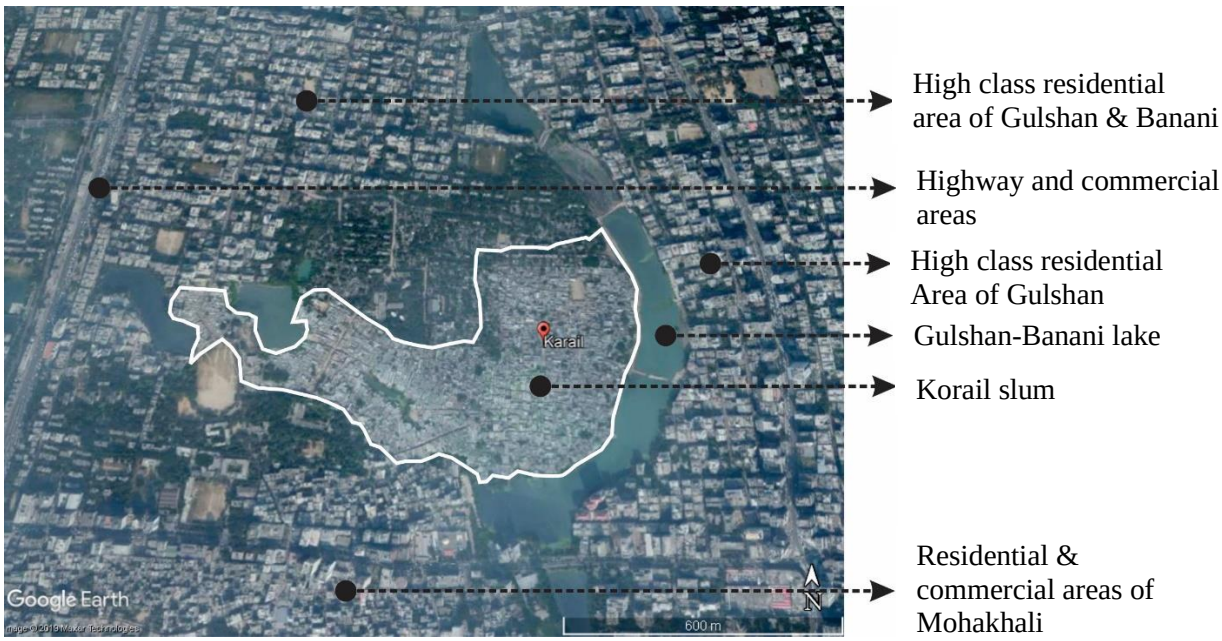


Figure 8: Annotated location map of the Korail slum area in Dhaka.

Source: Authors representation based on (Google Earth 2019).

The land where the slum had grown over the years occupies unsolved, disputed ownership among different parties such as the Ministry of Telephone and Telegraph, the Public Works Department (PWD) and other private bodies (Jabeen, Johnson & Allen 2010, p. 420). The government had acquired land from different original private landowners through PWD for using in the development of Telephone and Telegraph board, but other new development plans had increased the dispute of legitimacy. In such unsettled, disputed condition urban poor

inhabitants had encroached at the vacant land and developed low-cost self-help housing which had extremely low tenure security and might face the threat of eviction. Some local politically influential parties (or local gangsters) developed low-cost houses in this location and used to rent them to the poor migrants to make money. Due to the low tenure security, poor inhabitants generally are not willing to spend their money on developing their living conditions and infrastructural services (Ibid). The low tenure security and recognition have also resulted in the disinclination of the city's service providing organizations for giving the slum dwellers legitimate access to the civic facilities. Banks et al (2011, pp. 493–494) have argued that different NGOs are working in the urban region but their presence and activities in the urban poor's slum areas are very limited and less than their development initiatives in the country's rural parts. For the low tenure security, low recognition of the urban poor in policy issues, an influential culture of local political strongmen (*mastaans*) discourage the NGOs to invest in the development of poor settlement located in such a disputed location (Ibid).

2.4. Research-gap: Climate Change Vulnerability Studies in Dhaka

White's Climate change impact research back in 1974 considered the local region's exposure to understand and situate the global climate-related risk on a local scale (White 1974). But climate change related risk may not only confine to a region's proximity to coastal regions and exposures to the disastrous events. Nicholls's (1995) study considered megacities as the cities having more than 8 million population and reported that the costal megacities would be severely affected by sea-level rise and related urban problems. This study also reported that the fast urbanization process generates new megacities: in the 1950s there were only two megacities (London & New York), 20 megacities in 1990 and projected for 30 megacities in 2010. The study included Dhaka as a coastal megacity due to its very fast population increase, unplanned growth, land use, low capacity to deal with climatic risks and urban flooding as it has intrinsic but not direct exposure to the sea and coastal storms. Setting a research ground, Nicholls's study demonstrated, climate change would adversely impact urban life in the megacity Dhaka.

Turner et al's (2003) study had developed a 'vulnerability framework' for climate change's impact on the biosphere based on the Risk Hazard model and Pressure Release model. The 'vulnerability framework' considered three dimensions as exposure, sensitivity and coping capacity of a local system for global climate change impacts. De Sherbinin, Schiller & Pulsipher (2007) used the vulnerability framework's dimensions for their study and provided a descriptive understanding of the climate change impacts on the selected global cities of Mumbai, Rio de Janeiro, and Shanghai. Their study reported that the most vulnerable groups for climatic risks were the people having high exposure and sensitivity but low coping capacity to climatic impacts. The vulnerability framework (with exposure, sensitivity and adaptive capacity dimensions) developed by Turner et al (2003) may also be useful for understanding the local urban poor settlement's (the scale of 'place') climate vulnerability in Dhaka.

Alam & Rabbani (2007) had provided a descriptive study about Dhaka city's contribution to global climatic problems through the anthropogenic greenhouse gas emissions and the global climate change's local impact risks for the city. The study described the climate risk-related vulnerability's effects and impacts on infrastructure, livelihood, trade commerce, utility services in Dhaka. It also reported the measures adopted through different development programs in the greater city scale. It stated that for flood protection in greater Dhaka, initiatives

like embankments, raised roads, pump stations, and water reservoirs were adopted. It argued to develop natural drainage systems by protecting canals from illegal filling by the local politically influential people. However, the study lacked specifically addressing the climate change impacts on the Dhaka's urban poor settlements and adopted response measures. So, the urban poor's vulnerability level due to changing climatic conditions could not be determined by this descriptive study. But setting a research ground, the study argued that the urban development initiatives in Dhaka need to be climate resilient to face the increasing climatic impacts, vulnerabilities and also need to consider the incoming climatic migrants.

Jabeen, Johnson & Allen's (2010) study described the urban poor's grassroots coping practices for adaptation to climate-related risks and disasters. It considered the coping practice as the strategies adopted by the local poor by using the available resources, networks, and previous knowledge to face similar climatic problems. The study has reported, 'coping strategy' considers the climatic problems to be the same as experienced before but 'adaptive capacity' considers the climatic variabilities and extreme conditions as well (Ibid. pp. 416-417). The study recommended incorporating local grassroots knowledge in municipal policy developments and climate action plans for improved climate resilience of the poor community. This descriptive study lacked the use of any empirical framework to parametrically measure and compare the vulnerability's extents/levels in different dimensions of urban poor settlements in Dhaka. Such an understanding of vulnerability levels (in different dimensions) would guide sustainable resource mobilization and policy developments.

Rabbani, Rahman & Islam (2011) had studied the climate change scenario in Dhaka city by the statistical analysis of meteorological data and reported the problems of temperature increase, heatwaves, rainfall pattern change and frequent flooding in the city as the major climate-related risks. The study also argued to adopt immediate and necessary measures to reduce the climate change vulnerability of the whole Dhaka city's people. The analytic study presented climate change impacts in Dhaka, but it lacked the considerations of vulnerability levels specifically of the urban poor community due to climatic impacts.

Parvin and Shaw (2011) did an interesting analytic study for climate resilience assessment by the CDRI (Climate Disaster Resilient Index) framework for 10 different administrative zones of the whole Dhaka city. The study used an indicator based 5×5×5 matrix for analyzing CDRI and produced a mapping of climate disaster resilience of Dhaka city's different administrative regions. It collected data from the 'officials' working at zone level through 125 questions (developed for 5×5×5 matrix) using 1 to 5-point rating scales to calculate the individual indicators. However, the study was not focused specifically on the urban poor groups and considered the resilience in a broader/holistic context of the city for all classes of people. So, the vulnerability and resilience level of the urban poor (most disadvantaged group) in Dhaka cannot be determined by this study. But this study may develop a research ground to parametrically (using a scale/index) study the climate vulnerabilities of the urban poor by using the data from the local places (the grassroots level).

Braun & Aßheuer (2011) studied the flood vulnerability in Urban slums in Dhaka by a survey (sample size was: 625 respondents in 5 slums). It analyzed the flood's effect on the livelihood and flood induced vulnerabilities of the urban people using indicators and percentages. The study confined itself only to the flood vulnerability of the urban slums excluding other climatic impacts. Moreover, it did not use any single scale to measure and compare among the flood vulnerability indicators for their impact on the livelihood of urban poor. A similar parametric study of climatic impact on livelihood for the case of Mozambique

by Hahn, Riederer & Foster (2009) presented the vulnerability indicators to a comparable extent. Their study adopted a methodology to address the IPCC's vulnerability parameters of exposure, sensitivity and adaptive capacity, and the methodology was also congruent with Turner et al's (2003) vulnerability framework (Hahn, Riederer & Foster 2009, pp. 75–76; Turner et al. 2003, pp. 8076–8077). Hahn, Riederer & Foster's (2009) study presented the parametric study of the livelihood vulnerabilities based on the vulnerability framework's three dimensions which may validate the research ground for the urban poor's parametric climate vulnerability assessment.

Choudhury & Mowla (2011) reported the climate impacts and the climate refugee influx to the capital city Dhaka city for the major climatic impact scenarios in Bangladesh like the inundation of the flood plains and coastal part the country, salinity problems, riverbank erosion, and adverse weather condition. The study also argued the adaptation strategies for the climatic impacts by adopting losses sharing, threat modification and prevention, and change in livelihood options. But the descriptive study lacks to assess/quantify climate impact vulnerabilities of the migrated poor or other urban poor community in the megacity Dhaka and analytically study the problems. However, the study may develop the research context for the climate vulnerabilities of the migrated poor and set exploratory grounds for promoting better strategic adaptation options for climate impacts.

DePaul (2012) studied the climatic impacts, climate refugees and migration in Megacities, rapid urbanization and infrastructural problems in Bangladesh and India (Mumbai). Accepting Tacoli's (2009) research arguments the study pointed out that most of the policies in the lower or middle-income countries perceive environment-induced migrations not as local adaptation strategies. Addressing an empirical debate, the studies discussed the importance of policymaker's normative perception shift about the environmental crisis-induced internal migrations and urbanization. The studies argued that policies tend to change the volume, direction and mobility pattern rather than accepting the climate-induced migrants for 'positive potentials' and plan for them for the betterment of climate adaptation capabilities (DePaul 2012, p. 158; Tacoli 2009, pp. 514–515). Such descriptive studies lacked reference to the urban poor's climate vulnerability assessment but pointed out the debatable nature of policies in the lower or middle-income countries for climate adaptation issues.

Haque, Grafakos & Huijsman (2012) studied the adaptation measures for the flood vulnerability through a participatory study for the low lying areas in Dhaka city. The study has reported, UNFCCC suggests assessing the priority adaptation strategies for better adaptation actions at the national level through the formulation of National Adaptation Programmes of Actions (NAPA) for the least developed countries (LDCs). The study analytically studied the measures for a better flood resilient environment with the focus on the whole Dhaka city. Considering the criteria of cost, ecological conditions, public and political acceptance, the achievement of MDGs and technical capacity it assessed the predominant measures for reducing flood vulnerability in Dhaka city. The study confined itself only to the flood adaptation measures excluding other climatic impacts and lacked the references to the urban poor's vulnerability levels. But this study can set the research ground for studying the NAPA or other climate policies and the urban poor's inclusion levels.

Mowla & Islam (2013) provided a descriptive study of the destruction of the natural drainage system in Dhaka and dependency on the manmade sewage system with the increasing urbanization process. It reported, in past, the city had natural water drainage systems like rainwater flowing to lowlands and water infiltration to the ground but the built forms and hard

surfaces that came up with high urbanization pressure destroyed that natural system creating urban floods. The study also described the social, physical, economic and environmental impacts of waterlogging on the urban life of the whole Dhaka city. However, the study lacked any parametric assessment of the vulnerabilities for the waterlogging problem or other climate-induced problems on the urban poor's life in Dhaka. This study may signify a research ground for the study of climate impact on the urban poor settlements incorporating the social, physical, economic and environmental aspects.

Ahmed (2014, pp. 751–752) reported that NAPA and also Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2008 lacks adequate consideration of the urban poor's resilient living conditions and developing the strategic discourses linking the poor's initiatives at the grassroots level. This descriptive research did not present the urban poor's climate vulnerability levels but it can form the research ground for studying the climate policies considering the poor's climate vulnerability.

Table 2 compiles chronologically all the literature discussed above for summarising the empirical insights from the previous researches and refers to the study of the urban poor's climate vulnerability in Dhaka. The understanding from the discussion of the chronological literature shows, the studies of global climate change's impacts at the local scale of Dhaka city were confined mostly to the descriptive studies; some studies contained the broader focus with all classes of urban people, and some studies had specific focus to a particular climatic problem (e.g. flood). Most importantly, the 'vulnerability studies' for the urban poor who are the most vulnerable group in a megacity like Dhaka lacks the analytical reasoning to assess their 'climate vulnerability by any measurable or parametric framework. So, there is a research gap to understand the extent of climate vulnerability of the urban poor in the megacity Dhaka based on any measurable parameters/indexes and to perceive the priorities of vulnerable dimensions of the urban poor's life in the city. However, Pandey and Jha (2012) reported a methodology for determining the Climate Vulnerability Index, CVI to quantify the extent of climate vulnerability at a local place/settlement which can be easily adapted to other case studies. This thesis had adopted the calculation methodology from their study to assess the vulnerability extents in its case study area (Korail slum) addressing the above-mentioned research gap.

Table 2: The literature reviewed for assessing the research contribution to the vulnerability study of urban poor in Dhaka city.

Author(s)	**Objective**	**Data/ Methods**	**Results**	**Comments/ Contribution to the vulnerability study of the urban poor in Dhaka**
(White 1974)	To study the local place's vulnerability for global climate change	Descriptive study	Understands climate vulnerability only based on 'exposure' to the disastrous events.	Climate vulnerability is not only confined to the exposures to disastrous events or coastal context. So, the concept of vulnerability was inadequate.
(Nicholls 1995)	Studies vulnerability of coastal megacities	Descriptive study	Reported vulnerable megacities for climatic impacts	Forming research ground, it reported Dhaka as a coastal megacity facing climate impacts due to the high population increase, unplanned growth, and low coping capacity.
(Turner et al. 2003)	To study the analytic frameworks for understanding climate vulnerability	Analytic study based on RH and PAR models for studying vulnerability	Development of vulnerability framework incorporating a place's exposure, sensitivity, and coping capacity	Vulnerability framework's exposure, sensitivity, and adaptive capacity components can be applicable to the local scale of urban poor settlements (place) in Dhaka for assessing climate change vulnerability.
(De Sherbinin, Schiller & Pulsipher 2007)	To study the most vulnerable urban groups for climate change impacts	Used the vulnerability frameworks components for case studies from Mumbai, Rio de Janeiro, and shanghai	Reported the most vulnerable urban groups are those having high exposure and sensitivity but low adaptive capacity.	The study may set research grounds to assess the vulnerability condition of the urban poor in Dhaka using the vulnerability framework.
(Alam & Rabbani 2007)	To study Dhaka city's contribution to global climate change (GHG emission) and climate change impacts in city life.	It studied Dhaka's emission sources; analyzed meteorological data for studying urban floods and provided a descriptive study of climatic impacts in urban infrastructure, trade, commerce, livelihood and utility services	Emission: Fossil fuel burning in residential, energy, transport and commercial sector. Climate change occurring heat stress, floods, drainage problem adversely impacts civic life. Also reported some adopted measures	The study lacked addressing the climate change impacts specifically to the urban poor community and the poor's vulnerability level due to changing climatic conditions could not be determined by the descriptive study.
(Jabeen, Johnson & Allen 2010)	To study the urban poor's coping practices (at the grassroots level) in Dhaka for climate impacts resilience	Descriptive study based on the case study method	Described the poor's coping strategies and argued to incorporate the grassroots knowledge in developments	The descriptive study lacked presenting any comparative, parametric framework to assess the poor's measurable extent of vulnerability at different dimensions of vulnerability framework (exposure, sensitivity, and adaptive capacity).
(Rabbani, Rahman & Islam 2011)	To study the changing climatic condition in Dhaka	Statistical process of meteorological data analysis	The temperature in Dhaka city is increasing, and the rainfall pattern has changed. The study suggested adopting immediate policy measures to reduce the	The study had presented the changing climatic scenario in Dhaka with scientific analysis forming a research ground, but it lacked the assessment of vulnerability levels/extents for the urban poor community.

Author(s)	Objective	Data/ Methods	Results	Comments/ Contribution to the vulnerability study of the urban poor in Dhaka
			vulnerability of whole Dhaka city people.	
(Parvin & Shaw 2011)	To study the existing climate disaster resilience levels in whole Dhaka	CDRI method: collected indicator-based data from the officials of 10 administrative zones. It used a 5x5x5 matrix (125 survey questions) for mapping resilience levels in the city.	Developed parametric mapping of the disaster resilience for the 10 administrative zones of Dhaka city through climate disaster resilience indexing	The study had a broader contextual view of the whole Dhaka city and all classes of city people. The extent of vulnerabilities and resilience levels specifically of the urban poor could not be determined by this study.
(Braun & Aßheuer 2011) Similar study: (Hahn, Riederer & Foster 2009)	To understand the flood vulnerability in the urban slums in Dhaka (Hahn, Riederer & Foster 2009): To understand the livelihood vulnerability index for climatic impact in Mozambique	It conducted a questionnaire survey of 625 respondents from five slums in Dhaka. (Hahn, Riederer & Foster 2009): Conducted a questionnaire survey in the case study region. This analytical study used the vulnerability framework and relevant indicators.	Analyzed flood's impacts on livelihood and other flood induced vulnerabilities of the urban poor using indicator and percentages. (Hahn, Riederer & Foster 2009): The results presented a single scale parametric comparison among the studied components	The study confined itself only to the urban flood's impacts excluding other climatic crises. It did not use any single scale for parametric comparison of the extent of climate vulnerabilities. (Hahn, Riederer & Foster 2009): The methodology is useful for the parametric study of climate vulnerability levels.
(Choudhury & Mowla 2011)	Studied the problem of climate change impacts and climate refugee influx to Dhaka city	Descriptive study	Discussed the climate refugee influx problem to the Megacity Dhaka and argued different climate adaptation strategies.	The study lacks assessing the climatic impact on the migrated or other urban poor in Dhaka. It lacks insights from grassroots to analytically understand the vulnerability levels of the urban poor in the megacity Dhaka.
(DePaul 2012) and (Tacoli 2009)	Studied climate refugees, migration and urbanization in the megacities of India (Mumbai) and Bangladesh	Descriptive study about the climatic impacts in the context of India and Bangladesh.	Argues that environmental migration could be viewed as an adaptation strategy and policies should plan for the migrant's better adaptation capabilities.	The study has no reference to the vulnerability of the urban poor but setting a research ground, pointed out the debatable nature of the policies in the lower /middle-income countries.
(Haque, Grafakos & Huijsman 2012)	To understand the priority flood adaptation strategy in the low-lying areas in Dhaka city	Participatory method of data collection (stakeholders and experts). Analytical study based on different criteria for assessment	Studied the measures for better flood resilience based on the criteria of cost, ecological conditions, public and political acceptance, MDGs and technical capacity	The study confined itself to the flood adaptation only excluding other climatic impacts. It lacked presenting the vulnerability levels of the urban poor. It may set the research scopes for further climate vulnerability research.
(Mowla & Islam 2013)	Studied the natural drainage problems and	Descriptive study	Reported the adverse impact of the waterlogging problem in	The study confined its focus only on the urban water logging problem. The descriptive study also

Author(s)	Objective	Data/ Methods	Results	Comments/ Contribution to the vulnerability study of the urban poor in Dhaka
	waterlogging in Dhaka city and their impacts on urban life		urban life in Dhaka. Also argued to adopt some social, physical and planning measures to address the problem.	lacked any specific consideration to the urban poor's vulnerability to waterlogging and other climate impact problems.
(Ahmed, I. 2014)	To explore the issues for improving the resilience of urban slums for hazards context	Descriptive study	Presented challenges and opportunities for developing climate resilience in the slums. It also reported that climate policies are not responsive to the poor.	The descriptive study did not present the poor's vulnerability level for climate change. However, it can develop research scopes for studying the poor's vulnerabilities and climate policies.
(Pandey & Jha 2012)	To understand the climate vulnerability index in Himalaya, India	Analytical study based on a questionnaire survey in two regions in Himalaya India (25 respondents each).	Presented vulnerability extents based on a comparable parametric framework (in a single scale of measurable).	The methodology was found useful for the parametric study of climate vulnerability levels of the urban poor in Dhaka city with context-specific adjustments.

Source: Author's literature review.

3. ABOUT THIS RESEARCH

The knowledge about grassroots climate vulnerability, adaptation capacity from the urban poor community, activities of NGOs, and the strategic climate planning from the governance perspective can be linked to improving the urban poor's climate resilience (Broto, Boyd & Ensor 2015). The goal of this research was to parametrically study the climate vulnerability of the urban poor in Dhaka city, then studying the responsiveness of the climate policy and city development strategies addressing their vulnerability. Based on the empirical study, it also demonstrated sets of measures as recommendations that would help to reduce the urban poor's climate vulnerability. Adopting the case study method, a Climate Vulnerability Index (CVI) using grassroots level data was formulated to understand the vulnerable dimensions of the urban poor community. The methodology adopted by Panday and Jha (2012) to calculate the CVI for Himalaya in India was used in this research with relevant context-specific modification for the Korail slum in the megacity Dhaka.

3.1. Research Questions

The research questions of this thesis were:

1. What are the present major problems, risks and stresses the urban poor in the Megacity Dhaka are facing due to the climate change impacts?

2. To which extent the urban poor in the megacity Dhaka are vulnerable to climate change impacts, stresses, and shocks?

3. How responsive are the climate-related policies for reducing the climate vulnerabilities of the urban poor in the megacity Dhaka?

The main significance of this study is that it tries to focus on the research gap of understanding the extent of climate change vulnerability of the urban poor in the megacity Dhaka using a measurable parameter for different dimensions of vulnerability framework. It used grassroots data from field surveys for measuring the extents of the urban poor's climate vulnerability using an index (Climate Vulnerability Index, CVI) following a single scale (from 0 to 1) for different dimensions. It also studied the responsiveness of climate policies to develop relevant recommendations to reduce the urban poor's climate vulnerability.

3.2. Aim and Objectives

This research aims to study the climate vulnerability extents of the urban poor in the megacity Dhaka and develop a set of recommendations to reduce their climate vulnerability. To attain this aim following objectives were formulated (Table 3):

Table 3: Objectives and relevant Methods of the study.

Objectives	Methods
1. **Problems/Impacts:** Understanding the problems, stresses, and shocks for climate change impacts on the urban poor.	• Case study: CBPRA, surveying slum area/fieldwork • Developing Risk Matrix.
2. **Areas & extent of Vulnerability:** Understanding the extent of vulnerability of the urban poor the megacity Dhaka for climate change impacts (based on vulnerability framework).	• Case study: questionnaire surveying in the slum area, observation • Developing Climate Vulnerability Index (CVI).
3. **Responsiveness of the climate policies:** Studying the responsiveness of climate policies, action plans, and city-level strategic plans for the reduction of the urban poor's climate vulnerability.	• Secondary sources of data: The literature synthesis of policy documents or research articles.
4. **Recommendation:** Conceptualizing the key initiatives for reducing climate vulnerability of the urban poor as a set of recommendations.	• Based on empirical Understandings from literature and objective 1, 2, 3 • Group discussion with the community people.

Source: Author's representation.

3.3. Conceptual Framework

This thesis acknowledged the empirical research gap about the extent of the climate vulnerability of the urban poor in Dhaka (literature reviewed). It adopted the case study-based approach through the field surveys at the Korail slum which is the largest slum in the city. The study analyzed the risks and shocks due to climate change's local impacts on the urban poor at this settlement. With the surveyed grassroots data, it measured the extent of climate change vulnerability at different dimensions. Then it studied the responsiveness of the climate policies and city-level development strategies for reducing urban poor's climate vulnerability. Based on the researched empirical insights, the study finally provided recommendations for a better inclusive, climate-resilient environment for the urban poor (figure 9).

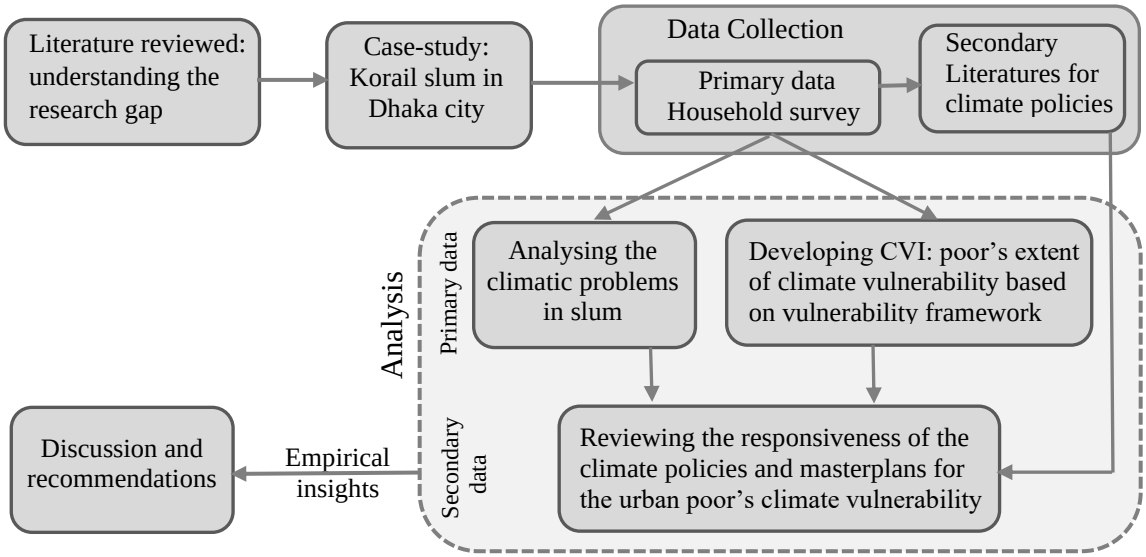


Figure 9: Conceptual Framework of the study.
Source: Author's representation.

3.4. The Vulnerability Framework

The researches of environmental change at a global scale focus on the improved understanding of the human and biosphere systems, functions and their interactions (Steffen, Jäger, Carson & Bradshaw 2002). The studies of the 'sustainability science' considers meeting the present human need and protecting the global environment for future needs. The questions arising from the process of meeting environmental science and practical sustainable systems are complex. For prioritizing the issues in the decision-making process, mobilizing the limited resources the research experts have developed different frameworks (or conceptual models) for a better understanding of human systems and environmental conditions (Kates et al. 2001, p. 641; Turner et al. 2003, p. 8074).

The vulnerability studies by Risk Hazard (RH) model try to understand a system's vulnerability as the degree of harm a system or its components would face for its exposure to any hazard or perturbations (Turner et al. 2003, p. 8074; Kates 1985; Burton, Kates & White 1993). It studies a system's vulnerability as the function of its exposure to the stresses, problems and perturbations and its sensitivity or the response level ('dose-responses') for the problems (figure 10). It overlooks the system's capacity characteristics for increasing or decreasing the hazard/impact's risk, the social, economic, political, and institutional contexts as well as the hazard levels for the affected system's different units (Turner et al. 2003, p. 8074). Such disadvantages have led to the recognition of the Pressure-And-Release (PAR) model of vulnerability studies.

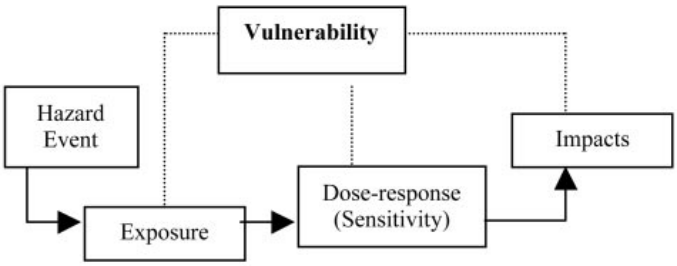


Figure 10: Vulnerability studies by RH framework.

Source: (Turner et al. 2003, p. 8075).

The Pressure-And-Release (PAR) model studies the vulnerability for the affected system's 'exposed units' as the function of the stresses, perturbations, and stressors (Blaikie, Cannon, Davis & Wisner 1994, pp. 8–10; Turner et al. 2003, p. 8074). It focusses on the situations and conditions that make the risky and unsafe exposure of the system's units under consideration for assessing the hazards, stress, perturbations, and stressors (figure 11). This model seeks to understand the vulnerability condition of different local social groups (social classes, social communities, ethnic groups, etc) for their exposures to environmental risks (Ibid). However, this model is not appropriate for applying to the broader human and bio-physical environment and their interaction. This incorporates less concentration on the hazard structures, the sequence of sensitivities and their interactions (Turner et al. 2003, pp. 8074–8075).

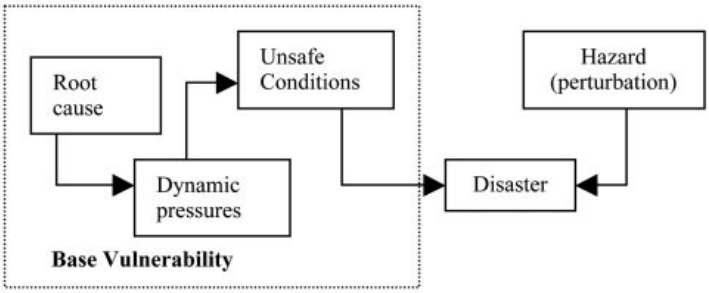


Figure 11: Vulnerability studies by PAR framework.

Source: (Turner et al. 2003, p. 8075).

The RH and PAR framework are not individually adequate to study the vulnerability of the human and bio-physical conditions and their sustainable interactions due to considerable limitations in the study's focus (Turner et al. 2003, pp. 8074–8075). The 'place-based' (human and environmental, biophysical coupled) approach of vulnerability analysis focuses on the need to understand the vulnerability in operational local scale for global concern like climate change. Turner et al (2003, p. 8076) had presented a 'vulnerability framework' (figure-12) incorporating the risk dynamics, vulnerability components and their linkages with functional spatial scales (place, region and global scale). With three different colors of blue, yellow and green it represented respectively the functional realm of place, region and world scales for human-environmental interaction, risks and responses. It shows, a local place's system can experience vulnerability due to the impacts (stress, parturbations, hazards) arising from human and environmental influences that may be occuring outside of the place's scale but in the realm of regional and global scale. The local (place) knowledges of coping capacities, resilience and adaptation strategies can lead to form the 'impact response' or the 'adaptation response' for broader regional and global scales (Ibid).

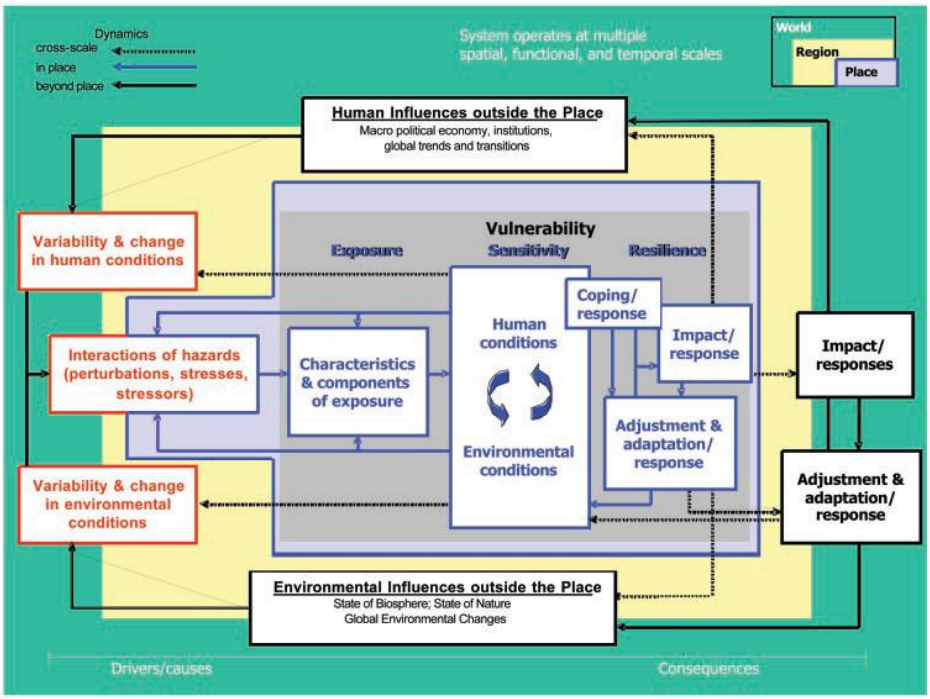


Figure 12: The vulnerability framework's relationship with different scales.

Source: (Turner et al. 2003, p. 8076).

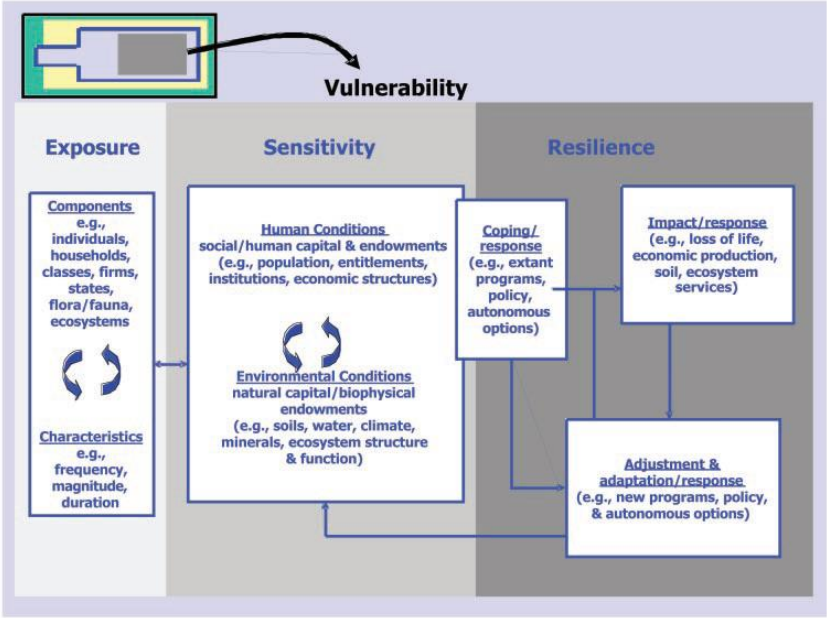


Figure 13: The vulnerability framework: vulnerability's dimensions at '*place*' (local) scale. Source: (Turner et al. 2003, p. 8077).

The local scale's (place) vulnerability analysis shows it has three different dimensions for understanding vulnerability arising from its human-environmental interaction (figure 13). 'Exposure' is the vulnerability of different components of human settlements (individual, classes, households, etc) due to the frequent risks and disasters. 'Sensitivity' is the vulnerability of the system occurring from different interactions of human conditions (social, economic, political and institutional structures, etc) and environmental conditions (soil condition, water, local climatic condition, ecosystem functions, etc). 'Resilience' is the adaptive responses occurring by the coping responses (due to programs, policy capacities, etc) and the impact responses (due to loss of income, production, etc).

The IPCC's third assessment report (working group II) also considers the three dimensions for climate change vulnerability as 'exposure', 'sensitivity' and 'adaptive capacity' which are also congruent with Turner et al's vulnerability framework (IPCC 2001, p. 6). The definition of climate vulnerability by IPCC is presented in box 1.

Box-1: Definition of vulnerability by IPCC

'Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.'

Source: (IPCC 2001, p. 6).

3.5. Structure of this Thesis

This paper is composed of seven consecutive sections. Followed by the first section of the introduction the second section incorporates the literature reviews relevant for the study and introduces the research gap. The third section explains the research including its aim, objectives, research questions, and conceptual frameworks. The fourth section represents the detailed methodology for the research and the fifth section analyses the surveyed data. The fifth section, using three subsections presents the analysis developed to answer the research questions of this study. The sixth section presents the discussions and recommendations based on the study and the seventh section develops the conclusion including judgments of future research from this study.

4. DATA & METHODOLOGY

4.1. Overview

Different methodological frameworks were considered in this study. To assess the climate risks and stresses it considered Community Based Participatory Risk Assessment (CBPRA) method and formulated a climate risk matrix for the survey area. To understand the extent of climate change vulnerability, it adopted the Climate Vulnerability Index (CVI) calculation methodology from Pandey and Jha's (2012) similar study at Himalaya (with contextual adjustments). To understand the responsiveness of the climate policies reviewing the works of literature, policy papers (from secondary sources) were considered. The methodology section discusses the detailed methods of the study.

4.2. Data of the Study

The primary data was collected from the case study location through the questionnaire surveys in the households of the study area and observations. 50 households were surveyed for the study based on a random selection in the community. The settlement consisted of similar or homogeneous characteristics for the household's condition. So, high variation in the responses would not be found for increased samples. For the houses (*bari)* that contained several families, randomly one family or household was surveyed to attain greater diversity of the context. The survey was done by the author in the month of August and September in 2019 and two local people helped in the process. The data was collected while making discussions with the respondents in the Bengali language following a questionnaire and each discussion lasted for 30 to 40 minutes. The detailed survey questionnaire is added to Annex 1. During data collection or discussion, if needed, the respondents were helped to understand the questions by brief explanations. Secondary data was collected from scientific research articles, books, journal papers, policy papers, strategy papers, etc.

4.3. Climate Risk Matrix Analysis

The household survey questionnaire contained Likert scales for mapping the grassroots perception about climate-related problems, their 'probability of occurrence/frequency' level and 'consequence/impact' level. Based on perception, the respondents had to list the climate-induced problems, stresses, and shocks and put a mark on the scale for their frequency and

impact level. Probability of occurrence/frequency contained five scales such as 5- very high, 4- high, 3- moderate, 2-low and 1-very low. Level of impact also contained five scales such as 5- catastrophic, 4- major, 3- moderate, 2- minor, 1- insignificant.

From this data, a climate disaster risk matrix was prepared based on a democratic process or the majority (by percentage) of the respondent's judgment/perception. The risk matrix classified the climatic risks in five categories: very high, high, moderate, low and negligible risks based on the risk's characteristics (frequency and impact) as perceived at the grassroots level.

4.4. CVI Calculation

A system's Vulnerability is the function of its three components of exposure, sensitivity and adaptive capacity (equation 1) which are considered as the dimensions of vulnerability (Pandey & Jha 2012, p. 492). The higher exposure and sensitivity bear a positive influence on vulnerability (increase) but the higher adaptive capacity bears negative influence on vulnerability (decrease) (Ford & Smit 2004, p. 393).

Vulnerability = *f* (exposure, sensitivity and adaptive capacity) …… (1)
(Pandey & Jha 2012, p. 492)

Following the climate vulnerability assessment by Pandey and Jha (2012), the dimensions of vulnerability were divided into eight major components and each major component was further sub-divided into multiple sub-components. The eight major components of CVI were the socio-demographic profile, livelihood strategies, social networks, health, food, water, natural disasters, and climate variability. The major components correspond to the dimensions of vulnerability according to their types and their sub-components are developed according to the relevant context-specific attributes. Table 4 shows the CVI's dimensions and their respective major components while table 5 details the subcomponents adopted for each major component.

To determine the CVI of the study area, this research adopted the methodical framework from a similar study of Punday and Jha (2012). The brief explanation about the associated calculation steps are discussed below:

- **<u>Step 1- Standardisation of 'subcomponents/variables':</u>** Each subcomponent contributes to the major components equally. The sub-components were adopted from the relevant literature, contextual observation, and key informant's suggestions. Data was collected by the household survey of the urban poor settlement at the case study location.

  The scale of the measurement of each individual sub-component can be different from one another. So, a method of indexing or normalization of the subcomponents was used as follows (equation 2):

  $$\text{Indexed Sub-component values} = \frac{S - S_{min}}{S_{max} - S_{min}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

  Where,
  S is the sub-component value found from the household survey
  S_{max} and S_{min} are respectively maximum and minimum value range for sub-components.

The reason to use the indexed values was to normalize/transform all the different types of individual subcomponent values to the proportion values on the same scale of 0 to 1. For a percentage value of any subcomponents, the maximum value (S_{min}) will be 100 and the minimum value (S_{min}) will be 0 according to the value range. For other types of subcomponent values (e.g. time, distance, etc if used) the highest and lowest recorded data can be considered for maximum and minimum value range. In the study, some index-type subcomponents were also used (e.g. Livelihood Diversity Index, LDI, House type diversity index, etc based on literature) that are also recorded on the same proportion scale of 0 to 1.

Example:
If the household survey found, 88% of the surveyed household reported climatic impacts (flood, water stagnation, drought, etc) increases the water crisis, then the indexed subcomponent value for this sub-component was calculated as follows:

Indexed Sub-component values = $\frac{S-S_{min}}{S_{max}-S_{min}} = \frac{88-0}{100-0} = 0.88.$ (on 0 to 1 proportion scale)

- **<u>Step 2- Calculating the values for 'major components':</u>** A major component had several subcomponents. After the indexing of the subcomponents, relevant major components was calculated by the following formula (equation 3):

$$\text{Value of a major component, M} = \frac{\Sigma\, Indexed\ subcomponents}{n} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$= \frac{\Sigma\, Indexed\ subcomponents\ of\ a\ particular\ major\ components}{number\ of\ subcomponents\ \ that\ major\ component\ contains}$$

Here, 'n' is the number of subcomponents a particular major component contains.

Example:
The major component 'socio-demographic profile' contains 6 subcomponents with individual indexed values. So, the value of major component 'social demographic profile' can be calculated as follows:

Major component	Subcomponents	Indexed values	Major component = Σ indexed subcomponents/n
Socio-demographic profile	Index of family dependency	0.63	$= \frac{0.63+0.2+0.82+0.38+0.16+0.12}{6}$
	Index of house type diversity	0.2	
	% of the households having only one bedroom dwelling	0.82	
	% of the households head having no schooling	0.38	$= \frac{2.31}{6}$
	% of the households having at least one child not attending school	0.16	= **0.385**
	% of female-headed household	0.12	

- **<u>Step 3- Weights/weighting the major components:</u>** The major components contributed to the CVI's respective dimensions based on their weights to ensure the proper judgment according to their degree of influence to the final indicator. Several weighting methods are used by researchers to determine the weights (W) of the major components. Following the

studies of Pandey and Jha (2012, p. 497) and Hahn, Riederer & Foster (2009) this study adopted the 'equal weighting approach' where the weights of the major components were determined by its number of the subcomponents. In this manner, each subcomponent contributed equally to the major component (or in CVI) even though different major components had different numbers and types of subcomponents.

Example: If the major components of 'socio-demographic profile', 'livelihood Strategies' and 'social networks' under 'adaptive capacity' dimension have respectively 6, 7 and 7 numbers of subcomponents, then by the equal weighting approach, the weights of those major components will be as follows:

Dimension	Major components	Number of subcomponents	Weights (W)
Adaptive capacity	Socio demographic profile	6	$W_{a1} = 6$
	Livelihood Strategies	7	$W_{a2} = 7$
	Social networks	7	$W_{a3} = 7$

- **<u>Step 4- Calculating the values of the 'dimensions' of CVI:</u>** Table-4 shows the methodology to determine the values for individual dimensions of CVI by calculating the weighted average values of the relevant major components (equations 4, 5, 6). For calculating the value for adaptive capacity dimension, the inverse values of the vulnerability subcomponents (1- the indexed scores) were considered for the associated major components of socio-demographic profile, livelihood strategies and social networks (Hahn, Riederer & Foster 2009, p. 87; Ahsan & Warner 2014, p. 39). (Please see annex 4 for the calculation process).

Table 4: The framework for calculating the values for individual dimensions of CVI.

Dimensions	Major components (MC)	Calculated MC's vulnerability values from indexed subcomponents *(by step 2)*	Weights (W) *(by step 3)*	MC's inversed vulnerability scores for calculating 'Adaptive capacity'	Individual dimension's value (weighted average values of relevant major components) *(step 4)*
Adaptive capacity	• Socio-demographic profile	*SD*	W_{a1}	*SD'= (1-SD)*	Adaptive capacity = $\frac{W_{a1}SD' + W_{a2}LS' + W_{a3}SN'}{W_{a1} + W_{a2} + W_{a3}}$ …… (4)
	• Livelihood Strategies	*LS*	W_{a2}	*LS'= (1-LS)*	
	• Social Networks	*SN*	W_{a3}	*SN'= (1-SN)*	
Sensitivity	• Health	*H*	W_{s1}	*Not applicable as they are vulnerability components*	Sensitivity= $\frac{W_{s1}H + W_{s2}F + W_{s3}Wa}{W_{s1} + W_{s2} + W_{s3}}$ …… (5)
	• Food	*F*	W_{s2}		
	• Water	*Wa*	W_{s3}		
Exposure	• Natural Disasters	*ND*	W_{e1}		Exposure= $\frac{W_{e1}ND + W_{e2}CV}{W_{e1} + W_{e2}}$ …… (6)
	• Climate Variability	*CV*	W_{e2}		

Source: Based on (Pandey & Jha 2012; Ahsan & Warner 2014; Hahn, Riederer & Foster 2009).

Example:
Let us consider for the process of step 2, the major components of 'health', 'food' and 'water' under 'sensitivity' dimension have respectively the values of 0.600, 0.666 and 0.906. If each of the above mentioned major components has 6 numbers of subcomponents, then by the equal weighting approach (by step 3), the value/vulnerability score of the 'sensitivity' dimension will be as follows:

Dimension	Major components	Calculated MC value from indexed subcomponents *(by step 2)*	Number of subcomp-onents	Weights (W) *(by step 3)*	The value of an individual dimension of CVI
Sensitivity	Health	0.600	6	$W_{s1} = 6$	Sensitivity= $\frac{W_{s1}H + W_{s2}F + W_{s3}Wa}{W_{s1} + W_{s2} + W_{s3}}$ $= \frac{6\times0.600 + 6\times0.666 + 6\times0.906}{6+6+6}$ = **0.711**
	Food	0.666	6	$W_{s2} = 6$	
	Water	0.906	6	$W_{s3} = 6$	

- **<u>Step 5- Calculating the Climate Vulnerability Index (CVI):</u>** CVI parametrically measures the vulnerability of a system to confront climate-induced risks or stresses. Adopting from the studies of Pandey and Jha (2012, p. 497), following formula (equation 7) was used for calculating CVI:

$$\text{CVI} = 1 - \left| \left\{ \frac{N_1 \times Exposure - N_2 \times Adaptive\ capacity}{N_1 + N_2} \right\} \right| \times \frac{1}{Sensitivity} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where,

N_1 = the number of major components used for 'Exposure' dimension
N_2 = the number of major components used for 'Adaptive capacity' dimension
Exposure = the value of the dimension 'Exposure' found by step 4
Adaptive capacity = the value of the dimension 'Adaptive capacity' found by step 4
Sensitivity = the value of the dimension 'Sensitivity' found by step 4.

By equation 6, the weighted CVI index was calculated by inferring the index on the per unit basis of its parameters. The CVI was calculated in the 0 to 1 range. In calculation, the inverse value of the sensitivity was considered so that the per-unit strength/capability of the system to adapt ('absolute performance') with the climate impact could be calculated. (Please see annex 5 for the calculation process of CVI by this study.)

- **Developing a vulnerability spider diagram:** The vulnerability spider diagram had presented the extent of the values of the major components in a graphical representation. It showed the comparison of the extent of vulnerabilities in different parameters (8 major components) of the studied urban poor settlement. This diagram/spectrum of vulnerability's parametric comparison (on a single scale) had represented the

components/factors requiring improvement for the urban poor's better adaptation with climate change impacts in Dhaka city.

- **Developing a vulnerability triangle:** With the three CVI dimension's values (adaptive capacity, sensitivity, and exposure) a comparative vulnerability triangle was prepared (on a single scale). It had graphically compared the vulnerability extents of the dimensions to study where the urban poor in the study area had more strength and weakness for coping with climate risk. This parametric diagram identified the dimensions needing improvement for the poor's better adaptation to climate change.

4.5. Study of the Policy Initiatives

This section provided a descriptive study about the present national-level climate adaptation policy initiatives and city-level development strategies that interpreted information from secondary sources. The relevant secondary source's information was adopted by reviewing the available literature like published books, scholarly article papers, policy papers, strategic masterplans, etc.

4.6. Limitations

The research studied the climate-related risks, shocks, and stresses through the documentation of the household's perception by the Likert scales (0-low to 5-high) for developing the probability and frequency matrix. The analysis unconditionally depended on the respondent's qualitative reasoning to understand the grassroots perceptions and was completely a subjective framework in the study area.

The study adopted a methodology from a similar study available from the scholarship of the research's context for climate vulnerability analysis. To understand climate vulnerability (by CVI) a specific set of major components (8 components) were considered based on the available framework in literature. The study did not incorporate new major components to the CVI parameters as it would need significant research justification, and which was outside of the scope of this research. The sub-components of CVI and the related survey questions were context-specific and in this study, they were selected based on the available literature, contextual observation, and key informant's suggestion. There would be diversified sets of sub-components and different sets of survey questions depending on the context of a region, but this study had limited itself within the selected subcomponents. Moreover, each survey question itself may contain potential limitations for improper understanding by the respondents and the provision of inappropriate data though explained to the respondents. The survey tried to assess the grassroots experience for vulnerability, hence, the information collected from the households were considered true based on the best of their knowledge.

For the adaptation policy initiative study, this research provided a descriptive study and tried to find the gaps/lacking in the initiatives for a better resilient environment for the urban poor. But as the initiative lacking has a time-specific influence and this study focuses on the present case-specific scenarios so, after a certain period, new gaps or new problems may arise for a certain region.

50 household was surveyed for this research due to the limitations of the resources and available time for conducting the study. Though the settlement has similarities in household characteristics, similar studies with larger sampling from the same/different population may attain more saturated data from the fieldwork. Different age of the person questioned, political inclination, freedom of response (for fear of eviction), social/family bonding, may have influence in the results.

Table 5: Major components and Sub-components of CVI.

Major components	**Sub-components**	**Explanation about sub-component**	**Survey questions**	**Reference** (Adopted from)
Socio-demographic profile	Index of family dependency.	A ratio calculated from the population up to the age of 18 years and over 55 years to the population between 19 to 54 years.	Household data about member's age.	(Pandey & Jha 2012, p. 493)
	Index of house type diversity.	The inverse function of (number of house type +1) based on the household's report.	House types: Building materials.	(Pandey & Jha 2012, p. 493)
	% of the households having only one-bedroom dwelling.	% of households who reside in a one-bedroom dwelling	The number of occupying rooms in the household.	Key informant's suggestion.
	% of the households head having no schooling.	% of households where the household head does not have any schooling for an education	Schooling level (class) of the household head	(Hahn, Riederer & Foster 2009, p. 77)
	% of the households having at least one child not attending school.	% of households that contain at least one child between 4 to 15 years not attending school.	The number of children (4 to 15 years) not attending school.	Key informant's suggestion
	% of the female-headed households.	% of households where the household is headed by a female.	Sex of household head.	(Hahn, Riederer & Foster 2009, p. 77)
Livelihood strategies	% of the households having migrated members.	% of the households having at least one migrated member for earning.	Migrated members in the household for earning.	(Pandey & Jha 2012, p. 493)
	% of the households having no access to tenure security.	% of the households having a threat of eviction due to insecure, informal household tenure.	If the Household has access to housing with tenure security in the city.	(Payne 2002, p. 153); Key informant's suggestion.
	% of households reported being a tenant of an informal squatter house.	% of household who are residing as a tenant in an informal squatter house as they have no other accommodation option.	How the household respondents are residing in the house: as Tenant/ house owner/ other.	Key informant's suggestion.
	% of the households having a lack of access to climate disaster protective building materials.	% of households reported a lack of access to climate-resilient building materials for housing.	Household's affordability for or access to climate protective building materials.	Based on: (Braun & Aßheuer 2011, p. 778)
	% of the household's head having no special training or formalized skills.	Household head's skill assessment for livelihood.	Does the Household head have formalized skills and special training/vocational skills?	(Braun & Aßheuer 2011, p. 779)

Major components	Sub-components	Explanation about sub-component	Survey questions	Reference (Adopted from)
	% of the households reported a loss in income during climatic impacts.	Financial capital's assessment for livelihood vulnerability.	If the household had experienced a loss in income due to climatic impacts (e.g. during heat waves, floods, cold waves, etc).	(Braun & Aßheuer 2011, p. 778) and key informant's suggestion.
	Livelihood diversification index.	The inverse function of (number of livelihood activities +1) as reported by a household.	List the activities of the male and female member of the household for income	(Hahn, Riederer & Foster 2009, p. 77)
Social networks	% of households reported getting assistance from social organizations or NGOs due to climate impact.	% of households reported seeking/getting help from different social networks.	If the household seeks support/ assistance from social organizations or NGOs due to climatic impacts.	(Pandey & Jha 2012, p. 494)
	% of households reported not to save money for future climate disaster's risk.	% of the households who do not save money for preparedness for future climate disaster's risk.	If the household saves money for climatic crisis conditions.	Key informant's suggestion.
	% of the households reported maintaining a good relationship with neighbors and help each other during the climatic crisis.	% of households who have good neighborhood relationships and help each other during the climatic crisis.	If the household provides support or help to other neighboring households during the climatic crisis?	(Pandey & Jha 2012, p. 494)
	% of households engage in money transactions with friends due to climatic reasons.	% of household reported engaged in borrowing or lending money with friends due to natural calamities	If the household lends or borrows money from friends during a climatic crisis.	(Pandey & Jha 2012, p. 494)
	% of households not accessing governmental offices for climatic assistance (in the last 1 year).	% of households reported that they did not access any local governmental offices for getting help for adverse climatic impact.	If the household accessed any govt offices for climatic assistance (last 1 year).	(Hahn, Riederer & Foster 2009, p. 78)
	% of the households having no television.	% of the households not having television as a mean of direct information transfer.	If the household has any television set.	Key informant's suggestion.
	% of the households having no mobile phone.	% of households not having mobile as a mean for information and communication with peers.	If the household has any mobile phone set.	Key informant's suggestion.
Health	% of the households reported illness/diseases due to climatic issues.	% of the households who reported suffering from illness due to climatic. impacts (heatwaves, heavy rainfall, flood, and cold waves).	If any household member suffered from any diseases during or due to climatic reasons.	(Pandey & Jha 2012, p. 494)

Major components	Sub-components	Explanation about sub-component	Survey questions	Reference (Adopted from)
	% of the households reported stress (physical and mental) owing to adverse climatic impacts.	% of households reported experiencing stress (physical and/or mental) owing to climatic issues.	If the household faces any physical or mental stress during or due to climatic reasons.	(Pandey & Jha 2012, p. 494)
	% of households reported an outbreak of new diseases.	% of households reported new diseases owing to climatic issues.	If the household observed any type of new disease due to climatic/environmental issues?	(Pandey & Jha 2012, p. 494)
	% of the households reported having a member with chronic illness.	% of households reported having at least one member with chronic illness.	If the family/household contains any member with chronic illness requiring regular treatment.	(Hahn, Riederer & Foster 2009, p. 77)
	% of the households require to spend a minimum of 1000 BDT in every month for treatment.	% of households who spent monthly greater or equal to 1000 BDT for treatment (a significant portion of income).	Household's monthly expenditure for health issues/treatment.	Key informant's suggestion.
	% of the households need to access private clinics for low capacity of public (Governmental and NGOs) hospitals in the last 12 months.	% of households who needed to access private clinics which are usually expensive than government or NGO's public hospitals.	In the last 12 months, where did you mostly go for treatment?	Key informant's suggestion.
Food	% of households earning food by informal physical labor-intensive work.	% of households earning daily food supply by informal labor-intensive work which relies heavily on their physical condition.	How does the household mainly earn food?	Key informant's suggestion.
	% of the households reported inadequate food supply due to the climatic crisis.	% of households experienced a decrease in food production due to climatic reasons.	If the household faced insufficiency in food supply during the climatic crisis situations (flood, heavy rainfall, hot days, cold waves, storms, etc)?	Adopted from: (Pandey & Jha 2012, p. 495).
	% of the households reported expending at least half of their income for food.	% of households reported expending half of their income or more for food supply.	How much the household expends monthly for the food of the family/ household?	Key informant's suggestion.
	% of the households reported consuming 'less expensive' and 'less preferred' food during the climatic crisis.	% of households experienced consumption of 'less expensive and less preferred' food during climatic impacts for income loss.	If the household experienced consumption of 'less expensive' and 'less preferred' food during climatic impacts?	(Keck & Etzold 2013, p. 86); Key informant's suggestion.

Major components	Sub-components	Explanation about sub-component	Survey questions	Reference (Adopted from)
	% of the households reported a decrease in the supply of nutritious food during the climatic crisis.	% of households experienced a decrease in nutritious food like fish, meat, dairy and fruits.	If the household faced any change in your daily supply of nutritious food (e.g. dairy, fruits, fish, meats, etc) during the climatic crisis (flood, heavy rainfall, hot days, cold waves, storms, etc)?	Adopted from: (Pandey & Jha 2012, p. 495)
	% of households reported not having a direct agricultural food supply.	% of the households having no supply of food from the direct agricultural process within the city (gardening etc).	If the household had a provision of getting food from direct agricultural process or gardening?	(Pandey & Jha 2012, p. 494)
Water	% of the households reported an inadequate supply of water throughout the year.	% of the households having an inadequate amount of water throughout the year.	If the household got an adequate quantity of water throughout the year.	(Hahn, Riederer & Foster 2009, p. 79; Pandey & Jha 2012, p. 495)
	% of the households reported the supplied water is not drinkable other than purifying.	% of households reported the supplied water is not drinkable and they need to purify to make it safe for drinking.	If the household could directly drink the water that it gets from the usual water source.	Key informant's suggestion & (Pandey & Jha 2012, p. 495)
	% of the households reported climatic impacts to increase the water crisis.	% of households who reported that climatic impacts (flood, heavy rainfall, hot days, cold waves, storms) increased water crisis.	If the household faced that climatic impacts (e.g. hot days, waterlogging, flood) affect water problem.	Key informant's suggestion.
	% of the households reported contamination of water due to climatic impacts.	% of the households experiencing water contamination during climatic impacts.	If the household has experienced water contamination during adverse climatic impacts.	Key informant's suggestion.
	% of the households having no access to a tubewell.	% of the households having no convenient provision for getting water directly from a tubewell.	If the household has access to the tube well for water.	Key informant's Suggestion.
	% of the households having no access to natural water sources.	% of the households who do not have access to water from natural sources like lakes, rivers, etc.	If the household can use the water from the natural sources (lake, river, etc) to meet water demand.	(Pandey & Jha 2012, p. 495)
Natural Disasters	% of the households reported a loss of property owing to natural disasters.	% of household reported physical property damage owing to climatic extreme events: falling of wall;	If the household has experienced the loss of property or houses due to natural disasters (e.g. breaking of	(Pandey & Jha 2012, p. 496)

Major components	Sub-components	Explanation about sub-component	Survey questions	Reference (Adopted from)
		damaging of the roof, door, windows, balcony; livestock loss, washing out of crops, loss of agricultural land, etc.	the wall, balcony, houses, loss of livestock, etc).	
	% of the households experiences flood or inundation of household.	% of households reported water logging in the household and poor drainage.	If the household faces the inundation of household and poor drainage.	Key informant's suggestion.
	% of the households reported not getting a warning before the climatic crisis.	% of the households reported not getting a warning before any climatic crisis like heatwaves, floods, heavy rainfall, drought, storm, cold waves, etc.	If the household gets any warning before climatic disasters.	(Hahn, Riederer & Foster 2009, p. 79)
	% of the households reported not to participate in any disaster preparedness/awareness program.	% of the households reported who did not participate in any climatic disaster-related awareness or preparedness program led by any organization.	If the household participated in any disaster preparedness/awareness program.	Key informant's suggestion.
	% of the households reported an increase in the overall natural disaster's frequency.	% of households reported according to their perception the natural disaster's frequency is increased.	Household's perception of natural disaster's frequency.	Adopted from: (Pandey & Jha 2012, p. 496);
	% of the households reported an increase in the overall natural disaster's intensity.	% of households reported according to their perception the natural disaster's intensity is increased.	Household's perception of natural disaster's intensity.	Adopted from: (Pandey & Jha 2012, p. 496);
Climate variability	Index for temperature and hot month's perception.	The inverse function of (change +1) based on the household's report.	Household's perception of temperature and hot month's pattern.	(Pandey & Jha 2012, p. 496)
	Index for rainfall pattern perception.	The inverse function of (change +1) based on the household's report.	Household's perception of rainfall pattern.	(Pandey & Jha 2012, p. 496)
	Index for cold wave perception.	The inverse function of (change +1) based on the household's report.	Household's perception of cold waves.	(Pandey & Jha 2012, p. 496)
	Index for the perception of the storms.	The inverse function of (change +1) based on the household's report.	Household's perception of storms.	Key informant's suggestion.

Source: As stated in the table.

5. ANALYSIS

5.1. Climatic Impacts: Perception Mapping about Problems

The assessment of prior problems, stress, and shocks was developed based on the household's perception of usual sufferings in their life due to climatic reasons by the household survey. The household questionnaire contained a Likert scale for mapping the perception about the climate impact related problems, stresses, and shocks to the lived urban life of the poor in the study area. Analyses of the data from the field surveys are presented in figures 14 and 15 respectively for consequence level (impact) and impact probability (frequency). Figure 16 compiles the data from figure 14 and 15 to generate a risk-matrix resembling the urban poor's perception about climatic stresses on their life (the grassroots perception).

5.1.1. Level of 'Consequence/ Impacts' of the Problems

Figure 14 shows the mapping of the impact's consequence level based on 5 scales of perception (scales: 5- catastrophic, 4- major, 3- moderate, 2- minor, 1- insignificant). For the changing climatic condition, a high percentage (the majority of respondents) among the surveyed 50 households had reported that heatwaves and temperature increase (58%), heavy rainfall (56%), and flood (52%) had a catastrophic consequence. The 'Major' impacts are drought (54%) and storm (60%) while the consequence of cold wave was reported as 'moderate' by the higher proportion (48%) of respondents.

Figure 14 also depicted that a high share of the surveyed households had reported, the polluted water (52%), sanitation problem (52%), drainage problem (58%), poor housing condition (56%), waterlogging (62%), and problem with inadequate water supply (66%) had the highest (catastrophic) impact due to the climatic impact's consequences and their poor living condition. The 'major' consequences of climate-induced risks as reported by the larger share of the respondents were health hazards (62%) and livelihood impacts (52%). The other consequence levels like moderate, minor and insignificant were not very significant according to the majority respondent's response to the selected problems or perturbations.

5.1.2. Level of 'Probability of Occurrence' of the Problems

Figure 15 shows the perception mapping about the occurrence probability or the frequency of the problems at the study region on 5 scales of perception (probability of occurrence scales: 5-very high, 4-high, 3-moderate, 2-low and 1-very low). The figure represented that larger shares (majority by percentage) of the surveyed 50 households had reported the heatwaves and temperature increase (62%), drought (52%), and heavy rainfall (56%) had a 'very high' probability of occurrence among the climatic problems. The majority of respondents reported flood (52%) having 'high' occurrence probability while storm (58%) and cold waves (50%) having 'moderate' occurrence probability.

Figure 15 also pointed that the high shares of the respondents from the surveyed household perceived inadequate water supply (62%), drainage problem (52%), waterlogging (62%), sanitation problem (56%) were likely to have 'very high' occurrence probability. The major portion of respondents also reported, impact on the livelihood (48%), health hazard

(54%), and climatic sufferings due to poor housing conditions (58%) are likely to have the 'high' occurrence/frequency level during climatic impacts.

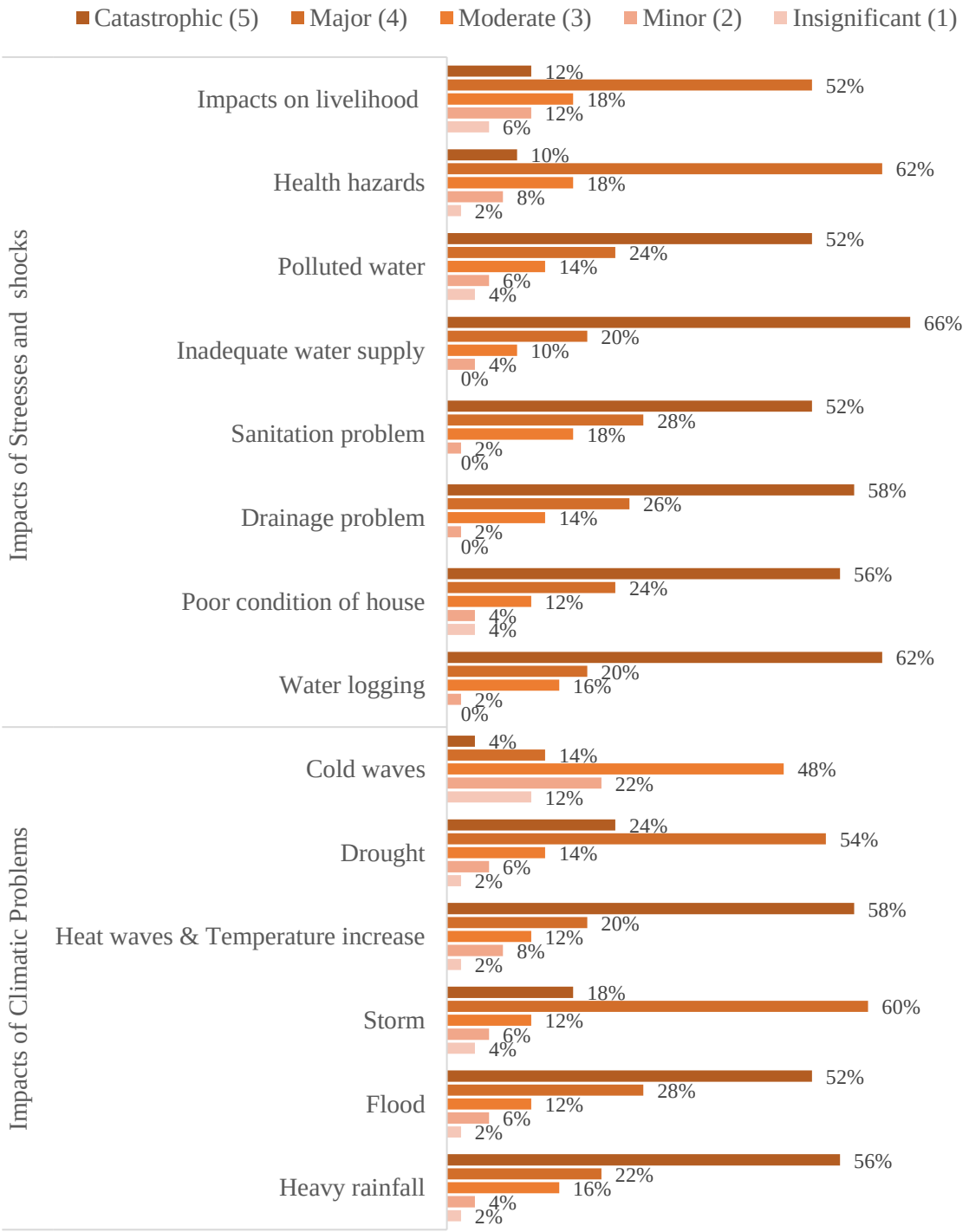


Figure 14: The urban poor's perception of the consequence/impact level of climate-induced problems, stresses, and shocks in the study area (grassroots perception).

*See Annex 2(a) for detail analysis.

Source: Author's Field survey, 2019.

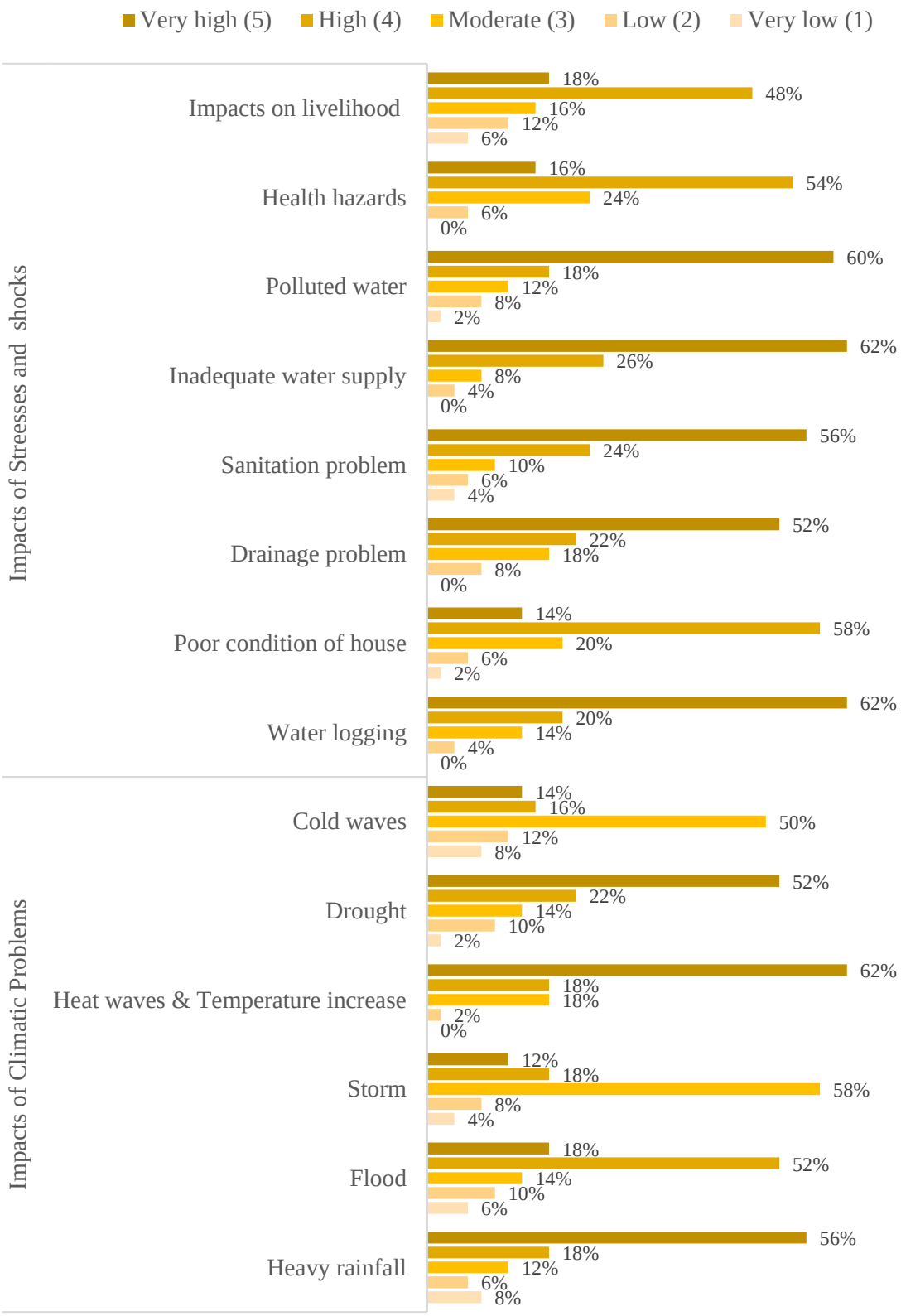


Figure 15: Urban poor's perception about the level of probability of occurrence (frequency) of the climate-induced problems, stresses, and shocks at the study area (grassroots perception).

*See Annex 2(b) for detail analysis.

Source: Author's Field survey, 2019.

5.1.3. Risk Matrix of the Climate-Induced Problems, Stresses, and Shocks

Combining the results from figure 14 and figure 15, figure 16 developed a climate 'risk matrix' for weighing the levels of consequence (impact) versus the levels of perceived occurrence probability. The risk matrix incorporated very high-risk, high-risk, moderate-risk, low-risk, and insignificant risks (see figure 16). In this study, all the climate problems and stresses that were considered based on the household perception fell on the top three categories of in the risk matrix: very high-risks, high-risks, and moderate risks. The risk matrix mapped the 'very high-risk' as those problems, stresses, and shocks having:

- 'catastrophic' consequence to urban life with 'very high' level of occurrence probability.

From the majority of the respondent's overview presented in figures 14 and 15, the problems associated with heatwaves and temperature increase, heavy rainfall, waterlogging, pollution of water, inadequate water supply, sanitation problem, and drainage problem were recorded as 'very high' risks (see figure 16).

The relevant 'high' risks in this study were those problems that were found to have:

- 'catastrophic' consequence level with 'high' level of occurrence probability, or
- 'major' consequence level with 'very high' level of occurrence probability, or
- 'major' consequence level with 'high' level of occurrence probability (see figure 16).

Based on the majority of the respondent's overview presented in figures 14 and 15 the problems associated with flood, drought, problems with the poor condition of the houses, impacts on livelihood and health hazards were recorded as 'high' risks.

The relevant 'moderate' risks in this study are those problems that were found to have:

- 'major' consequence level with 'moderate' level of occurrence probability, or
- 'moderate' consequence level with 'moderate' level of occurrence probability (figure 16).

Based on the majority of the respondent's overview presented in figures 14 and 15 the problems associated with storm and cold waves were recorded as 'moderate' risks (see figure 16).

5.1.4. Answer to RQ- 1: Insights from the Climate Risk Matrix

Answering the first research questions this section of analysis had pointed out the climate-related risks of the studying urban poor community and categorizes with a matrix system (figure 16) to map out the nature and importance of the reported climatic risks. The study found that most of the recorded problems as proposed by the respondent households were concentrated around 'very high' risks and 'high' risks zone and relatively few at 'moderate' risk zone but none was in the 'low' risk or the 'negligible' risks zone. This may be due to their higher level of suffering form the reported problems than the other non-reported problems insignificant for their context. Based on the results of the analysis, this study also supports the results from a similar study by Ahmed (2016, p. 207) in the urban slum of Talab camp in Mirpur, Dhaka using the 'risk quadrant' method. Both the studies found congruity with the result that problem having the highest consequence level with very high occurrence level or 'very high risks' included heatwaves and temperature increase, heavy rainfall, waterlogging, pollution of water, inadequate water supply, sanitation, and drainage problem. Climatic impacts

persuade the other problems associated with the ‘cause’ and ‘effect’ relationships due to infrastructural problems in the urban poor community. Poor drainage, poor housing, poor water supply, and poor sanitation may have such cause and effect relationship with waterlogging, water pollution, health hazards, and livelihood impacts exacerbated by the climatic crisis. Other ‘high risks’ for climatic impacts were reported to be constituted by flood, drought, poor condition of houses, impacts on livelihood and health impacts. The moderate level of risks was found for storms and cold waves which may be due to the fact that Dhaka is an inland megacity (non-coastal city) and it has high built-up areas (increased heat island effect). There were no ‘low’ or ‘negligible’ categories of climate impact risk identified in the study (according to the responses). The absence of such categories of risk may signify the exorbitant sufferings levels of the poor due to climate impact risks in the dense megacity.

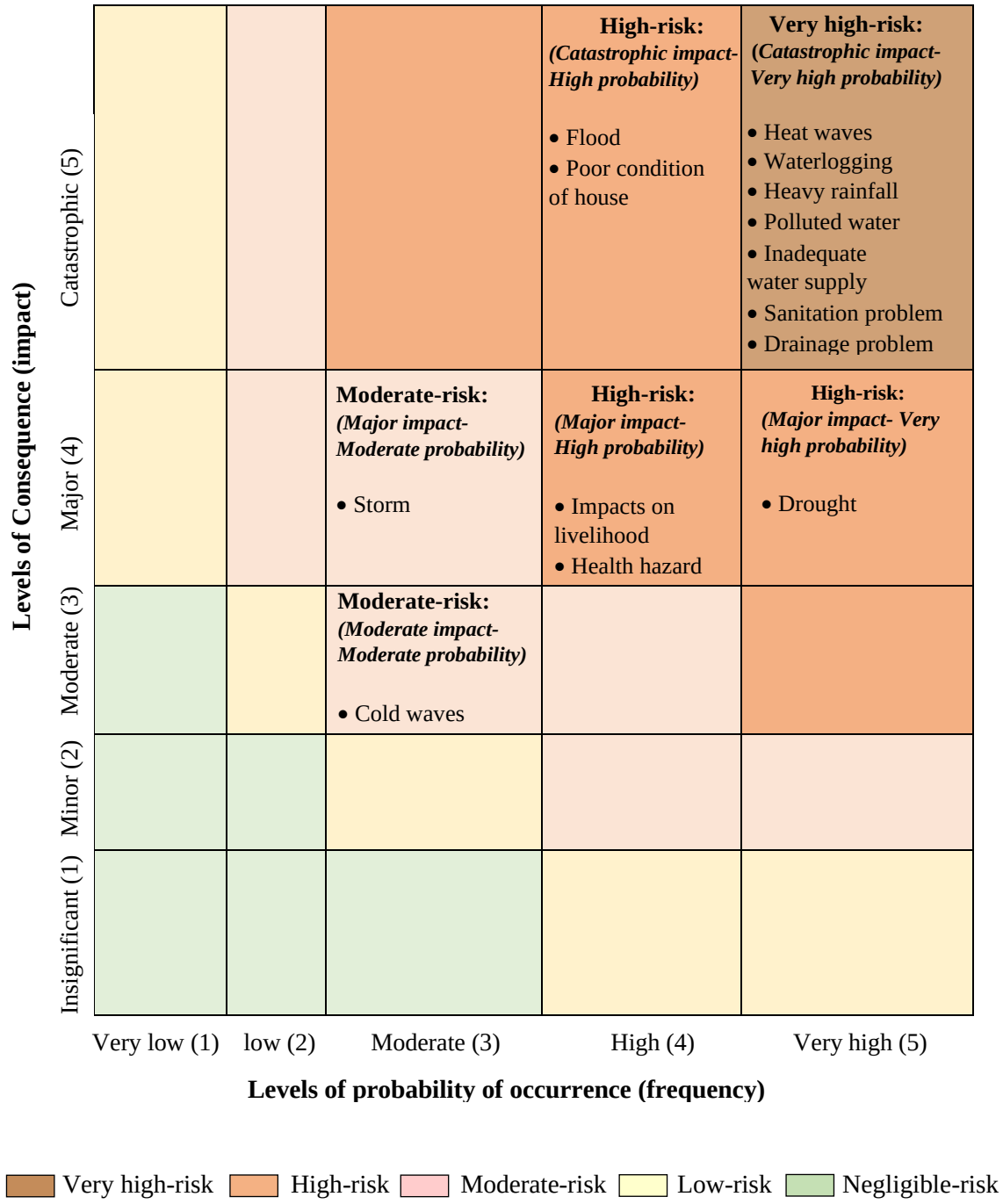


Figure 16: Risk matrix diagram of the urban poor's perception of climate-induced problems, stresses, and shocks in the study area.

Source: Author's field survey, 2019.

5.2. Climate Vulnerability Index (CVI)

5.2.1. Socio-demographic Profile

The survey of the 50-household gathered age data of 190 people (average family size was 3.8 people/family) (figure 17). In the age data of 190-coverage population, 26 people (13.7%) was up to 6 to 9 years; 37 people (19.5%) was between 10 to 18 years; 116 people (61%) was between 19 to 54 years and 11 people's (5.8%) age was above 55 years. So, the family dependency ratio was found by the ratio of the population up to 18 years and above 55 years to the population between 19 to 54 years of age which was (26+37+11)/ 116= 0.637.

The household survey identified four types of houses according to the building materials. The house types were: CGI (Corrugated Galvanised Iron sheets) in roof, CGI in wall with cement concrete floors (68% houses); CGI in roof, brick in wall with concrete floors for (14% houses); CGI in roof and wall with wooden-plank/bamboo floors (12% houses); CGI in roof and wall with mud floors (6% houses). The house type diversity index for four types of houses was 1/ (4+1) =0.20. 82% of the surveyed houses had only one-bedroom dwellings while the other services like kitchen and toilet were shared in the household.

Among the respondent households, 38% household-head had no schooling, 22% had 1 to 5 years of schooling, 24% had 6 to 9 years of schooling and 16% had 10 and above years of schooling. 16% of the surveyed households reported that they had at least one child (aged between 6 to 9 years) who did not go to school. 12% of the surveyed slum households reported being female-headed where the husband or the male head was away from the slum and worked elsewhere.

Figure 17: The household survey in the study area.

Source: Author's field survey, 2019.

5.2.2. Livelihood Strategies

78% of the surveyed household reported having at least one member migrated from other parts of the country. 84% of the surveyed households reported that they have no secured tenure in the informal squatter settlement and are in constant threat of eviction. The land was owned by the government, but the ownerships of the slum dwellings were occupied by the other private owners (*bariwala*) who rented the household dwellings to the poor. 82% of the surveyed occupants replied that they were tenants at the household's dwellings owned by other people

while 18% of the occupants replied as the owner of the dwelling. Local political strongmen, local leaders, musclemen (*maastans*) also built private squatter settlements on the government land and used to make profits by renting them to the migrated urban poor. The surveyed household indicated that there might exist a culture of profit-percentage sharing among the chain of the local political bodies.

Most of the houses were built of the CGI sheet at the roof and the wall and the materials were also in poor condition for weak structure, low maintenance, and oldness. Due to unaffordable cost for improved materials, maintenance, and low tenure right in a rented informal dwelling, 82% of the surveyed households reported they did not have access to climate protective building materials for extreme climatic conditions (flood, excessive rain, and heatwaves). The households reported that during rainfall the rainwater leaked through the holes or patch-works on the CGI roof. Due to poor drainage, the water logging in the household premises had become a usual climatic problem. During the storms, the weak structure and poor materials of the house were vulnerable to damage and cause a high cost of repair.

84% of the surveyed household reported that the household head not having any special training or skill development for making income opportunities in the city. Other (22%) households reported that they got a connection with some skill development training by NGOs. The occupation of the family's male and female members as recorded in the survey are presented in table 6. It shows that the household's income generates from diversified informal activities in the city and the urban poor may associate with additional secondary income sources along with their primary activities. Primary activities were those they considered as their major income source and secondary activities supplemented their income. However, the primary and secondary activities were not fixed due to their low skills and informal nature of the jobs. They could take secondary activities alongside the primary activities, occasionally or depending on their needs.

Table 6: Occupation of the surveyed household families.

Occupation	(N=50 family)					
	Male member (N=50)				Female member (N=50)	
	Primary activity		Secondary/ additional activity		Primary activity	
	n	%	n	%	n	%
Day labour	12	24%	5	10%	--	--
Garments worker	3	6%			12	24%
Rickshaw or Van puller	10	20%			--	--
Street vendor	9	18%	5	10%	--	--
Petty businessmen	7	14%	4	08%	04	08%
Domestic worker	--	--			17	34%
Self employed	2	04%	2	04%	11	22%
Small Private service	4	08%	4	08%	--	--
Agriculture	--	06%	2	04%	--	--
No job	3	06%			6	12%
total	50	100%	22	44%	50	100%

Source: Author's field survey, 2019.

82% of the surveyed families (41 families) reported that they have two earning members. Out of those double earner's family, 43% (36% of the total 50 households) reported that the male members had the experience of associating with two jobs (for secondary income) simultaneously or occasionally. The female members usually had only one job. 18% of the total respondents of 50 households had one earning member. Among those single earner's family, 44% (8% of the total 50 households) males had an experience of associating with secondary income job. All the working female members of the surveyed families replied that they preferred to do single income activities and would change the job types according to the needs. This may be due to the social nature of the community that women have to manage time for working outside after taking care of the children and household activities (cooking, cleaning, etc). 6% male members and 12% female members of the total surveyed families had no job and every family had at least one earning member (male/female). Table 7 calculates the livelihood diversification index using the surveyed data.

Box-1: *A view into the local cases: occupation*

Mr. Abdul Majid, a slum dweller stated that he used to earn by physical labor-intensive works during day time (9 AM to 4 PM) at the local rice storehouse (godown) and in evening (6 PM to 9 PM) he used to vend banana in the local market street so that he could get some additional income from that. By day laboring he earned 200 BDT daily and from street vending, he made 150 BDT daily profit. Usually, He used to buy bananas from the wholesalers in the very early morning before going to work at a relatively low price when the trucks from different parts of the country carrying banana used to arrive in the city. Like him, another slum-dweller Mr. Rubel was a petty businessman of vegetables who often used to pull vans for additional income. Mr. Harun used to sell peanuts near schools during the daytime and in the evening worked as a helper in a tea-stall in the nearby market.

Table 7: Livelihood diversity index of the surveyed households.

Family's income pattern	Categories	LDI * = 1/ (total no probable income source +1) 'P'	Number of respondents 'n'	'X' %	Indexed for 0 to 100 range 'A'	Overall LDI Σ P× A
Double earning members: 82%	Male member has 01 job and female member has 01 job experience	1/ (1+1+1) = 0.33	23	46%	0.46	0.3182
	Male member has of 02 jobs female member has 01 job experience	1/ (2+1+1) = 0.25	18	36%	0.36	
Single earning member: 18%	Male member has experience of 02 jobs and female member has no job	1/ (2+0+1) = 0.33	4	08%	0.08	
	Male member has no job and the female member has 01 job Or, Male member has 01job and female member has no job	1/ (0+1+1) = 0.5	5	10%	0.10	

*Livelihood diversity index (LDI) was calculated based on (Hahn, Riederer & Foster 2009, p. 77).

Source: Author's calculation based on the household survey, 2019.

88% of the surveyed households reported to perceive that problems due to climatic conditions in recent years had increased and it had an impact on their income loss also. The respondent houses stated that as they used to earn by providing physical labor, during very hot days and heatwaves they could not work for long hours outside the house. During heavy rainfall, waterlogging and flood they could not go out for work even for three to four days as they needed to try removing stagnant water from household premises and repairing the damaged floor, balconies and roof.

5.2.3. Social Networks

42% of the surveyed household reported that they got assistance from NGOs during climatic impacts like floods and waterlogging. They replied NGOs helped them to repair the houses and provide microcredit loans for repairing/improving their housing conditions and for improving their socio-economic status. 74% of the respondents informed that they used to save money as the preparation for the emergency need during and after the climate-related crisis and probable income losses. But the other 26% household reported not being able to save money as preparedness for climatic crisis (for low income). 90% of the surveyed households replied that they keep good relationships with neighbors and help each other during climatic crises like water logging, storm, heatwaves, and illness. 32% of the surveyed household replied that they used to lend and borrow money from friends and neighbors when an emergency need occurred during the climatic crisis. Households reported that they needed to engage in monetary transactions with amounts that often went above half of their monthly income and they repaid the debt in installments. So, climate-related debt often influences several month's incomes, expenditures, and savings. As the settlement was informal in nature, 54% of the respondents replied that they did not have gone to any local governmental offices for getting help/assistance during or after the climatic crisis. 36% of the surveyed household possessed no television (for access to forecast and awareness) and 34% did not have mobile phones for information and communication coverage.

5.2.4. Health

88% of the surveyed household reported, climatic adverse condition brings sufferings from illness. Fever, cold-cough, dysentery, Jaundice, diarrhea and cholera were reported as the most common diseases during and after the climatic crisis of flood and heavy rainfall. During flood and waterlogging the vulnerable water supply pipes (having leaks) and the drainage lines get inundated with water causing water pollution and health risk. During heatwaves, the water crisis becomes a serious issue affecting health and normal working capacity. 84% of the household reported that climatic crises like heatwaves and temperature increase, flood, waterlogging, heavy rainfall had created physical and mental stress for the community people. 86% of the surveyed households reported that the outbreak of new diseases like Dengue and Chikungunya were very common in the community which might be due to stagnant water and poor drainage (mosquito-spread diseases). Chronic diseases were common mostly among the aged people and 28% of the surveyed households replied that they have at least one member with chronic illness (high blood pressure, heart disease, Arthritis, etc) requiring treatment on regular basis. 46% of the surveyed household said that they need to spend at least 1000 BDT every month on health expenditure. For the informal, low income poor monthly health expenditure sometimes becomes a significant portion of their income.

The government and NGO hospital provides treatment and medicine to the poor at a very negligible price (or freely). The households reported that they used to go to the public hospitals (government or the NGO hospitals) for treatment as they could get diversified specialized treatment at low cost. But the government hospitals were reported to be most often crowded and during climatic crisis or outbreak of diseases (e.g. cholera) their condition (service capacity) worsened. When the government hospitals do not have enough bed space for admitting patents the poor use to accommodate their patients on hospital floors and balconies. Considering the last 12 month's health overview, 72% of the surveyed household replied that they depended on the public hospital for treatment of illness. But the others (28%) replied that they needed to go to the local clinics due to urgency and the low capacity of government hospitals.

5.2.5. Food

Poor's illness, reduction in working capacity and inability to go out for work influence their supply of food. 82% of the respondents replied that they mostly depended on physical labor-intensive jobs for earning their daily food who were prone to vulnerable food supply due to a reduction in physical laboring capacity. Heatwaves during summer reduce their physical laboring capacity (labors get tired quickly, suffer from sickness) and during heavy rain, water clogging and flood they cannot go out for work (for adverse weather, repairing damaged houses and even illness). 64% of the surveyed household replied, due to extreme climatic conditions like the inundation of household premises or kitchen, flood, waterlogging (in monsoon), 2 to 3 months in a year they faced a reduction in the adequate food supply. 48% of the surveyed households reported that they used to expend at least half of their income for earning and making food which constituted the major share of their expenditure. The poor needed to reduce their expenditure on food for income reduction caused by the inability to go for work, illness, flood, inundation during the climatic crisis. 72% of the surveyed households reported that they used to consume 'less expensive' and 'less preferred' food to adapt to the adverse condition and income loss during unfavorable climatic impacts. 66% of the respondents mentioned that they needed to adapt by decreasing the nutritional food intake like dairy, meat, fish, and fruit during climatic crisis conditions. The poor do not have any access to direct agricultural food production in the dense city. 68% of the respondent households reported that they did not have any direct agricultural food supply in the city. Only 32% of the surveyed households reported, they planted vegetables and fruit trees near the household premises, or on fallen land near the embankments which supplied nominal fresh fruit and vegetables occasionally. (figure 18). The creeper type vegetable plants (e.g. pumpkin, beans, etc) were observed to be planted on the fallen lands near the households and embankment (figure18, 19). Such plants also cool the household environment (reducing heat gain) during hot days. Combined community gardening was not prominent due to low tenure security and lack of available land in the congested city.

Figure 18: Vegetable plantation near the household and the embankment in the study area.
Source: Author's field survey, 2019.

Figure 19: Understanding grassroots insights about gardening near the slum households.
Source: Author's field survey, 2019.

5.2.6. Water

88% of the surveyed household replied that there was an inadequate supply of water in the slum community and they used to share their water sources with the neighbors. DWASA, local NGOs (Dustho Shastho Kendro, DSK was reported by the households) and international donors (UNESCO) have contributed to limited supply water in specific water points. The water points supplied water to the specified number of slum households, but all the houses were not under its coverage. Inadequate supply quantity, high water demand, and illegal connections caused the supply of water to be sporadic. 92% of the respondents reported that they could not drink the supplied water directly and needed to boil or filter the water for making it safe potable water. They used to share the water from the source of supply by plastic pipes, and illegal water supply connections were also provided and managed by the house owners (*bariwala*) by making due connections with the local political people and strongmen. 88% of the surveyed household experienced that climatic impacts had increased the water problem in the community. During the heatwaves and hot months of summer, the scarcity and inadequate water problems were reported to become even worse in the community as the supply used to become sporadic and remained stopped for days. At that time, they needed to collect water from far places wherever they could get access. 94% of the surveyed households replied that during climatic crises like floods and waterlogging, the supplied water got polluted due to the poor nature of the plastic pipes and illegal connections. Pipe breakings, faulty joints, and illegal connections percolate dirty rain/flood water that gets mixed with the supplied water (figure 20). Among the surveyed households, 86% had no access to tubewell for drinking water, and 96% reported that they could not use the natural water sources (e.g. nearby lake water) due to waste disposal and excessive levels of water pollution (figure 21).

Box-2: *A view into the local cases: water crisis*

Amina Khatun (22) a survey respondent reported that last year (2018) during summer her family did not get enough water even for daily basic needs. There was also no water in the neighbouring house's supply so that they could not get helped by water sharing. Her family had to fetch water with pitcher from a mosque near the high-class community which was about 1.5 kilometre away from her house. She also mentioned, regardless from wherever they collect 'supplied water' (neighbour or other points, legal or illegal pipes) they need to boil the water for 30 to 40 minutes, strain, and then cool it to make it safe drinkable water. During waterlogging the water gets polluted much and they need to fetch water from safe location. She stated, "during waterlogging, water is everywhere but no water to drink".

Figure 20: Open plastic water pipes from shared water points.

Source: Author's field survey.

Figure 21: Waste disposal and pollution of the lake water.

Source: Author's field survey, 2019.

5.2.7. Natural Disaster

The occurrence of natural disasters and adverse climatic impacts increase the sufferings in the poor community. 58% of the surveyed household replied they experienced a loss of property or damage due to climatic impact. Natural disasters like storm, flood, and heavy rainfall caused property damages which included damaging of wall, door, and windows; damaging of the roof; damaging of balconies. 78% of the surveyed household reported that they used to face inundation of their household premises during heavy rainfall and flood every year. Lack of any disaster preparedness by warning and awareness building before adverse climatic conditions also increased the urban poor's exposure to climatic risks. The respondents mentioned that climatic impacts that might not be considered risky for the other high or middle classes people of the city, might often be a matter of high risk for the poor. Such increased sensitivity was due to their impoverished living conditions and vulnerable infrastructural situation (low coping capacity). Figure 22 illustrates the vulnerable infrastructural condition of the typical houses near the embankment of the lake. It shows that during heavy rainfall and flood the wastewater from the nearby drain inundates the household premises (due to lack of drainage infrastructure). The stagnant dirty water often stays in the household premises for weeks.

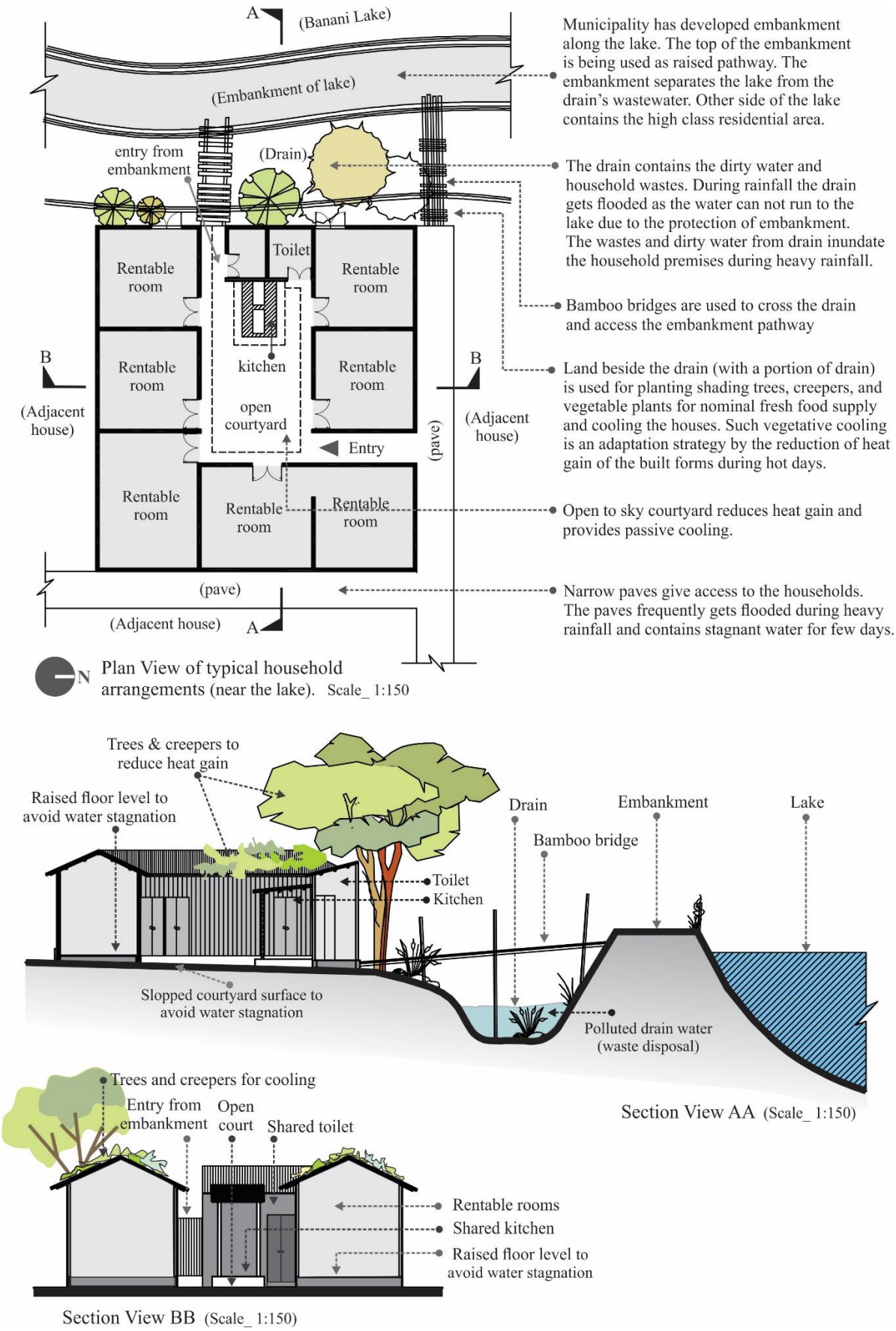


Figure 22**:** Condition of the typical households near the lake.
Source: Author's drawing based on the household survey, 2019.

Figure 23 shows the wasteful drain beside households located near the lake's embankment. It also shows the poor's adaptive measures by vegetable plants and creepers for cooling.

Figure 23: Waste disposal drainage by the households near the embankment. Vegetable creepers reduce heat gain.

Source: Author's field survey, 2019.

Figure 24 shows the illegal and vulnerable hanging houses (elevated by bamboo) over the lake. These houses were built on a low land developed by filling a portion of the nearby lake by regular dumping of wastes. Such illegal waterbody/low-land filling was due to the urban poor's accommodation needs facing the scarcity of land and the high cost of land value in the city. During flood and rainfall, the rainwater massively carries the wastes to the lake and the household gets inundated with dirty water.

Figure 24: Waste dumping and in the lake and hanging houses (elevated by bamboo).

Source: Author's field survey, 2019.

68% of the surveyed household replied they did not get any warning from any institution before adverse climatic conditions while the others (32%) reported that sometimes they used to consider coastal climatic information from television (for storms, depressions, etc). 58% of the surveyed households replied that they were not covered or participated in any awareness-building program for disaster preparedness and reducing probable damage with reference to

their present capacity. The other respondents (42%) reported mostly to take part in NGO programs. Based on their perception 54% of the surveyed household reported that the overall probability of occurrence of climate-related problems (heavy rainfall, heatwaves, drought) had increased than the past. 62% of the surveyed household replied that the level of overall sufferings due to climatic problems had also increased than before.

5.2.8. Climate Variability

Based on the household's perception, vulnerability for the following climate variability was analyzed:

- change in the hot months;
- change in the temperature during hot months;
- change in the average wet months;
- change in the heavy rainfall;
- change in the cold months;
- cold waves frequency; and
- perception about storms.

Perceived sufferings were measured in high (indexed as 0) and relatively moderate (indexed as 1) category for each of the above change components of climatic variability. The resultant climate variability perception indexes are presented in table 8 (see annex 3 for details).

Table 8: Climatic variability perception indexes.

Climatic variability perception types	Indexes
Temperature and hot months perception index	0.65
Perception index for Rainfall pattern change	0.67
Perception index for Cold waves pattern change	0.48
Perception index for Storms	0.55

(Please see Annex 3 for survey responses and detailed calculations)

Source: Author's calculation based on household survey and (Pandey & Jha 2012, p. 496).

5.2.9. CVI Calculation

The data and information discussed above are summarised in table 9 for determining the values for different major components of CVI.

Table 9: Values of major components from respective sub-components.

Major components	Sub-components	Data	Indexed vales	Major components
Socio-demographic profile	Index of family dependency	Ratio	0.63	0.385
	Index of house type diversity	Index	0.2	
	% of the households having only one-bedroom dwelling	82%	0.82	
	% of the households head having no schooling	38%	0.38	
	% of the households having at least one child not attending school	16%	0.16	
	% of female-headed households	12%	0.12	
Livelihood Strategies	% of the households having migrated members	78%	0.78	0.762
	% of the households having no access to tenure security	84%	0.84	
	% of the households reported being the tenant of an informal squatter house	86%	0.86	
	% of the households having lack of access to climate disaster protective building materials	82%	0.82	
	% of the household's head having no special training or formalized skills	84%	0.84	
	Livelihood diversification index	Index	0.318	
	% of households reported experiencing loss in income due to climatic impacts	88%	0.88	
Social Networks	% of households reported getting assistance from social organizations or NGOs due to climate impact	42%	0.42	0.448
	% of households reported not to save money for future climate disaster's risk	26%	0.26	
	% of households reported maintaining a good relationship with neighbors and help each other during the climatic crisis	90%	0.9	
	% of households engage in money transaction with friends due to climatic reasons	32%	0.32	
	% of households not accessing governmental offices for climatic assistance	54%	0.54	
	% of the households having no television	36%	0.36	
	% of the households having no mobile phone	34%	0.34	
Health	% of households reported illness due to climatic issue	88%	0.88	0.600
	% of households reported stress (physical and mental) owing to adverse climatic impacts	84%	0.84	
	% of households reported an outbreak of new diseases	86%	0.86	
	% of households reported having one member with chronic illness	28%	0.28	
	% of households require to spend a minimum of 1000 BDT in every month for treatment	46%	0.46	
	% of households need to access private clinics for low capacity of public (Governmental and NGOs) hospitals in the last 12 months	28%	0.28	
Food	% of households earning food by physical labor-intensive work	82%	0.82	0.666
	% of households reported inadequate food supply due to the climatic crisis	64%	0.64	
	% of households reported expending at least half of their income for food	48%	0.48	

	% of households reported consuming 'less expensive' and 'less preferred food during a climatic crisis	72%	0.72	
	% of households reported a decrease in the supply of nutritious food during the climatic crisis	66%	0.66	
	% of households reported not having a direct agricultural food supply	68%	0.68	
Water	% of households reported an inadequate supply of water throughout the year	88%	0.88	0.906
	% of households reported the supplied water is not drinkable other than purifying	92%	0.92	
	% of households reported climatic impacts increases water crisis	88%	0.88	
	% of households reported contamination of water due to climatic impacts	94%	0.94	
	% of the households having no access to a tube well	86%	0.86	
	% of the households having no access to natural water sources	96%	0.96	
Natural disasters	% of households reported the loss of property owing to natural disasters	58%	0.58	0.630
	% of households experiences flood or inundation of the household	78%	0.78	
	% of households reported not getting a warning before the climatic crisis	68%	0.68	
	% of households reported not to participate in any disaster preparedness/awareness program	58%	0.58	
	% of households reported an increase in the overall natural disaster's frequency	54%	0.54	
	% of households reported an increase in the overall natural disaster's intensity	62%	0.62	
Climate variability	Index for temperature and hot month's perception	Index	0.65	0.588
	Index for rainfall pattern's perception	Index	0.67	
	Index for cold wave's perception	Index	0.68	
	Index for storm perception	Index	0.55	

Source: Based on the author's field survey, 2019.

Table 10 compiles the values of the major components (from table 9) and shows that the CVI's dimensions of adaptive capacity, sensitivity and exposure had the values of 0.461, 0.711 and 0.613 respectively (see annex 4). Using these values, the CVI for the study area was calculated as 0.956 (see annex 5).

Table 10: Values of vulnerability dimensions and CVI from respective major components.

Dimensions	Major components (MC)	Vulnerability: MC's Values*	Dimension's Values	CVI value*
Adaptive capacity	Socio-demographic profile	0.385	0.461	0.956
	Livelihood strategies	0.762		
	Social networks	0.448		
Sensitivity	Health	0.600	0.711	
	Food	0.666		
	Water	0.916		
Exposure	Natural Disasters	0.630	0.613	
	Climate variability	0.588		

*please see annex 4 and 5 for the detail calculation of the values for dimensions and values for CVI.
*higher MC value indicates higher vulnerability.

Source: Based on the author's calculation.

5.2.10. Answer to RQ- 2: Insights from CVI Analysis

With the analyzed data (of table 10), the vulnerability spider diagram (figure 25) and the vulnerability triangle (figure 26) was prepared. Such a diagram could represent the urban poor's climate vulnerability extents answering the research questions two.

The vulnerability's comparative spider diagram for the 8 different major components is presented in figure 25. It shows that there is a very high climate change vulnerability in water (0.906). Such vulnerability was pronounced mostly by the lack of drinkable water supply, inadequate water supply, water contamination, increasing climatic impacts like droughts and lack of availability of natural water sources for domestic use by the urban poor. Moreover, in the context of increasing global climatic impact, in the future, this problem will be more acute if not addressed properly by improving the coping capacities.

Livelihood Strategies of the urban poor also contained high vulnerability (0.762) for climate change impacts. Such vulnerability was very prominent due to the low tenure security of the urban poor in the city, threat of eviction, lack of access to climate-resilient houses/materials. The migrated members from rural places and low skill levels of the urban poor increased livelihood vulnerability. But the livelihood diversity index depicted, the poor's involvement in the alternative ways of earning or multiple jobs reduced their livelihood vulnerability.

After water and livelihood, the urban poor's food supply was also recorded to contain a significant extent of vulnerability (0.666) for climatic impacts. The poor usually reduce their daily food consumption and nutrition food intake during adverse climatic impacts. Climatic impact badly increases the food vulnerability of the poor who earn food by providing daily physical labor. There was an inadequate level of agriculture or community gardening in the urban region for coping up with food vulnerability.

Natural Disasters and health had a climate vulnerability level of 0.630 and 0.600 respectively. The poor's vulnerability from natural disasters arises from the increasing natural disasters' frequency and intensity of impacts, loss/damages due to climatic impacts, lack of disaster preparedness, inclusive awareness programs. Health vulnerability was pronounced by the health impacts of adverse climatic conditions, contamination, and the outbreak of new diseases. The poor use to access the government or NGO hospitals for treatment at low-cost which is supporting/increasing the poor's coping capacity for health issues. But the pressure of increasing population in the megacity affects the quality and availability of the treatment in those hospitals during the climatic crisis.

Vulnerability extent for climatic variability was found as 0.588 which was documented from the poor's perception about their level of sufferings for temperature increase, rainfall pattern change, cold waves, and storm. The poor need to keep good relationships with neighbors, save money for future crises, and use to help each other during climatic adverse condition as the coping strategies. Such social bonding, money savings and the culture of mutual help resulted in the vulnerability score for social networks as 0.448. However, there was inadequate networking with government offices.

The vulnerability score for the poor's socio-demographic profile was 0.385. The availability of different types of rentable (informal) houses according to income, spreading of

education by the government and the NGOs and the poor's eagerness to educate their children resulted in a low vulnerability score.

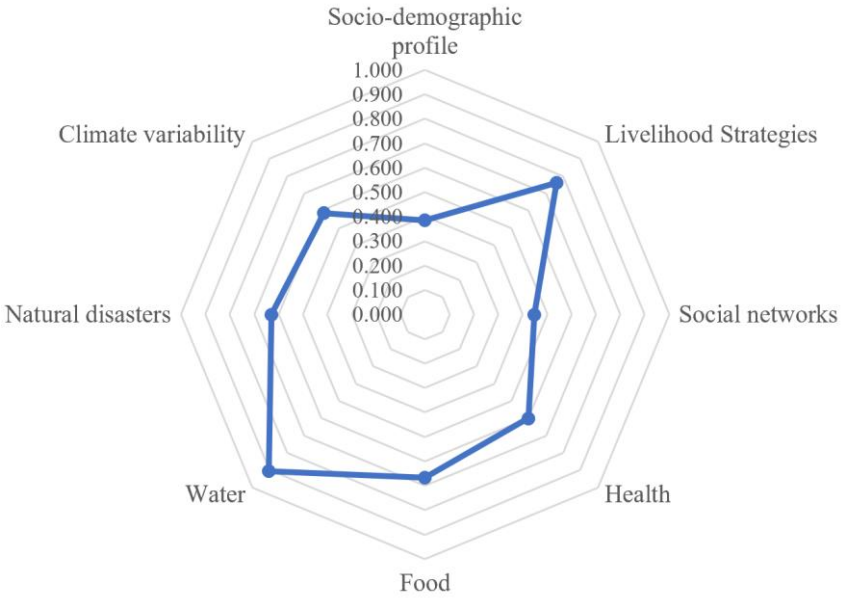
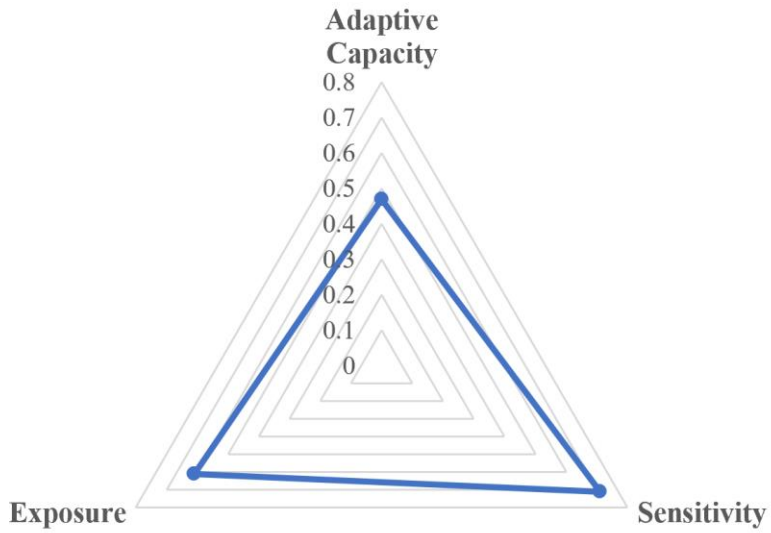


Figure 25: Comparative spider diagram of the major components of CVI. A higher value indicates higher vulnerability (0=low vulnerability, 1= high vulnerability).

Source: Author's representation.

The study found high vulnerability extents in the vulnerability framework's three dimensions (exposure, sensitivity and adaptive capacity). The comparative vulnerability triangle incorporating the three dimensions of the vulnerability of the study region is presented in figure 26. It shows, the sensitivity of the climatic impact of the study region was very high (0.711) than the exposure (0.613) and the adaptive capacity was low (0.461). Which was due to the poor's exclusion from the civic facilities, lack of security of the tenure, informal nature of the infrastructure and housing condition, lack of food security, the water crisis in the face of climatic impact. Vulnerability for climatic risk's exposure in the megacity city is different from that of the usually considered climatic exposure at the coastal regions. It consists of the urban poor's lack of inclusion in the formalized civic services, awareness program, development policy directives (inclusive or exclusive), and direct or indirect (cause and effect) sufferings due to climatic adverse impacts. The overall adaptive capacity was low (0.461), however, the poor's existing adaptation capacity was mainly contributed by the spreading of education, diversified economic/livelihood opportunities in the city, social and economic supports from neighbors and opportunity of savings for climatic crisis conditions. The overall climate vulnerability index of the urban poor was found very high (0.956) (table 10) which was contributed by the high vulnerabilities in the dimensions of sensitivity, exposure and low adaptive capacity of the poor in the megacity context. The poor are coping with the prevailing climate vulnerability by adopting informal coping initiatives.



Vulnerability contributions:

- For exposure and sensitivity: the higher value indicates higher vulnerability,
- For adaptive capacity: the lower value indicates lower adaptive capacity (i.e. higher vulnerability).

Figure 26: Vulnerability triangle of different dimensions of CVI.
Source: Author's representation.

5.3. Climate Policies and the Urban Poor

5.3.1. National Level: Relevant Policy Frameworks

In the context of global climate change, the Government of the People's republic of Bangladesh had initiated the national level policy initiatives outlined by the National Adaptation Program of Actions (NAPA) in 2005 based on the decisions from the UNFCCC's seventh conference (COP7) (MOEF 2005). The Ministry of Environment and Forests had developed the policies based on the decisions from the four subnational level stakeholder workshops, one national level workshop and other previous research reports (Ibid. p. 1). Depending on the NAPA adaptation framework the Government had proposed the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009. BCCPSAP, 2009 was considered to be formulated for expanding the scope of the NAPA framework of 2005 (MOEF 2009, p. xviii). The two policies of NAPA and BCCSAP are considered recent climate adaptation relevant policy contribution at the national scale and their objectives and contents are presented in table 11.

Table 11: Climate change related policy initiatives at the national scale.

National Policies	Year	Context & organization	objectives	Policy's content output
National Adaptation Program of Actions (NAPA)	2005	Decisions of COP7 of UNFCCC Organization: Ministry of Environment and Forests, Government of Bangladesh	Formulation of national adaptation strategies for reducing climatic adverse effects from climatic variability and fostering sustainable developments.	It suggested 15 folds of adaptation strategies for future initiatives.
Bangladesh Climate Change Strategy and Action Plan (BCCSAP)	2009	Adaptation action plans were developed for the ten-year period (2009 to 2018) by expanding the NAPA framework, 2006. Organization: Ministry of Environment and Forests, Government of Bangladesh	Formulation of National Action plans for Climate Change impacts.	It consisted of 44 programs of actions divided into 6 major pillars covering food security, disaster management, infrastructure, research initiatives, mitigation programs, and capacity developments.

Source: (MOEF 2005, 2009).

5.3.1.1. **NAPA Framework**

The National Adaptation Program of Action (NAPA) framework proposed 15 national adaptation strategic measures divided into two categorical groups namely *'intervention type measures'* (8 measures) and *'facilitating type measures'* (7 measures) (MOEF 2005, pp. 21–22). Table 12 discusses the NAPA's proposed measures and finds their characteristics to map out the relevant 'national-level measures' that may be applicable for megacities like Dhaka and cover the urban poor community's better adaptation to climate change impacts. It represents that most of the 'intervention type' of measures are specific to the coastal region and incorporates inadequate considerations for adaptation measures for the country's urban areas including Megacity Dhaka. Table 12 also analyses, the intervention frameworks have absolutely no reference to the inclusive measures for improving the climate resilience of the urban poor communities in the megacity Dhaka in Bangladesh. This may be due to the lack of an inclusive understanding of grassroots climate vulnerabilities of the poor in the urban areas.

Some of the policies within the 'facilitating measures' may have the adaptation scopes for the country's urban areas as their scopes may not be confined to the specific regional focus (e.g. coastal region or agricultural focus). But such measures only concentrated on institutional capacity build-up, policy-programs, and research initiatives for new adaptation knowledge. However, in the facilitating measures also, the NAPA framework had no clear definition and reference for the inclusion of the urban poor communities in the climate adaptation programs (table 12).

Table 12: Mapping the inclusive strategies for the urban poor in the megacity Dhaka in the present NAPA's adaptation framework.

NAPA adaptation strategies		Characteristics/ scopes	Relation to the megacity Dhaka	Responsiveness to the urban poor's climate vulnerability
Intervention type measures	1. Promoting the adaptation measures for coastal crop agriculture battling salinity.	Adaptation measures for the coastal regions.	Not applicable for inland urban Dhaka.	No reference to urban poor people.
	2. Adaptation measures for agricultural systems in the northern, eastern and central region's areas susceptible to flash flooding.	Adaptation measures for flash flooding areas in the northeast and central region's areas.	No clear reference for any urban areas	No reference to urban poor people.
	3. Promoting the adaptation measures for coastal fisheries by the salt-tolerant fish culture at the coastal areas.	Adaptation measures for the coastal regions having salty water problems.	Not applicable for inland urban Dhaka.	No reference to urban poor people.
	4. Adaptation measures for fisheries in the northern, eastern and central regions affected by flood through diversified practices of fish culture.	Adaptation measures for fisheries in the northeast and central region.	No clear reference for the urban areas.	No reference to urban poor people.
	5. Building flood shelters, assistance center and information centers for facing the flood risks at the major floodplains.	Adaptation measures through providing flood shelters, assistance, and information.	No clear reference for the urban areas. It provided no explicit directions for urban areas for the high population & intensity of climate problems.	No clear reference to the urban poor people. The importance of major floodplains may be a subjective issue for assistance.
	6. Reducing the climatic hazards by afforestation at the coastal regions through the participation of the communities.	The adaptation measures for the coastal regions, local coastal people.	Not applicable for inland megacity Dhaka	No reference to urban poor people.
	7. Provision of drinking water for the communities in the coastal regions for fighting with sea-level rise and salinity.	The adaptation measures for the coastal regions, and the coastal people.	Not applicable for inland megacity Dhaka.	May not be applicable to the non-coastal urban poor people as it explicitly had limited scopes for focusing on the coastal regions.
	8. Improving the urban infrastructure and industry's resilience for climate change impacts along with floods and cyclones.	The adaptation measures for developing resilient urban infrastructure and industries.	Applicable for megacity Dhaka.	No reference for the urban poor community's inclusiveness for improving climate resilience.

NAPA adaptation strategies		Characteristics/ scopes	Relation to the megacity Dhaka	Responsiveness to the urban poor's climate vulnerability
Facilitating type measures	9. Capacity development for incorporating climate change issues in planning, infrastructural designs, management of conflicts and zoning for land water for the institutions dealing with water management.	The adaptation measures through institutional capacity development.	May be applicable for megacity Dhaka, as the measure is not confined to any regional specification.	No clear reference for inclusive service for urban poor settlements.
	10. Exploring the promotion of insurance options to deal with the increasing climatic risks.	The adaptation measures through insurance support.	May be applicable for megacity Dhaka, as the measure is not limited by the regional specifications.	No reference for the inclusion of the urban poor for the insurance coverage.
	11. Integrating climate change adaptation issues at the policies and programs of different specialized sectors (disaster management, health, water, industries, and agriculture).	The adaptation measures for linking policies and programs with climate change issues.	May be applicable for megacity Dhaka, if the relevant service sectors have the capacities.	No reference for inclusive service for the urban poor.
	12. Incorporating climate change related issues in the educational curriculum of the secondary and tertiary levels.	Developing adaptation awareness through educational programs.	May be applicable for megacity Dhaka through the education system's curriculum.	No reference for the urban poor's access to inclusive education and skill developments.
	13. Promoting the adaptation-related information to the climate-vulnerable communities for better awareness and preparedness.	Developing resilience through awareness and disaster preparedness.	It may be applicable for megacity Dhaka through necessary information dissemination.	No clear reference for the recognition of informal urban poor's climate vulnerability.
	14. Promoting agricultural research for drought, flood and saline water-tolerant crops for better future adaptation.	Developing resilience through agricultural innovation.	Inland urban Dhaka has less agricultural land and requires innovative and sustainable urbanization research.	No reference for adopting researches for generating knowledge about urban poor's climate vulnerability and required adaptation supports.
	15. Promoting 'eco-specific' and indigenous adaptive knowledge for understanding climate vulnerability and better adaptive capacity.	Developing resilience through indigenous and eco-specific knowledge	May be applicable for urban Dhaka through the studies of indigenous & grassroots insights.	No clear reference for the incorporation of grassroots adaptation knowledge from the urban poor communities.

Source: Author's representation based on (MOEF 2005, pp. 21–22).

5.3.1.2. **BCCSAP Programme**

BCCSAP Programme's Organization

BCCPSAP, 2009 was developed by the organization structure for climate action planning under the strategic guidance of the 'National Environment Committee' headed by the prime minister of Bangladesh. Figure 27 shows the national climate action's organizational diagram. The 'National Steering Committee' (chaired by the MOEF) developed for climate impact issues was responsible for overall program coordination and it directly reported to National Environment Committee (MOEF 2009, p. 30). According to MOEF (2009, p. 30), a 'National steering committee' was developed consisting of the MOEF, civil society, and the business communities to address climate impact issues. It got support from the 'climate change units' under MOEF which worked with the 'climate change focal points' set up in all ministries (figure 27). The 'climate change focal points' had their responsibilities to plan for and implement climate actions with their relevant organizational capacities and networks. Both the 'National steering committee' and the 'Climate change units' worked for climate change negotiations with foreign agencies, bi and multilateral collaborative climate programs, and climate-related researches (Ibid).

MOEF (2009, p. 30) declared that the BCCPSAP program's action plans were developed based on a 'participatory process' with ministries, civil societies, agencies, researches, and business sectors. The action plans would be implemented through the relevant ministries, civil societies, private sectors, agencies, and other relevant stakeholders. It mentioned the climate plans would be reassessed and revised on a regular basis (Ibid).

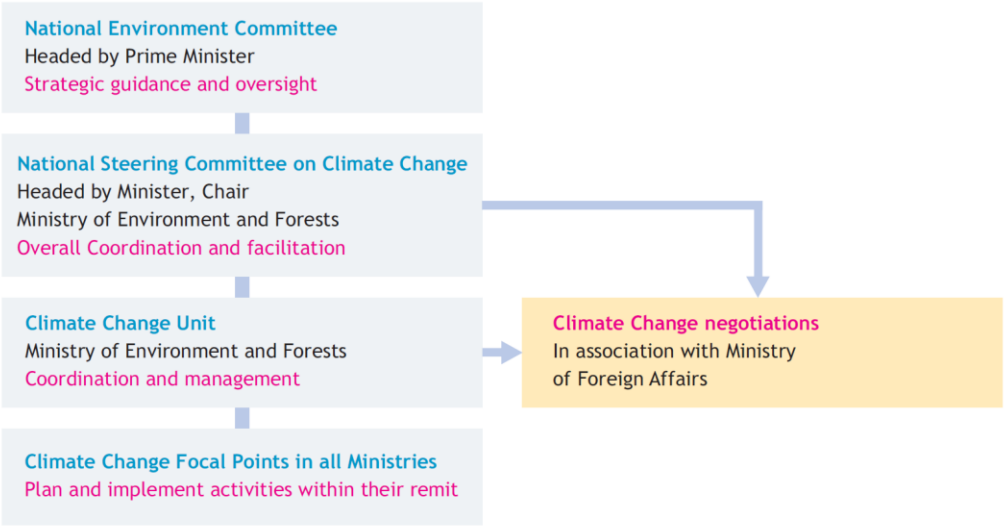


Figure 27: Organizational chart for the development of national climate actions.
Source: (MOEF 2009, p. 30).

The BCCPSAP's organizational structure shows that both the 'National steering community' and the 'climate change focal points' had access to civil societies, business organizations and public sectors (ministries) for climate negotiations and sustainable development projects. However, in the organizational setup, the definitions and scopes of different sector's responsibilities were not clearly demarcated. It had access to civil society's

decisions, but the definition and the role of civil society were not made clear here. By the definition, civil societies are a third party between the public and private sectors and work intermediately among the state, the markets and the individual families (Schwartz & Pharr 2003, p. 23). It may be comprising of Civil Society Organizations (CSOs) and Nongovernmental Organizations (NGOs). In this context, the composition of the civil society and whether the civil society had the capacity for the inclusion of the urban poor communities (or their representatives) were not mentioned clearly. Tasnim (2017) argued that politicization, priorities of the individual benefit, loyalty, communalism may be a matter of research for the civil society's capability in Bangladesh. The so-called civil society leaders (or even politicized strongmen) could exploit the poor's rights of inclusion due to political biases, personal interests, and profit capturing tendencies.

BCCSAP Programme's Composition

Figure 28 shows the BCCSAP's 44 programs under the three broad pillars. In relation to the major problems analyzed in the climate risk-matrix (section 5.1.3) it shows, under the food security, social protection and health pillar (T1) it has programs bearing potential scopes for adaptation to drought (T1P2); water and sanitation program in the vulnerable areas (T1P7); health problems (T1P6) and livelihood protection for socio-economic groups having high climate vulnerability (including women) (T1P9) (MOEF 2009, pp. 33–41). However, in the detail action plans, it lacked to mention any reference to the vulnerability of the poor in the urban areas and their clear inclusive consideration among the programs.

Under the comprehensive disaster management (T2) pillar the programs having potential scopes were floor forecasting (T2P1); awareness-raising (T2P3); risk management for loss of income and property (T2P4) (figure 28) (MOEF 2009, pp. 42–45). This pillar's key programs also lacked to mention clearly the urban poor's inclusion under its coverage.

The infrastructural development (T3) pillar covered the programs having potential scopes were the maintenance of flood embankments (T3P1); improvements of urban drainage (T3P4); adaptations for floods (T3P5); resuscitation of canals and rivers (T3P8) (MOEF 2009, pp. 46–53). The rest of the other programs were relevant to coastal areas (figure 28). The programs under the 'infrastructure' pillar lacked any development, inclusion or recognition of the urban poor settlement's infrastructures.

The Research management (T4) pillar covered the programs having a potential scope of knowledge generation about climate-induced internal population migration and capacity developments (T4P6) (MOEF 2009, p. 59); The rest of the other research program's focus was on coastal areas and climate impacts on economy and biodiversity (figure 28). The programs under the 'research' pillar had no initiative for any knowledge development about climate vulnerability of the urban areas, the urban poor's climate resilience, climate adaptation capacities of different urban socio-economic groups and sustainable ways forward for integrated and inclusive climate resilience.

Under the 'mitigation and low carbon development' (T5) pillar the programs having potential scopes were urban waste management (T5P6); the Built environment's efficiencies for energy and water (T5P9) (figure 28) (MOEF 2009, p. 66,69). This pillar's key programs also had not clearly recognized urban poor's inclusion under its coverage.

Theme	**T1: Food Security, Social Protection and Health**
Programme	P1. Institutional capacity for research towards climate resilient cultivars and their dissemination P2. Development of climate resilient cropping systems P3. Adaptation against drought P4. Adaptation in fisheries sector P5. Adaptation in livestock sector P6. Adaptation in health sector P7. Water and sanitation programme in climate vulnerable areas P8. Livelihood protection in ecologically fragile areas P9. Livelihood protection of vulnerable socio-economic groups (including women)
Theme	**T2: Comprehensive Disaster Management**
Programme	P1. Improvement of flood forecasting and early warning P2. Improvement of cyclone and storm surge warning P3. Awareness raising and public education towards climate resilience P4 Risk management against loss on income and property
Theme	**T3 : Infrastructure**
Programme	P1. Repair and maintenance of existing flood embankments P2. Repair and maintenance of cyclone shelters P3. Repair and maintenance of existing coastal polders P4. Improvement of urban drainage P5. Adaptation against Floods P6. Adaptation against tropical cyclones and storm surges P7. Planning and design of river training works P8. Planning, design and implementation of resuscitation of river and khals through dredging and de-siltation work
Theme	**T4: Research and Knowledge Management**
Programme	P1. Establishment of a centre for knowledge management and training on climate change P2. Climate change modelling at national and sub-national levels P3. Preparatory studies for adaptation against sea level rise P4. Monitoring of ecosystem and biodiversity changes and their impacts P5. Macroeconomic and sectoral economic impacts of climate change P6. Monitoring of internal and external migration of adversely impacted population and providing support to them through capacity building for their rehabilitation in new environment P7. Monitoring of impact on various issues related to management of tourism in Bangladesh and implementation in priority action plan
Theme	**T5: Mitigation and Low Carbon Development**
Programme	P1. Improved energy efficiency in production and consumption of energy P2. Gas exploration and reservoir management P3. Development of coal mines and coal fired power stations P4. Renewable energy development P5. Lower emission from agricultural land P6. Management of urban waste P7. Afforestation and reforestation programme P8. Rapid expansion of energy saving devices eg. Compact Florescent Lamps (CFL) P9. Energy and Water Efficiency in Built Environment P10. Improvement in energy consumption pattern in transport sector and options for mitigation
Theme	**T6: Capacity Building and Institutional Strengthening**
Programme	P1. Revision of sectoral policies for climate resilience P2. Main-streaming climate change in national, sectoral and spatial development programmes P3. Strengthening human resource capacity P4. Strengthening gender consideration in climate change management P5. Strengthening institutional capacity for climate change management P6. Main-streaming climate change in the Media

Figure 28: Frameworks of BCCSAP Programs (2009-2018).

Source: (MOEF 2009, p. 32).

Under the 'capacity development' (T6) pillar the programs having potential scopes were institutional capacity development (T6P5); introducing climate change issues in media (T6P6) (figure-3) (MOEF 2009, pp. 75–76). This pillar's key programs also had not clearly recognized urban poor's inclusion for their capacity development to improve their adaptive capacity to adverse climatic impacts.

The climate action plan also lacks clear demarcation about the responsibility distribution (work-packages) among different stakeholders and other instruments to implement the action plans. The assessment shows it provides only the list of organizations and timelines as defined by the short to long term (MOEF 2009, pp. 33–76). Ministry of Environment and Forests (MOEF) has set climate action strategies but it lacks coordination with the policies and plans by other national development institutions and ministries that are important for city-level adaptations (Araos et al. 2017, p. 8). Araos, Ford, Berrang-Ford, Biesbroek & Moser (2017, p. 8) reported the following national policies contained no reference for climate impact responses and hence lacked coordination with the guidelines of climate-related adaptation action plans of BCCSAP:

- National water management plan (2000)
- National Land-use policy (2001)
- National Housing policy (2008)
- Urban and Regional Planning Act (2014)
- National Urban sector Policy (2014)
- Delta plan (for 2100).

5.3.2. Answer to RQ-3 (part 1): Insights from the National Level Climate Policies

The descriptive analysis of the previous section shows that

- Present national adaptation programs lack clear references for the 'recognized coverage' and inclusive consideration of the urban poor group's climatic problems and vulnerabilities. Hence, the policies may lack responsiveness to the urban poor's climate vulnerability.
- The 'recognition' and 'inclusion' of the urban poor community in the climate policy-program development is not clear and their inclusive participation in the climate policy negotiation is also not mentioned.
- The definition and the role of civil society in climate policy development is not also transparent. The politicized group, local strongmen (*maastans*), local leaders denoted as 'civil society' and profit capturing business community may pave the way for corruption for reaping individual interests from not only national policy negotiation but also from international supports (through 'steering committee' and 'climate change focal points').
- The national climate policies lack the recognition of promoting affordable housing development, formalized urban service delivery, infrastructural development, and integrated community development programs for the urban poor.
- The national climate programs lack organized governance and responsibility distribution among the stakeholders for implementation (*who does what?*). This may create problems in assessing their present capacities and the facilities necessary for enabling purposes. Moreover, it may create ambiguous conditions by bouncing off responsibilities.

5.3.3. City-level: Climate Change Adaptation Initiatives

Several public and autonomous institutions are working for the development of the Dhaka city. RAJUK (Capital City Development Authority) under the ministry of housing and planning of the Government of Bangladesh (GoB) is responsible for the development projects in Dhaka city and the areas under its jurisdictions. Dhaka City Corporation, DCC (divided in north and south region) is the administrative public institution where the chief public representatives (Mayors) are elected by the public-elections. The Dhaka Structure Plan (2016- 2035) has been developed for the City's 15 years development from 2016 to 2035 and RAJUK is the responsible agency for the implementation of the plan (RAJUK 2016, p. 1). Dhaka Structure plan (2016-2035) was developed through the Regional Development Project (RDP) by reviewing the previous Dhaka Metropolitan Development Plan, DMDP (1995 to 2015) (Ibid). This section of the thesis studied the relevant aspects form the Dhaka Structure plan (2016-2035).

5.3.3.1. **Housing and Tenure Security**

Tenure security and affordable housing and are very important criteria for the urban poor community and their access to inclusive services in the city. Dhaka Structure plan shows that in Dhaka city most of the housing land is occupied for the higher- to-middle income group having a low proportion of the city's population, but a comparatively large proportion of the low-income group have very little scopes for accessing housing land (figure-29). Dhaka city lacks the development of affordable housing market for the poor communities, so, the poor need to find their accommodation in rented informal, squatter and slum settlements (*Bustees)*. RAJUK reported, even for the lower middle-income-group, only 4.88% had affordable housing while 78.05% of this group's people had unaffordability and 17.07% had severe unaffordability for access to housing (table 13) (RAJUK 2016, p. 122). The Dhaka Structure plan incorporated several policy measures to develop affordable housing for different classes of urban people. It considered incorporation of the public sector for affordable housing supply, public sector's playing facilitator role for housing supply, ensuring adequate land supply, hosing within urban centers and close to transit points for solving city's housing problems (RAJUK 2016, pp. 124–128). It proposed the slum improvement or relocation policies incorporating the National Housing Authority, RAJUK, Local Governments, DCC and GoB and private slum owners. It had plans to exercise a 'rent control' which proposed that the private slum owners should not increase the rents (for five years) (Ibid, p.128). But, in Dhaka, the private slum business is often politicized and may cause eviction by the private landowners for other profitable developments. Rent control can massively increase the risks of eviction of the slum dwellers. Without improving the affordable housing market/supply for the urban poor group such a decision would adversely affect the situation. How the affordable housing provision for the poor would be improved, how the adopted policies would be implemented, their governance, roles, and responsibilities of different stakeholders were not clear in the Dhaka Structure Plan.

Dhaka Structure Plan (2016- 2035) does not show any detail mechanism and policy guidelines to facilitate the climate resilience of the urban poor's housing and adopt measures for the poor's inclusion in the city policy. It has calculated the housing need based on a flat calculation by dividing the census's estimated population number (25 million) by average household size (4.51 in 2011) (formula: H= P/S) (RAJUK 2016, p. 120). It mentioned no

consideration or coordination with the NAPA and BCCSAP policy and city's future planning about how the city would handle the migrants (including climate migrants) coming to the capital city and the city's future responses to slum formation.

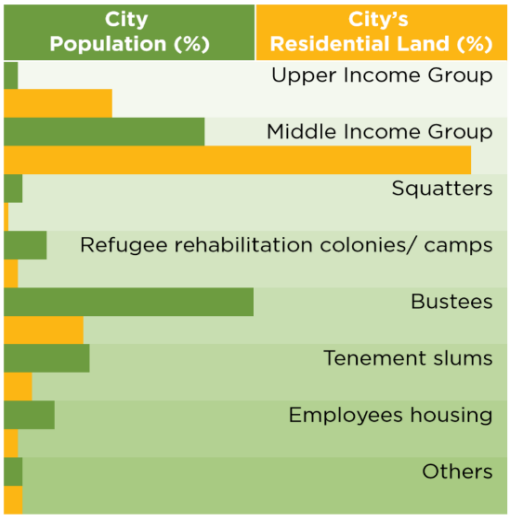


Figure 29: Access to urban residential lands for different socio-economic groups and related population in Dhaka.

Source: (RAJUK 2016, p. 118).

Table 13: Affordability levels of housings in Dhaka for different income groups in percentage.

Affordability Levels of housings in Dhaka	Lower middle-income group (%)	Middle-income group (%)	Upper Middle-income group (%)
Affordable	4.88	21.95	47.97
Unaffordable	78.05	70.73	52.03
Severely unaffordable	17.07	7.32	0

Source: (RAJUK 2016, p. 122).

5.3.3.2. **Water Supply**

The changing climatic condition combining with the unplanned urban growth can instigate a very high vulnerability for the urban water supply, and the poor in the squatter settlements may suffer much due to exclusion and their low adaptive means. Dhaka Structure Plan (2016- 2035) reported that the water problem in Dhaka city was more severe in the central and southern west part of the city than in the northern region (RAJUK 2016, p. 231). It stated that over the last seven years, the city's underground water table had become lowered about 20 meters having a depletion rate of 2.81 meters per year. The policy in its scenario analysis recognized not only the increasing urban population but also unauthorized deep tube wells, rapid urban build-up hampering rainwater percolation to the underground, and climate change impacts in the city as the responsible causes for the underground water depletion problem (Ibid). It reported that 48% of the city area had become transformed into the urban built-up area due to unplanned urbanization that hampered the natural rainwater percolation. Dhaka Water Supply & Sewerage Authority (DWASA) depended on the underground water aquifer for 80% of its water production (RAJUK 2016, pp. 231, 166).

There were 37.4% of the city population in the Dhaka metropolitan region living in over 4966 slums who were lacking inclusive water services (Angeles et al. 2009, p. 8). According to RAJUK (2016, p. 166), in 2011, DWASA had provided 189 million liters of water per day (MLD) to the slums dwellers which was only 9.4% (nearly 10%) of its total domestic consumptions of 2,004 MLD (by table 1, city's 37.4 % people live in slums) (figure 30). Table 14 shows for 2011, the urban slum dwellers got even less than the city's standard limit of 60

lpcd for the low-income community where the other residential had higher than the standard supply rate of 160 lpcd (DWASA 2014, p. 62).

Table 14: State of water services at slums, other non-slum residential areas, and service losses in Dhaka city.

Category	% of city people	Served (people million)	Served quantity (in 2011) (MLD)	Litters of water served per capita per day (lpcd)	DWASA per capita consumption rate, 2011 Based on: (DWASA 2014, p. 62)		Basic Water requirements (Unit: lpcd)
					Low-income community (lpcd)	Other residential (lpcd)	IWM survey, 2012 in Dhaka shows the water demand as follows (DWASA 2014, p. 60): Showering and ablution: 72 Cooking: 3 Drinking: 3 Sanitation: 31 Utensil Washing: 27 Cloth Washing: 20 The poor's 33.4 lpcd water is inadequate to meet all demands
Slum people	37.4%	5.65	189	**33.4** (lower than the consumption rate of 60 lpcd)	60	160	
Other reside-ntial	62.6%	9.47	1815	**191.6** (higher than the consumption rate of 160 lpcd)			
Water loss			576	Lost Potential: **= 576 MLD ÷ 60 (lpcd).** = 9.6 million low-income people can be served.			

Source: Author's calculation based on (RAJUK 2016, p. 166; DWASA 2014, pp. 59–62).

The master plan shows, by 2035, the slums will get 362 MLD (10.8%) and other residential areas will get 2960 MLD (89.2%) out of its total service provision of 3322 MLD. The masterplan for 2035 considers the provision of 10.8% of total water service provision to slum dwellers (by percentage nearly that of 2011, 10%). By 2035, the increasing slum population may find that the city's water supply (362 MLD) is insufficient and may face the water crisis badly. This data/scenario represents the urban poor's negligence, weak level of inclusion and so-called access to the civic services. The supply data depicts, it had 'loss' quantity even beyond the water supply quantity for slums. There is a lack of consideration over the years to reduce the water loss, but it holds the restriction for the poor's access to the formalized water supply. Table 2 shows, by utilizing the lost water, 9.5 million low-income people can be served at the city's standard of 60 lpcd (for low-income people). Supporting the case study, it demonstrates, the high 'loss' category may pave the way for profit capturing of the influential groups by promoting illegal water supplies rather than providing formalized water supply to the slums.

Item / Year	2011	2015	2020	2025	2030	2035
Coverage Area (Sq. Km)	404	404	502	502	611	611
Total Population (Million)	15.12	17.31	19.90	22.33	24.51	26.31
Residential Consumption (MLD)	1815	1947	2239	2512	2757	2960
Slum Consumption (MLD)	189	216	273	307	337	362
Total Domestic consumption (MLD)	2004	2163	2512	2819	3094	3322
Other Consumption (MLD)	300.6	346	433	620	773	831
Total Demand/ Consumption (MLD)	2304.6	2509	2945	3439	3867	4153
Fire Fighting (function of population) (MLD)	50	54	63	70	77	83
Sub-Total (MLD)	235.6	2563	3008	3509	3944	4236
Loss (MLD)	576	577	589	619	580	622
Total required Demand/ Production capacity (MLD)	2931	3140	3597	4128	4524	4858

Figure 30: DWASA water supply plan.
Source: (RAJUK 2016, p. 166).

5.3.3.3. **Employment and Skills**

A high share of the Dhaka city's employment is informal, and the poor are mainly involved in informal and service delivery activities. Dhaka Structure Plan (2016- 2035) had mentioned policy objectives to upraise the informal earning activities for higher value addition prospects (RAJUK 2016, p. 144). Higher value addition may ensure the informal poor's better-earning opportunities, improved affordability, and infrastructural improvement potential. However, it lacks to demonstrate any skill development policy mechanism for the urban poor so that the values added by the informal workers would be improved. Without skill improvement of the informal sectors, higher value addition by the urban poor would not be a responsive strategy.

The Dhaka Structure Plan mentioned considering, selecting, and developing places for informal businesses and adopting suitable mechanisms for formalizing processes. It plans to start small scale projects to accommodate (at suitable places) the informal business activities according to types avoiding hindrance to the civic facilities (e.g. traffic movements) (Ibid). But it lacks the details about the applicable tools, guidelines, responsibility distribution, governance structures, funding and other directions for implementation of such broad strategies. Without clear directions, there would be a lack of coordination among the development actors (responsibility throwing around) and the effective implementation of the policies would not be achieved. It has also a consideration for peri-urban development through the improvement of infrastructural connection with the city and creating employment opportunities (promoting

garments industry, knitwear industry, the establishment of economic zones, etc) (RAJUK 2016, pp. 146–148). Without proper strategic planning, such employment opportunity development may increase the migration rate and unplanned growth in the peri-urban areas. The structure plan lacks mentioning detail applicable measures or guidelines to reduce migration and promote decentralization from the dense capital city (for reducing pressure on one city).

5.3.3.4. **Natural Drainage and Flood Management**

For improved natural drainage, the Dhaka Structure Plan (2016- 2035) undertakes policies based on two objectives. The first objective, focusing on flood prevention, considers the policies for protecting the flood flowing zones. It plans to promote controlling and prohibiting the commercial, industrial, and residential developments on the flood-flowing lowlands and removing present obstacles. It also considers the protection of the canals (*khals*), the rivers and the protection of the floodwater retention areas (RAJUK 2016, pp. 161–162). The second objective with the focus on the protection of life, property, and settlements incorporates building flood embankments in the flood-risk prone areas (eastern part) of the city and developing institutional capacity, good governance and manpower's skill of BWDB, LGED, and DWASA (Ibid, p.163). However, Dhaka Structure Plan has no policy reference for the urban poor's vulnerable climatic concerns and their informal settlement's protection and adaptation. The skill development program lacks to consider the incorporation of the vulnerable urban poor's adaptation/coping skill development. The flood embankment has increased the drainage problem in the city for hampering the free flow of rainwater to lowlands as the city's increasing impervious surface hampers the rainwater percolation to the underground water table (Mowla & Islam 2013, p. 23).

5.3.3.5. **Flood Resilient Urban Environment**

For the Disaster prevention and mitigation, the Dhaka Structure Plan (2016- 2035) proposes to develop the land use plan with risk sensitivity incorporating the urban slums in consultation (RAJUK 2016, p. 232). It plans to develop a flood resilient urban environment with improved adaptation techniques (by remodeling of buildings, floatable buildings, storing of rainwater for the dry season, etc) rather than protective flood control measures (Ibid, p. 236). However, the plan lacks mentioning any inclusive policy instruments, implementing organizations, funding sources, detail guidelines to improve the resilience, and adaptive capacity of the informal urban poor to flood and waterlogging.

5.3.4. Answer to RQ-3 (part 2): Insights from the City Level Structure Plans

The descriptive understanding of the Dhaka Structure Plan at the previous section shows that,

- Dhaka Structure Plan (2016-2035) lacks to demonstrate any policy mechanism to improve the tenure security of the urban poor's informal settlements and any process of inclusion to the formal system.
- It lacks the inclusive policy instruments for improving the urban poor's affordable housing supply and it lacks the responsiveness for housing the migrants (also climate migrants).
- It also lacks detail guidelines about economic decentralization to reduce migration.

- It shows the water supply inequality for the urban slums and the water supply master plan (up to 2035) may not also be responsive to reduce the urban poor's water crisis.
- It lacks the detail policy mechanism and implementation guidelines to improve the poor's skill development and the formalization procedures of their informal income activities.
- It lacks the detail policy instruments for improving the poor's coping capacities by awareness building and training for climatic disasters.
- It lacks considering the urban poor's inclusion into the natural drainage improvement programs and also provides no clear implementation guideline for improving flood resilience in the urban slums.
- It is prominent that due to the lack of tenure security and the informal nature of the settlements, the urban poor cannot access formalized civic services.
- It shows no clear guidelines, coordination processes, and responsibility distribution for the development organizations to implement the policies.

6. DISCUSSION AND RECOMMENDATION

6.1. Insights from Grassroots Vulnerabilities and Adaptation

The analysis of the urban poor's perception about the climatic problems, risks, and stresses (risk matrix) showed that heatwaves, heavy rainfall, waterlogging, drainage problem, polluted water, inadequate water supply, sanitary problems and poor condition of the house constituted the very high climate risks for the grassroots level. The poor suffer worse than the other socio-economic classes of city people from the adverse climatic impacts due to the 'cause-and-effect' influences of poor infrastructures and informal housing conditions. The poor have also low capacity to develop a climate-resilient living environment due to the prevailing informality, low income, policy exclusion and the fear of eviction.

The studied slum community had an alarming climate vulnerability index (0.956) for high vulnerability extents in the dimensions of sensitivity and exposure but low adaptive capacity considering the vulnerability framework. The detailed understanding of the 'sensitivity' dimension (vulnerability extent 0.711) represented that the poor had very high vulnerability at the major component 'water' (0.906). Supporting the case study, the DWASA master plan in the Dhaka Structure Plan (2016- 203) also depicts that the low-income group gets supplied water less than the stipulated standard and even the supply percentage would not change much in future (up to 2035). The sensitivity dimension also represented high vulnerability for major components food (0.666) and health (0.600). The poor used to adapt to the climate-induced health issues by taking low-cost treatments opportunity from the government hospitals but high demand and increasing population are creating pressure on the available capacity. The poor used to adapt to the climate-induced food vulnerability by reducing nutrition intake and taking less costly food. Climate policies lack the inclusive adaptative measures to address the urban poor's such climate-induced food and health vulnerabilities.

The poor in the study area had also significant vulnerability due to their low 'adaptive capacity' (0.461) to climatic impacts. Detail understanding of this dimension showed the poor had a high vulnerability extent for livelihood strategies (0.762) for climate change impact. The poor used to adapt by taking multiple alternative earning sources/jobs. The climate policies and the city development masterplan lack to incorporate any clear reference for the skill

development programs for the urban poor. High migration and low education/skill level of the household head caused the vulnerabilities for the socio-demographic profile component (0.385). The poor are thinking to educate their children for better adaptation in the future as the response for the non-school going children (6 to 9 years) was less. The vulnerability extent for social network (0.448) component was composed of the high dependency on the neighbor's help, monetary transactions and low preparedness (due to low income) for climatic impacts. The climate policies lack clear policy inputs/references for reducing the poor's such adaptation challenges and shortcomings (at the grassroots level).

The 'exposure' dimension had a vulnerability extent of 0.613. Such vulnerability level was composed of the high vulnerability extent for the natural disaster component (0.630) and the vulnerability extent by the poor's perception of climatic variation component (0.588). In line with Jabeen, Johnson and Allen's (2010) research this study also finds that the poor use to adapt by raising their floor level, slope their household premises to drain out rainwater, plant trees and creepers for reducing heat gain. Climate policies and city development structure plans have also no clear reference to improve the infrastructural condition in the informal, slum settlements.

6.2. Judgments from Empirical Studies

The study showed different national-level climate action plans like NAPA and BCCPSAP as well as the city development structure plans lacks coordination and considerations for the urban poor and other migrants coming to the city from different parts of the country. The city development structure plan lacks policy guidelines to plan for the incoming climate migrants in the city preventing new slum formation. Both the national and city-level policies lack the scopes for considering the poor's climate vulnerability, grassroots adaptation measures, and prevailing challenges. The policies lack inclusive consideration and detailed guidelines for the urban poor's affordable housing supply, skill development, formalization of their income activities, drainage management, flood management, awareness programs, and water services.

Accepting the research arguments of DePaul (2012) and Tacoli (2009) this research also finds that the policies in lower-income countries like Bangladesh are not considering and planning for the poor's migration to cities as their adaptation strategies for climatic impacts. The urban areas lack inclusive planning for the poor migrants (both short-term and permanent) in the city that may govern unplanned urban growth.

Accepting the research arguments of Anguelovski et al. (2016) this study finds that the climate change impacts and associated urban problems are increasing the urban inequality in the context of a global south city, Dhaka. The formalized adaptative conditions or civic services of the Dhaka city for climatic impacts are 'omitting' (neglecting) the urban poor's access while 'commissioning' for the other non-poor groups.

Choudhury & Mowla (2011, pp. 3–6) argued fourfold strategies to improve climate adaptation broadly in whole Bangladesh such as sharing the climate impact losses, prevention and modifying the risks and changing the uses of resources. Some of the suggestions from their fourfold strategies may bring insights for reducing the climate vulnerability of the poor in the urban areas. Impact's 'loss-sharing' by the government or NGOs through subsidies, loans or other types of financial support may assist and improve the adaptation initiatives by the poor. Water management, structural (housing, infrastructure) and non-structural (biodiversity,

health) developments, and community-based developments would 'manage' and 'prevent' the climate risks (for 'cause and effect' mechanism). 'Changing the use' may suggest promoting livelihood diversification to adapt to the adverse climatic condition and income losses. The study also suggested to include climate adaptation in education and to use the media for climate awareness-raising and disaster preparedness.

Introducing the study of Indonesia's successful Kampung Improvement Program (KIP, 1969) Jones (2017, p. 11) discussed that urban poverty reduction decreases the proportion of urban people dwelling in slums. The study reported, during the 1990s to 2000 urban poverty in Indonesia was reduced from 48% to 13%, in response, the proportion of urban people dwelling in urban slums reduced from 51% in 1990 to 22% in 2014. KIP was jointly funded by the Jakarta city authorities and the World bank which focused on improving the infrastructure, drainage, pavements, sanitation and health facilities in the urban slums. With the KIP's successful bases, the Social Safety Net program and P2KP (urban poverty alleviation Program) contributed to improve the sustainable housing, livelihood improvement, and other developments in socio-economic and physical sectors in slums (Ibid, p. 12). Such collaborative policy examples from successful practices can bring insights for formalized slum improvements in Dhaka. Livelihood improvement, adopting a strategic formalization process for informal economic activities, as well as collaboratively improving the housing and infrastructure may improve the living condition of urban poor. However, developments focusing on one city or capital Dhaka would increase the pace of migration so decentralization and regional development creating planned growth centers at different cities/towns across the country is necessary (Afsar 2003, p. 10; Begum 2004, pp. 108–109).

Baruah (2007) demonstrated the integrated efforts by Multi-stakeholder partnerships of public, private, NGOs, CBOs, and international donors for the development of affordable housing, sanitation, pavements, drainage, in the slum areas by the 'Ahmedabad Slum Networking Project' (*Parivartan*) in India. It contributed positively by governing pilot projects for low-cost technologies, preventing poor's eviction, improving the poor's housing rights, participatory approach for policy developments, emergency reliefs and poor's capacity improvements (Ibid p. 229). Boonyabancha (2009) discussed participatory slum development by engaging the urban poor and the government through Baan Mankong Program in Thailand. The urban poor CBOs could get flexible infrastructure development loans through Community Organisations Development Institute (CODI, an institution under ministry), can invest community savings and negotiate for affordable housing development on suitable public lands. The urban poor get integrated into a development network of experts, universities (researchers), NGOs, government, and different land tenure arrangements. From 2003 to 2009 this program positively benefited 78,884 urban poor families in 260 cities. (Ibid p. 314-315).

The empirical studies, examples from urban slum development strategies mentioned above shows, providing access to formalized and affordable civic services to the slum dwellers would improve the urban poor's living conditions reducing their climate vulnerability. Inclusive urban development strategies, sustainable planning, improvement of the poor's sense of tenure security, improving the poor's right to develop their condition, negotiation process, and the capacity building would reduce the poor's vulnerabilities for climate impacts in cities.

6.3. Tenure Security, Vulnerability and a Way Forward:

The understanding from this research demonstrates, the condition of informality increases climate change's adverse impacts, risks, and vulnerabilities for the poor community. Due to informality and lack of tenure security, the urban poor's settlement cannot access the formalized infrastructural services of the city. The service providing institutions are disinclined to provide civic services and infrastructural facilities in the informal settlements. Considering the constant threat of eviction, the slum businessmen (who are mostly politicized strongmen), NGOs and development organizations are reluctant to invest and improve the present condition in the slums. The poor inhabitants also have very little capacities (low income) to improve the situation facing the development costs and high land values in the city while having no security against eviction. The housing market also lacks affordable housing solutions for the urban poor in the dense megacity Dhaka. Improving the poor's tenure security by adopting viable formalization mechanisms for the informal urban poor may contribute to the improvement of the infrastructural conditions in the urban slums. Such an improved sense of secured tenure, affordable housing options, and infrastructural improvement will reduce the climate impact vulnerabilities for the poor in the megacity Dhaka.

A trend of research literature argues the options to upgrade the security of tenure in the informal settlements in different contexts [e.g.: (Durand-Lasserve & Royston 2002; Van Gelder 2010; Marx, Stoker & Suri 2013)]. This paper discusses two tenure development options considering the contextual informality of the urban poor in Dhaka. One option is from the concept of flexible tenure option for enabling the poor for exercising their rights to develop, and the other is from the concept of government's perspective change for promoting an affordable housing market for the urban poor.

- **Orienting Towards the 'Right Based Tenure':**

World Bank (1993, p. 76) reported that the houses or the land properties with secured tenure occupies 25% to 60% increased value than the properties without the security of tenure. So, providing the 'land-title' based full freehold tenure ownership to the informal urban poor may negatively distort the present housing market (Nahiduzzaman 2012, p. 26; Payne 2001). A decision like this will provide a message to the land developers that a sudden increase in the values of the informal housing types will be experienced. This, in turn, will cause illegal land subdivisions and give rise to more squatter settlements for getting benefits from that increased price. The poor or the politicized/corrupted private slum businessmen (*musclemen*) would sell their present slum houses at a high price and make another slum elsewhere for capturing profit and becoming rich (Nahiduzzaman 2012, p. 26).

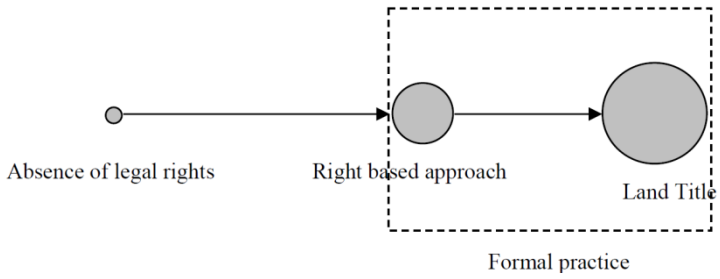


Figure 31: 'Right based approach' for improving tenure security of the urban poor.
Source: (Nahiduzzaman 2012, p. 27).

According to Durand-Lasserve and Royston (2002, p. 1), tenure security may be formed by different concepts and should not always be considered as only the land-based freehold or leasehold. It can also be arranged by the provision of 'degree of legitimacy' or sense of security for the informal settlement's non-eviction and to allow the poor people to develop their present infrastructural or living conditions. The legitimate security for the non-eviction of the informal settlements can be provided for a specific period (say 10 to 15 years) to allow/enable the poor to develop and improve the vulnerable condition of their houses/settlements within this period. The authority can provide different facility bundles (e.g.: low-risk credits, microcredits, expert input, etc) for enabling the poor to exercise their 'rights to develop' their housing and other infrastructural systems in an 'aided-self-help' or participatory basis (Marx, Stoker & Suri 2013, p. 203). For that specified 'secured' period (10 or 15 years) a flat, affordable land rent can be charged to the poor. By that time, depending on different criteria (declared by authority) some self-help houses may be provided full titling, or some may be provided communal titling for long term tenure security. Figure 31 shows, such 'right based tenure security' being in the middle position, can bridge the gap between the formalized practices of tenure security and improvement of the vulnerable condition of the poor's informal settlements.

Case studies for the aided-self-help development and the right-based tenure option from Egypt (the 'ground-rent' system for the poor communities while ensuring legal security of providing compensation for the houses displacement) and India (1995 'Ahmedabad Slum Networking Project') documented the positive impacts. The development and upgradation of the informal settlements that once were adjudged as hard or even impossible were accomplished within a short time by the participatory process.

- **Orienting Strategies Towards 'Investments' from 'Give Away':**

According to Nahiduzzaman (2012, p. 131), in the urban slum upgradation projects in Dhaka, the government followed the strategy to provide land ('give away') to the poor slum inhabitants for developing their housing [e.g.: slum upgradation projects at Mirpur and Bhasantek in Dhaka]. Such strategic disposition might be the outcome of the government's inadequate knowledge about the poor's capability (at the grassroots level) and the inadequate appreciation for capturing the long-term benefit from the upgradation projects. With such a 'give away' strategy the government pays much (resources) but loses to reap the long-term benefit as this strategy does not develop affordable housing supply and affordable housing market for the poor (Ibid). However, the government's strategic orientation to view the poor's affordable housing market as a 'social business' may improve the supply scenario. The government can integrate the banks, NGOs, real estate developers, private sectors, international donors and financial institutions for providing 'social services' adopting a 'no profit' and 'no loss' basis (figure 32). The government can invest by controlling the degree of rights, land lease, tax rebate, tax-subsidies and promote affordable housing market/supply for the poor through the 'welfare returns' of the social business (Ibid).

Nahiduzzaman (2012, pp. 132–137) has explained the key concerns for the social business of poor's affordable housing solution as follows:

- Understanding the poor's affordability at the grassroots level and determining their needs
- Orienting towards right based tenure option
- Providing acceptance to the poor's rental contracts and formalizing the process

- Integrating developers and real estate sectors
- Integrating financial service providers (banks, international development agencies)
- Integrating city-level service providers (DCC, DWASA, etc)
- Promoting public-private-partnerships
- Clearly declaring and following the standards for construction and development works.

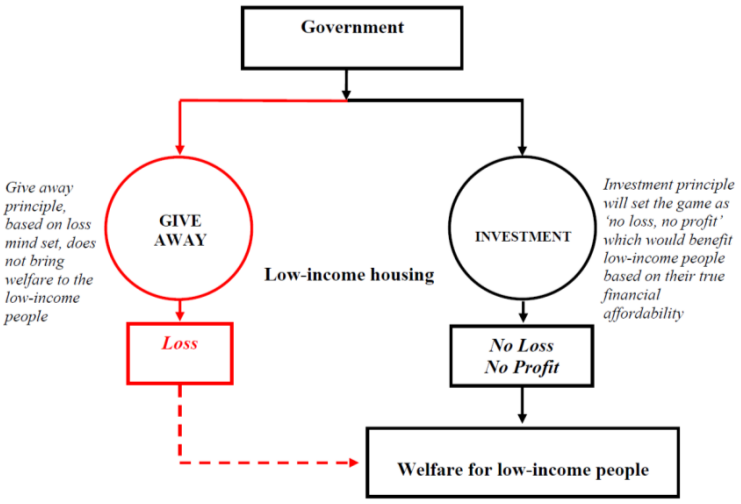


Figure 32: Strategic concept of 'investment' than 'give away' for developing an affordable housing market for the urban poor community.

Source: (Nahiduzzaman 2012, p. 132).

6.4. Recommendation

The grassroots perception, insights from the study, empirical discussions of the researches, and understanding of the climate policy and city development plans may develop the ground for identifying key concerns for reducing the climate change vulnerability of the urban poor. Three focused group discussions were also arranged at the study area for understanding the grassroots insights for reducing the climatic vulnerability of the urban poor in the future (figure 33).

Figure 33: Group discussion.

Source: Author's field survey, 2019.

The important insights from the study's researched bases and the group discussions were considered for developing recommendations for future policy adjustment and sustainable developments. The relevant recommendations are as presented below:

- Accepting and developing the 'right based tenure' concept for improving the poor's tenure security and the inclusion of the urban poor in the urban services and civic facilities.
- Promoting an affordable housing market/supply through a 'social business' concept may develop climate-resilient housing for the urban poor community.
- The government needs to control the illegal slum formation in the city by concentrating on the decentralization of the civic facility and income opportunity to the other parts of the country. So, the rural poor may not need to migrate and congregate on only the capital city (as Dhaka is the only large business center in Bangladesh) creating overpopulation and infrastructural bottlenecking.
- Skill development of the urban poor can improve their income opportunities and improve their adaptive capacity to climate change impacts. Formal training and formalization mechanism (following a viable strategy) for the income activities of the poor migrants/urban poor may improve the condition. Skill development can also pave the way for the alternative, less vulnerable job/livelihood option for the urban poor (considering climate impacts).
- Preaching of education to the urban poor may improve their knowledge of adaptation strategies. It will also develop the socio-demographic condition of the urban poor.
- Awareness building and adaptation training programs (for before, during and after the disasters) should extensively incorporate the urban poor groups for improving their adaptive knowledge and capacities. Such programs should also be incorporated into education systems to train future generations. Disaster forecasting (for heavy rainfall, flood, heatwaves, cold waves, storm) should also be provided/circulated to the informal urban slum areas and make available to the urban poor.
- Promoting the research initiatives about grassroots challenges, requirements, and specific shortfalls may map the priorities for resource utilization in a developing country. Climate Policies, action plans, and other city-level master planning should be developed with an inclusive basis for the urban poor groups. Researched knowledge about the urban poor's climate vulnerability, exposure, sensitivity and adaptation capacity are needed to be addressed in the development strategies.
- Coordination among the service providing institutions, city development masterplans, climate policies, and climatic action plans was not clear. Hence, sustainable development coordination is necessary following a clear inclusive strategy for the urban poor communities.
- Capacity development of the service-providing sectors (e.g. hospitals, water, drainage, etc) is necessary which may reduce their challenges. Inclusive urban civic service for the urban poor is necessary to reduce their sensitivity towards climatic impacts.
- Multi-stakeholder based (NGOs, CBOs, PPP, private sector, international organizations) development initiatives for the urban poor communities may reduce the climate-vulnerable conditions of the urban poor. The multi-stakeholders can also enable the poor communities to improve their bargaining power for the acquisition of their legal rights and inclusion in policy developments.

Addressing the above key recommendations in relevant climate policies, climate change action plans, and city-level development strategies may reduce the climate vulnerability of the urban poor groups in the megacity Dhaka.

7. CONCLUSION

The megacity Dhaka is the major economic center of the country. So, the rural poor and the climate migrants are congregating in this city for better economic potential. High population density due to high migration is causing infrastructural challenges and unplanned growth of the city. Dhaka has become the city that contains a high share of the informal settlements of the country. Also, a high share of city people lives in slums in Dhaka city. Facing the accommodation challenges in the dense city the poor find their accommodation in the informal settlements (slums). The urban poor settlement's prevailing nature of having no tenure security, informality and lack of inclusion to the civic facilities increases their climate impact risks, stresses, and problems. By mapping the climate-induced problems in the slum, the study found that the informal and poor nature of the housing and infrastructural condition created a very high climatic risk for the poor (by a 'cause and effect' relationship). The analysis of the climate vulnerability index found that the studied poor community in the megacity Dhaka had a very high extent of climate impact vulnerability (0.956). The urban poor's climate vulnerability arose from their low adaptive capacity (extent= 0.461), high sensitivity level (vulnerability extent= 0.711), and high exposure (vulnerability extent= 0.613) to the climate-induced risks (considering the vulnerability framework's dimensions). The climate policies and climate change action plans lack inclusive consideration for the urban poor and clear directions to improve their vulnerable condition. The city development structure plans also lack inclusive programs to increase the poor's sense of tenure security and incorporation to the civic services and facilities that would reduce their climate vulnerabilities. Such studies of vulnerability extents may demonstrate the grassroots requirements, capacities, and direct the utilization of limited resources accordingly for developing an inclusive urban resilience.

Based on the empirical insights from the parametric research, discussions of the literature, expert's ideas and group discussions this study had formulated the recommended key concerns to reduce the climate impact vulnerability of the urban poor. Such key concerns may be useful for inclusive climate policy development and sustainable city development strategies for improving climate resilience in the megacity Dhaka. This research recommended incorporating policy mechanisms to improve the tenure security of the poor by enabling them to exercise their rights to improve the infrastructural conditions in slums by a participatory process. It suggested promoting affordable urban housing through multi-stakeholders based social businesses. It also recommended to preach education, promote decentralized regional development, awareness program, livelihood diversification for improving adaptation capacities. Inclusive governance, detail responsibility distribution, coordination, and capacity building of the relevant institutions are also necessary for the effective implementation of inclusive policies.

Climate vulnerabilities may be different in rural and urban areas due to contextual aspects in a developing country like Bangladesh. It may also be different in the coastal areas and the inland cities/megacities. Contextual and grassroots climate vulnerability assessment may guide inclusive, sustainable, and climate-responsive regional development. The parametric reasoning of climate vulnerabilities of this study can pave the scopes for the future researches to approach the research questions like:

1) How the climate vulnerabilities of the urban poor differ from the rural poor in Bangladesh depending on the context? How policies are comparatively responsive to promote climate resilience in those contexts?
2) How the climate vulnerabilities of the urban poor vary among the coastal and inland cities?
3) How the social context and political-economic attitudes in different counties affect climate vulnerabilities of the urban poor?

Understanding from this grassroots climate vulnerability research, policy studies, and its recommendations would guide necessary adjustments, new inclusive policy incorporation to the national climate policies and also to the city level development strategies. The above-mentioned research scopes would promote/guide future research trends for grassroots climate vulnerability studies linking different urban, rural, social, political, economic and contextual arenas.

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ANNEXES

Annex 1: Household Survey Questionnaire

Declaration: The objective of this survey is to understand the grassroots climatic problems in the urban poor settlements in Dhaka city and to develop a Climate Vulnerability Index (CVI). This survey is completely for academic purposes at TU Berlin and the contents are the intellectual property of the author. The responses of the survey shall be considered true based on the best knowledge of the participant.

Survey number: _____

Date: _____

Part A: Mapping local Problems, Stresses, and Shocks due to climate change

What are the problems you face due to climatic reasons? *(put tick marks)*

Problems/Risks/ Stresses & shocks	**Impact consequences (5 scales)**					**Probability of causing stress (5 scales)**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**	**Very low**	**Low**	**Moderate**	**High**	**Very high**
Likert Scale	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Heavy rainfall										
Flood										
Storm										
Heatwaves & Temperature increase										
Cold waves										
Waterlogging										
Poor condition of the house										
Poor drainage condition										
Poor sanitation										
Inadequate water supply										
Polluted water										
Health hazards										
Impact on Livelihood										
Fire										

Part B: Survey for assessing Climate vulnerability Index

Socio-demographic profile

1. House type: building materials

Roof	wall	floor

2. Number of occupying rooms in house: _____
3. Number of Family Members: _____
4. Write the number of family members beside the age limits:
   - Up to 18 years: _____
   - 18 to 54 years: _____
   - 55 years and above: _____

5. Head of household:

   ☐ Male Age: _____, ☐ Literate. / Schooling level: (class) _____.
   ☐ Illiterate.

   ☐ Female Age: _____, ☐ Literate. / Schooling level: (class) _____.
   ☐ Illiterate.

6. Number of children (aged between 4 to 15) not attending school: _____.

Livelihood Strategies

7. How many migrated members the household has from another city/ district/ village for earning?

   _____

8. Do you have access to housing with tenure security in the city?

   ☐ Yes ☐ No

(main reasons/explanation) _____

9. How are you residing in this (informal) settlement?

   ☐ Tenant / ☐ Houseowner (*bariwala*) / ☐ Other (explain) _____

10. Do you have affordability for/ access to housing materials that can protect from climate disaster risks?

    ☐ Yes ☐ No

Explanation: _____

11. Does the household head have any special training/formalized vocational education or skill?

    ☐ Yes ☐ No

Explanation: _____

12. Do you usually experience loss in income during adverse climatic impacts (e.g. during heat waves, floods, cold waves, etc)?
    ☐ Yes ☐ No

Brief explanation:

_____

_____

13. List the main activities of the family's/household's earning members:

Male member		Female member	
jobs	details	jobs	details
(1)		(1)	
(2)		(2)	

14. Household's monthly income: _____.

Social Networks

15. Do you get support or help from social organizations or NGOs due to climatic impacts?
    ☐ Yes ☐ No
    If yes, from where?
    ☐ Social organisations ☐ NGOs ☐ other _____

    Brief explanation (support types/ problems): _____
    _____

16. Do you save money for climatic crisis conditions?
    ☐ Yes ☐ No

    usual amount of savings: _____

17. Do you provide support or help to other neighboring households during a climatic crisis?
    ☐ Yes ☐ No

    Explanation _____

18. Do you borrow or lend money from friends due to climatic impact reasons?
    ☐ Yes ☐ No

    Explanation about the transactions (e.g. borrowing/lending, repayment, etc.):
    _____

19. Do you access local governmental offices for climatic assistance (in the last one year)?
    ☐ Yes ☐ No

    Main reason: _____

20. Do you have any-
- Television set: ☐ Yes ☐ No
- Mobile phone: ☐ Yes ☐ No

Health

21. Did any household member suffer from any diseases during or due to climatic reasons (heatwaves, heavy rainfall, flood, and cold waves)?
☐ Yes *(mention)*_____ ☐ No
_____

22. Did you suffer from any type of stresses (physical & mental) due to temperature, rainfall or other climatic issues?
☐ Yes *(explain)*_____ ☐ No
_____

23. Did you suffer from or observed any type of new diseases due to climatic/environmental issues?
☐ Yes *(mention)*_____ ☐ No

24. Does the family/household contain any member with chronic illness requiring regular treatment?
☐ Yes *(number of member)* _____ ☐ No
Types of diseases_____.

25. What is your usual monthly expenditure for health issues/ treatment? _____BDT

26. In the last 12 months, where did you mostly go for treatment?
☐ Government public hospitals or NGO hospitals ☐ Private clinics or private hospitals

(Explanation)_____.

Food

27. How you mainly earn your daily food (income source for food)?
Explanation:_____

28. Do you face insufficiency in food supply during the climatic crisis situations (flood, heavy rainfall, hot days, cold waves, storms, etc)?
☐ Yes ☐ No
(Explanation)
_____
_____

29. How much do you expend monthly for food of the family/ household? _____BDT.

30. Do you face any change in your daily supply of nutritious food (e.g. dairy, fruits, fish, meats, etc) during a climatic crisis (flood, heavy rainfall, hot days, cold waves, storms, etc)?
Supply: ☐ increased ☐ decreased ☐ uncertain ☐ no change

31. Did you experience the consumption of ‘less expensive’ and ‘less preferred’ food during climatic impacts?
☐ Yes ☐ No
(Brief explanation)
_____

32. Do you get food from direct agricultural processes or gardening?
☐ Yes ☐ No
(How? / from Where?/ Brief explanation)
_____

Water

33. What is the source of your water supply for daily use? _____
34. Do you have access to tube well as a source of water? ☐ Yes ☐ No

35. Can you use the water from the natural sources (lake, river, etc) to meet your water demand?
☐ Yes ☐ No
(explanation)
_____

36. Do you have an adequate supply of water throughout the year?
☐ Yes ☐ No
(explanation) _____
_____

37. Can you directly drink the water that you get from your daily source of water?
☐ Yes ☐ No
(if No, mention reason)
_____

38. How do you face climatic impacts (e.g. hot days, waterlogging, flood) affecting water problems?
Climatic impacts: ☐ increased ☐ decreased ☐ do not affect water problems/ crisis.

(explanation) _____
_____

39. Do you face the problem of contamination of water due to climatic reasons (e.g. flood, heavy rain, water stagnation)?
☐ Yes ☐ No
(explain)_____
_____

Natural disasters

40. Did you experienced loss of property or houses due to natural disasters (e.g. breaking of wall, balcony, houses, loss of livestock etc)?
☐ Yes, ☐ No
*(explain)*_____
_____

41. Do you experience flood or inundation of your household and poor drainage?
☐ Yes ☐ No
If yes:
- How often? Every- ☐ year ☐ 2-year ☐ 3-year and above

42. Do you get any warning before climatic disasters?
☐ Yes ☐ No
(if yes, from where?)_____

43. Did you participate in any disaster preparedness program?
☐ Yes ☐ No
(if yes, explain) _____

44. What is your perception of the natural disaster's frequency?
☐ increasing ☐ decreasing ☐ no change

45. What is your perception of the natural disaster's intensity?
☐ increasing ☐ decreasing ☐ no change

Climate variability

46. Based on your perception please tick beside the level of sufferings/problems for the followings:

Climatic issues	Variabilities	Perception about the level of sufferings/problems (put tick mark)	
		high	Moderate
Temperature change and hot months perception	(a) Changes in hot months		
	(b) Changes in temperature		
	(c) Both the Changes in (a+b)		
Rainfall pattern change and wet months perception	(d) Changes in wet month		
	(e) Changes in rainfall pattern		
	(f) Both the Changes in (d+e)		
perception for change in cold waves pattern	(g) Changes in cold months pattern		
	(h) Changes in cold waves pattern		
	(i) Both the Changes in (g+h)		
Storm perception	(j) changes in storm occurrence		

Thank you for your kind support and co-operation.

Annex 2: Data Analysis for Mapping Climatic Problems

(a) Urban poor's perception of the consequence/impact level of climate-induced problems, stresses, and shocks in the study area (grassroots perception).

Problems	Respondents	Consequence/impact levels					Total respondents, N	Perception of Majority
		(1) Insignificant	(2) Minor	(3) Moderate	(4) Major	(5) Catastrophic		
Heavy rainfall	Number of Respondents, 'n'	1	2	8	11	28	50	Catastrophic 56%
	Percentage: n/N x 100%	2%	4%	16%	22%	56%	100%	
Flood	Number of Respondents, 'n'	1	3	6	14	26	50	Catastrophic 52%
	Percentage: n/N x 100%	2%	6%	12%	28%	52%	100%	
Storm	Number of Respondents, 'n'	2	3	6	30	9	50	Major 60%
	Percentage: n/N x 100%	4%	6%	12%	60%	18%	100%	
Heatwaves/ temperature increase	Number of Respondents, 'n'	1	4	6	10	29	50	Catastrophic 58%
	Percentage: n/N x 100%	2%	8%	12%	20%	58%	100%	
Drought	Number of Respondents, 'n'	1	3	7	27	12	50	Major 54%
	Percentage: n/N x 100%	2%	6%	14%	54%	24%	100%	
Cold waves	Number of Respondents, 'n'	6	11	24	7	2	50	Moderate 48%
	Percentage: n/N x 100%	12 %	22 %	48%	14%	4%	100%	
Water logging	Number of Respondents, 'n'	0	1	8	10	31	50	Catastrophic 62%
	Percentage: n/N x 100%	0%	2%	16%	20%	62%	100%	
Poor condition of house	Number of Respondents, 'n'	2	2	6	12	28	50	Catastrophic 56%
	Percentage: n/N x 100%	4%	4%	12%	24%	56%	100%	
Drainage problem	Number of Respondents, 'n'	0	1	7	13	29	50	Catastrophic 58%
	Percentage: n/N x 100%	0%	2%	14%	26%	58%	100%	
Sanitation problem	Number of Respondents, 'n'	0	1	9	14	26	50	Catastrophic 52%
	Percentage: n/N x 100%	0%	2%	18%	28%	52%	100%	
Inadequate water supply	Number of Respondents, 'n'	0	2	5	10	33	50	Catastrophic 66%
	Percentage: n/N x 100%	0%	4%	10%	20%	66%	100%	
Polluted water	Number of Respondents, 'n'	2	3	7	12	26	50	Catastrophic 52%
	Percentage: n/N x 100%	4%	6%	14%	24%	52%	100%	
Health hazard	Number of Respondents, 'n'	1	4	9	31	5	50	Major 62%
	Percentage: n/N x 100%	2%	8%	18%	62%	10%	100%	
Impacts on livelihood	Number of Respondents, 'n'	3	6	9	26	6	50	Major 52%
	Percentage: n/N x 100%	6%	12 %	18%	52%	12%	100%	

Source: Author's field survey, 2019.

(b) Urban poor's perception of the probability of occurrence/frequency of climate-induced problems, stresses, and shocks in the study area (grassroot perception).

Problems	Respondents	Consequence/impact levels					Total respondents, N	Perception of Majority
		(1) Very low	(2) Low	(3) Moderate	(4) High	(5) Very high		
Heavy rainfall	Number of Respondents, 'n'	4	3	6	9	28	50	Very high 56%
	Percentage: n/N x 100%	8%	6%	12%	18%	56%	100%	
Flood	Number of Respondents, 'n'	3	5	7	26	9	50	High 52%
	Percentage: n/N x 100%	6%	10 %	14%	52%	18%	100%	
Storm	Number of Respondents, 'n'	2	4	29	9	6	50	Moderate 58%
	Percentage: n/N x 100%	4%	8%	58%	18%	12%	100%	
Heatwave/ temperature increase	Number of Respondents, 'n'	0	1	9	9	31	50	Very high 62%
	Percentage: n/N x 100%	0%	2%	18%	18%	62%	100%	
Drought	Number of Respondents, 'n'	1	5	7	11	26	50	Very high 52%
	Percentage: n/N x 100%	2%	10 %	14%	22%	52%	100%	
Cold waves	Number of Respondents, 'n'	4	6	25	8	7	50	Moderate 50%
	Percentage: n/N x 100%	8%	12 %	50%	16%	14%	100%	
Water logging	Number of Respondents, 'n'	0	2	7	10	31	50	Very high 62%
	Percentage: n/N x 100%	0%	4%	14%	20%	62%	100%	
Poor condition of house	Number of Respondents, 'n'	1	3	10	29	7	50	High 58%
	Percentage: n/N x 100%	2%	6%	20%	58%	14%	100%	
Drainage problem	Number of Respondents, 'n'	0	4	9	11	26	50	Very high 53%
	Percentage: n/N x 100%	0%	8%	18%	22%	52%	100%	
Sanitation problem	Number of Respondents, 'n'	2	3	5	12	28	50	Very high 56%
	Percentage: n/N x 100%	4%	6%	10%	24%	56%	100%	
Inadequate water supply	Number of Respondents, 'n'	0	2	4	13	31	50	Very high 62%
	Percentage: n/N x 100%	0%	4%	8%	26%	62%	100%	
Polluted water	Number of Respondents, 'n'	1	4	6	9	30	50	Very high 60%
	Percentage: n/N x 100%	2%	8%	12%	18%	60%	100%	
Health hazard	Number of Respondents, 'n'	0	3	12	27	8	50	High 54%
	Percentage: n/N x 100%	0%	6%	24%	54%	16%	100%	
Impacts on livelihood	Number of Respondents, 'n'	3	6	8	24	9	50	High 48%
	Percentage: n/N x 100%	6%	12 %	16%	48%	18%	100%	

Source: Author's field survey, 2019.

Annex 3: Data Analysis for Climate Variability Perception Index

Index	Parameters, n = number of parameters (e.g.: a, b, c= 03 or a, b= 02)	Level of sufferings	Climate variability perception index* = 1/ (no of change + 1) 'A'	%	Indexed with 0 to 100 range 'B'	Indexed values (in a scale of 0 to 1) Σ (A×B)	Overall Index from all parameters Σ(A×B)/n
Temperature change and hot months perception index	(a) Changes in hot months	(high, 0)	1/ (0+ 1)= 1	26%	0.26	0.63	0.65
		(moderate, 1)	1/ (1+ 1)= 0.5	74%	0.74		
	(b) Changes in temperature	(high, 0)	1/ (0+ 1)= 1	74%	0.74	0.87	
		(moderate, 1)	1/ (1+ 1)= 0.5	26%	0.26		
	(c) Both the Changes in (a+b)	(high, 0)	1/ (0+1+ 1)= 0.5	82%	0.82	0.46	
		(moderate, 1)	1/(1+1+1)= 0.33	18%	0.18		
Rainfall pattern change and wet months perception index	(d) Changes in wet month	(high, 0)	1/ (0+ 1)= 1	52%	0.52	0.76	0.67
		(moderate, 1)	1/ (1+ 1)= 0.5	48%	0.48		
	(e) Changes in rainfall pattern	(high, 0)	1/ (0+ 1)= 1	62%	0.62	0.81	
		(moderate, 1)	1/ (1+ 1)= 0.5	38%	0.38		
	(f) Both the Changes in (d+e)	(high, 0)	1/ (0+1+ 1)= 0.5	78%	0.78	0.46	
		(moderate, 1)	1/(1+1+1)= 0.33	22%	0.22		
perception index for change in cold waves	(g) Changes in cold months pattern	(high, 0)	1/ (0+ 1)= 1	8%	0.08	0.54	0.48
		(moderate, 1)	1/ (1+ 1)= 0.5	92%	0.92		
	(h) Changes in cold waves pattern	(high, 0)	1/ (0+ 1)= 1	10%	0.10	0.55	
		(moderate, 1)	1/ (1+ 1)= 0.5	90%	0.90		
	(i) Both the Changes in (g+h)	(high, 0)	1/ (0+1+ 1)= 0.5	12%	0.12	0.35	
		(moderate, 1)	1/(1+1+1)= 0.33	88%	0.88		
Storm perception index	(j) changes in storm occurance	(high, 0)	1/ (0+ 1)= 1	10%	0.10	0.55	0.55
		(moderate, 1)	1/(1+1)= 0.5	90%	0.90		

*Climate variability perception index was calculated based on (Pandey & Jha 2012, p. 496).
*higher value indicates higher vulnerability.

The vulnerability can be considered as the inverse function of the conditions that decrease risks (inverse of adaptability's crude indicator) (Hahn, Riederer & Foster 2009, p. 76). Moderate sufferings category reduces the risks or increases the adaptability indicator (so denoted as 1). The high sufferings category increases risk or reduces the adaptability indicator (so denoted as 0). The vulnerability due to climate variability can be found when the inverse of the adaptability indicator is made: 1/ (number of changes + 1) (Pandey & Jha 2012, p. 496).

Source: Author's calculation based on the household survey, 2019.

Annex 4: Calculation of CVI's Dimension Values

From Table 9 the major component values are as follows,

Dimensions	Major Components (MC)	MC's vulnerability scores	MC's inversed vulnerability scores for calculating Adaptive capacity	Weights (W)= Numbers of subcomponents in a particular MC
Adaptive capacity	Socio-demographic profile	*SD*= 0.385	*SD'=(1- 0.385)* = 0.615	W_{a1} = 6
	Livelihood strategies	*LS*= 0.762	*LS'= (1- 0.762)* = 0.238	W_{a2} = 7
	Social networks	*SN*= 0.448	*SN'= (1- 0.448)* = 0.552	W_{a3} = 7
Sensitivity	Health	*H*= 0.600	Not applicable as they are vulnerability components	W_{s1} = 6
	Food	*F*= 0.666		W_{s2} = 6
	Water	*Wa*= 0.916		W_{s3} = 6
Exposure	Natural Disasters	*ND*= 0.630		W_{e1} = 6
	Climate variability	*CV*= 0.588		W_{e2} = 4

So, the value for the Dimension, Adaptive capacity $= \frac{W_{a1}SD' + W_{a2}LS' + W_{a3}\,SN'}{W_{a1}+W_{a2}+W_{a3}}$

$$= \frac{(6\times0.615)+(7\times0.238)+(7\times0.552)}{(6+7+7)} = 0.461$$

The value for the Dimension, Sensitivity $= \frac{W_{s1}H + W_{s2}\,F + W_{s3}Wa}{W_{s1}+W_{s2}+W_{s3}}$

$$= \frac{(6\times0.600)+(6\times0.666)+(6\times0.906)}{(6+6+6)} = 0.711$$

The value for the Dimension, Exposure $= \frac{W_{e1}ND + W_{e2}\,CV}{W_{e1}+W_{e2}}$

$$= \frac{(6\times0.630)+(4\times0.588)}{(6+4)} = 0.613.$$

Annex 5: Calculation of CVI

We Know by Pandey and Jha (2012),

$$\text{CVI} = 1 - \left| \left\{ \frac{N_1 \times Exposure - N_2 \times Adaptive\ capacity}{N_1 + N_2} \right\} \right| \times \frac{1}{Sensitivity}$$

Here,

- N_1 is the number of major components used for 'Exposure' dimension = 02
- N_2 is the number of major components used for 'Adaptive capacity' dimension = 03
- In the CVI equation, the number of major components used for the 'Sensitivity' dimension will be canceled out as they are numerator and denominator.
- Value of 'Exposure' dimension= 0.613
- Value of 'Adaptive Capacity' dimension= 0.461
- Value of 'Sensitivity' dimension= 0.711.

$$\text{So, CVI} = 1 - \left| \left\{ \frac{2 \times 0.613 - 3 \times 0.461}{2+3} \right\} \right| \times \frac{1}{0.711}$$

$$= 1 - | - 0.0314 | \times 1.406469761$$

$$= 1 - 0.044163$$

$$= 0.955837.$$

[(-) ve value of the difference inside modulus indicated the influence of adaptive capacity]

Explanation: Here, the negative value inside modulus indicated the influence of adaptive capacity as it had a negative sign in the equation. The remaining adaptive capacity's value (- 0.0314) got multiplied with the system's unit strength (i.e. the inverse of the vulnerability score of the sensitivity dimension). So, the value derived after multiplication (0.044163) was the unit capacity of the system to cope with the prevailing vulnerabilities. Subtracting this unit coping capacity/strength from the vulnerability's full scale (i.e. 1) the unit climate vulnerability of the system was calculated which was the Climate Vulnerability Index (0.956).