IDRiM (2024) 14 (2) **ISSN: 2185-8322**
DOI10.5595/001c.124782

Journal of Integrated Disaster Risk Management

Regular Article

Practical Indicators to Improve Urban Flood Resilience of a Community: A Case of Urban Flood Mitigation in Dhaka, Bangladesh

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Received: 18/02/2024 / Accepted: 19/08/2024 / Published online: 26/11/2024

Abstract Climate change exacerbates natural hazards, prompting countries to adopt comprehensive adaptation and resilience strategies to mitigate the increasing losses and damages. Resilience is a critical concept that integrates disaster risk management, sustainable development, and climate change adaptation. Despite various community resilience frameworks and flood resilience measurement tools, there is a significant knowledge gap in identifying practical indicators to measure urban flood resilience. This study aims to fill this gap by developing a unified list of indicators to measure urban flood resilience, focusing on Dhaka City, Bangladesh. This research will identify and validate indicators contributing to urban flood resilience through a detailed comparative analysis of different resilience frameworks, expert opinions, focus group discussions, and key informant interviews. Dhaka City, a rapidly growing megacity, is prone to waterlogging and flooding, resulting in significant economic losses, diseases, and stresses. The study's findings will provide a comprehensive understanding of urban flood resilience in Dhaka City and inform stakeholders and government officials on strategies to enhance resilience and adaptation capacities. The approach will also highlight gaps and issues, enabling policymakers to develop targeted interventions to minimize flood risks and promote sustainable urban development.

Keywords: urban flood, flood resilient community, practical indicators, community resilience framework

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1. INTRODUCTION

According to the latest United Nations urbanization projections, 55% of the global population resided in urban areas in 2018, displaying a 24% increase from 1950 – furthermore, the rate of urbanization is set to increase in the future, such that 68% of the world's population are expected to be urban by 2050 (United Nations, 2019). The increased agglomeration of people, buildings, and infrastructure suggests a more vulnerable society in climate-induced hydro-hazards (Jahn, 2015). A stressed hydrological cycle due to climate change has increased the frequency of natural hazards, such as floods, in recent years (Ghazali et al., 2018).. Worldwide, the likelihood of flooding is increasing, with most of the damage caused by floods occurring locally. Unless flood risk is drastically increased, climate change and the rapid urbanization of flood-prone areas will continue exposing an increasing number of communities to intensifying flooding (Bulti et al., 2019; Pervin et al., 2020). In order to give reliable predictions and reduce the unpredictability of extreme flood occurrences, Collet et al. (2017) have acknowledged the significance of comprehending climate change uncertainty (Collet et al., 2017; Hegger et al., 2016). Resilience is one of the alternative flood risk management techniques (FRM) needed since, even with great efforts to minimize uncertainty, there is still an immediate danger due to more frequent and unpredictable events and, hence, more severe repercussions (McClymont et al., 2019).

'Resilience' in simple terms means 'bounce back,' which has become very popular in different academic fields. It also drawn the attention of the researcher of disaster risk management field. The term' resilience', introduced by C. S. Holling (Holling, 1973), refers to the ability of a system to withstand disturbance, absorbing the impacts of shock and reorganizing afterward (Walker et al., 2004)The application of the resilience concept in urban planning and natural hazard management has been recently compared to engineering and ecology (Bulti et al., 2019; Liao, 2012). After realizing the importance of resilience in disaster risk management, researchers started developing different frameworks and tools to measure resilience. Despite increased understanding and application of the resilience concept across disciplines, consensus about consistency in resilience assessment is lacking (Bulti et al., 2019; Winderl, 2014) a vital question, resilience to what has stroke to the mind of the researchers. They understood the need for a proper scale to measure resilience, and after that, the concept of 'community resilience' was introduced in disaster risk management and flood risk management.

In disaster management, a community-level focus is appropriate because disasters are local events that require and elicit distinct responses depending on the community in which they occur. Every community is different, with its own needs, resources, experiences, and methods for handling disasters. A community-level approach highlights the significance of local stakeholders' involvement, community ownership of the process, and local empowerment (Jones & Tanner, 2017; Longstaff et al., 2010; Tariq et al., 2021). Studies have shown that communities that are adapted, not resistant, to disturbances are long enduring (Starzomski, 2004). As the trend toward resilience has coincided, it is also necessary to concentrate on

community-level risk management strategies and flood consequences. So community-level efforts to combat rising disaster risk and manage effects can be extremely cost-effective. World Bank estimates that if cities don't become more resilient by 2030, natural disasters may cost cities all over the world around US$300 billion, and climate change alone could push 77 million people back into poverty. South Asian countries are extremely vulnerable to floods, and this region has the most people at risk of flooding, at 1.24 billion, making up more than two-thirds of global exposure. According to the World Bank report, Bangladesh is in the second position at flood risk as the country's 57.7% population is exposed to flood.

Bangladesh's capital, Dhaka, is a climate risk hotspot because of its high population density and rapid urban growth, making it one of the world's most rapidly developing megacities. In recent years, Dhaka has become increasingly susceptible to urban flooding due to the rapid development and unlawful encroachment along drainage routes. Over the years, this city has experienced frequent flooding during the monsoon season. The first recorded instances of river flooding were in 1787–1788 when strong monsoon floods sank city streets to the point where boats were needed to navigate them (Hunter, 1877). The city was again destroyed by river floods in 1833–1834 and 1870. The floods of 1954, 1955, 1962, 1966, 1974, 1987, 1988, 1998, and 2004 were among the worst in the last century in terms of property loss and human casualties (Choudhury et al., 2021). Intense rains causing urban flooding in the western and southern regions of the city and river flooding in the eastern section are common occurrences nowadays. A robust and sustainable urban strategy is required in light of this. Urban floods are different types of floods with some significant features that we need to understand and then incorporate into mitigation strategies. There are a huge number of studies on flood resilience and community resilience frameworks. However, these frameworks are being developed to visualize the general context of a flood. Most of the frameworks developed in the Western world may be of little relevance to land use planning for disaster management in South Asia and developing countries. There is a need to identify some context-based indicators that consider the unique characteristics of urban flooding. This paper has sought to pinpoint the gaps and problems found in the literature to develop useful indicators to increase a community's resilience to urban flooding. This study will also shed information on Dhaka's current urban flood vulnerability and incorporate community perspectives on resilience. The opinions of experts and stakeholders will be taken into account when finalizing the list of practical indicators that aim to apply resilience theory to real-world scenarios.

2. LITERATURE REVIEW

Selection of the Community Flood Resilience (CFR) based Literature included articles related to CFR that were published from January 2001 to April 2022 from Web of Science (WoS) and Scopus, as both databases can provide advanced search functions to allow us to restrict the search terms. Due to the diversity of research on CFR, we selected papers for literature review that put community resilience and Flood resilience at the core of the research.

We restricted the search limitations as follows: (1) "community resilience" or "resilient community" and "Flood resilience' were included in the title; (2) only English articles were included; (3) journal articles specifically included community resilience as a concept; (4) community resilience in the context of flooding was the main theme or a dominant focus throughout the abstract. The Keywords limiting the selection were Flood, flood risk, urban flood, flood management, flood resilience, resilience in FRM, community resilience, flood resilient community, community resilience to urban flooding, and resilience for Dhaka. Our main focus was to find the literature on the topic of community resilience and how it may be incorporated into urban flood mitigation. We have also reviewed a few community resilience frameworks to identify the gaps and issues.

2.1 Defining Community Resilience

The term "community" is ambiguous and has been defined in various ways based on various academic areas. A community could be a small neighborhood or a big county. A definition on the social site highlights the dynamic nature of community by defining it as "a group of people in a shared geographical area, who have common interests, are connected by dynamic socio-economic interactions, and engage in collective action" (Rapaport et al., 2018; Zhong et al., 2020). The concept of community can also be seen as having multiple layers. For example, smaller communities can be nested within larger ones, overlaps between communities are possible, and people can be a part of multiple communities.

A community's ability to withstand disasters and recover from them is known as community resilience. CARRI (Community and Regional Resilience Initiative) has developed the following definition for its use: "Community resilience is the capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent change."(CARRI, 2013). Norris et al. claimed that community resilience was derived from four adaptation capabilities: economic level, social capital, information and communication, and organization ability (Norris et al., 2008). To analyze and evaluate community resilience, Cutter et al. proposed an index system of community resilience in which ecology, society, economy, institution, infrastructures, and community capital were included. (Cutter et al., 2010) Paton et al. discussed the importance of self-efficacy, problem-focused coping, a sense of community, and age when assessing resilience to volcanic hazards (Ostadtaghizadeh et al., 2015). Sherrieb et al. reckoned that improving individuals' defensive ability in disaster is critical when enhancing community resilience (Sherrieb et al., 2010). We selected economic conditions, social support, disaster events, social capital, and information transmission to construct a community resilience analysis model based on individuals' capabilities. Studies on resilience can help improve the community's adaptation quickly and try to reduce loss in the hazards. Zurich Flood Resilience Alliance defined community as "The ability of a system, community, or society to pursue its social, ecological, and economic

development and growth objectives while managing its disaster risk over time, in a mutually reinforcing way." (Keating et al., 2017; Laurien & Keating, 2019).

2.2 'Community Resilience' Concept to Mitigate Urban Flooding

A paradigm change in Flood Risk Management (FRM) has given rise to the notion of resilience. (McClymont et al., 2019). Traditional FRM has always placed a strong emphasis on "fighting the water" and "restorative resilience" (Odemerho, 2015). On the other hand, resilience in FRM emphasizes human knowledge, local resources, and flood experience. Thus, it can help to adapt, absorb, and transform a system (city, community, neighborhood) in an effective way, minimizing the adverse consequences of hazards like flooding. "Flood Resilience" and "Community Resilience to Flood" have focused on explaining the significance of resilience concerning flood risk management and how to incorporate this idea into the current framework. Subsequent academics concentrated on evaluating how to quantify a community's resilience. Considerable progress is required to address the growing concern about developing reliable and consistent methods of measuring community food resilience and better comprehending and operationalizing the resilience concept in food risk management (Bulti et al., 2019).

Two contentious phrases, "community" and "resilience," which have diverse definitions, are combined to form Community Flood Resilience (CFR). "Shared fate" or a common geographic limit characterizes a community of flooded neighborhood residents. Further, drawing on an expanded definition of resilience proposed by Meerow et al., the definition of community flood resilience is framed as Community flood resilience is the ability of a community and all of its socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of flood events, to adapt to change, and to transform systems that affect the current and future adaptive capacity. 'Community flood resilience' comprises six basic features of resilience. First, it focuses on a specific hazard (i.e., flood), which is concrete for evaluation. Second, a community is conceptualized as a complex and adaptive system encompassing socio-ecological and socio-technical networks. Third, it acknowledges the importance of resilience in multiple spatial scales. Fourth, it recognizes the importance of resilience in different time periods. Fifth, it recognizes that resilience combines multiple capacities, such as recovering after a flood, adapting to a changing environment, and transforming (Bulti et al., 2019; Keating et al., 2017). Though in recent decades, an ample amount of studies have been done on integrating the community resilience concept in flood risk management and also in developing different frameworks to assess community resilience in the context of hazard still, there is no such particular framework to measure urban flood resilience of a community (Bruneau et al., 2003). Because of the distinctiveness of the local environment, a number of scholars have claimed that evaluating community resilience is a difficult task that requires intricate interactions within communities (Cutter et al., 2008;

Frankenberger, 2013). Measuring community resilience is vital as it exposes the weaknesses of the community (Kirmayer et al., 2009).

2.3 Overview of Community Resilience Frameworks

A comparative study on community resilience frameworks was conducted to assess their applicability in the community resilience context, especially those frameworks applied in the community context at the local level in varied settings, such as those in developed and developing countries. Several theoretical frameworks have been proposed in the literature to measure resilience in a community's social and ecological systems (Cutter et al., 2008; Gunderson & Holling, 2002; Tobin, 1999).

The San Francisco Planning and Urban Research (SPUR) framework measures resilience by determining the community's ability to recover from earthquakes with a focus on building and infrastructure. Baseline Resilience Indicators for Communities (BRIC) measure overall pre-existing community resilience by evaluating the community's economic, social, institutional, ecosystem, and infrastructure capacities. Resilience United States (ResilUS) measures recovery over time of critical infrastructure. The NOAA Coastal Resilience Index assists communities by specifying key indicators that preliminary assess a community's disaster resilience. This index can determine if the community can function well after a disaster in critical infrastructures, transportation, community plans, mitigation measures, social systems, and business plans. (Kunreuther, 2016). In Table 1, we have shown the key features, major components, strengths, and limitations of different community resilience frameworks.

Table 1. Overview of different community resilience frameworks

	Framework	**Form at**	**Key Features**	**Components**	**Strengths**	**Limitations**
1.	**Capital Based Approach Year- 2006**	Index	A livelihood asset-based approach. Resilience is conceptualized in five capitals: **social, economic, human, physical, and natural.**	Livelihood capitals (**social, economic, human, natural, and physical**) where **each asset** has a set of **indicators** used to measure resilience	Provides **detailed and simplified variables** for constructing **disaster resilience** indices by sub-component.	Some of the **indicators are intangible and, therefore, difficult to quantify.**
2.	**Disaster Resilience of Place (DROP) Year- 2010**	Model	**It presents inherent resilience as a function of the interaction of social, natural, and built environment systems.**	**Ecological, social, economic, institutional, infrastructure, and community competence.**	**Allows comparative assessments** of resilience at different levels.	**The model is salient on transformative capacities that are critical for resilience.**

3.	**Baseline Resilience Indicators for Communities (BRIC)** **Year- 2010**	Index	BRIC focuses on the **existing resilience capacities** of a community. Resilience is often portrayed as a process, an adaptive response to adversity, in which community actors **utilize community resources to adapt to changing circumstances** and to moderate or avoid negative consequences.	**49 indicators divided into six resilience subdomains**: social, economic, institutional, infrastructure & housing, community capital, and environmental.	**Allows for the use of contextual and robust variables.** Provides **detailed simplified variables** used to construct disaster resilience index by sub-component.	The term 'community' is reduced to a locality, **side-lining social and relational aspects of community that are of critical importance in crises. BRIC does not seek to measure community resilience as a process.**
4.	**The People Resilience Framework** National Institute of Standards & Technology, 2010	Model	**Seven dimensions of community resilience** have been identified and are represented by the acronym PEOPLES.	Population and Demographics, Environmental/ Ecosystem, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social Cultural Capital.	The PEOPLES Resilience Framework has been implemented **in decision support mechanisms to assess pre and post-disaster response of communities .**	The PEOPLES Resilience Framework requires the combination of qualitative and quantitative data; as a consequence, information needs to be aggregated or disaggregated to match the scales of the resilience model and the scales of interest for the model output.
5.	**Community Disaster Resilience Index (CDRI)** Stephen Mayunga et al. 2013	Index	Assesses disaster resilience from **five dimensions: physical, social, economic, institutional, and natural.**	Each dimension **comprises five parameters, and each parameter consists of five variables.**	Two concepts- Disaster management phases activities and capitals.	
	The Embrace		The emBRACE resilience framework	Three interrelated domains- resources	It is a simplified heuristic framework	Oversimplification of the framework.

	Resilience Framework Kruice et al. 2017		conceptualizes community resilience as a set of intertwined components in a three-layer framework.	and capacities, actions, and learning.	that can be operated by the community's people by themselves.	
	Disaster Resilience Scorecard for City Year- 2016	Score card	Framework provides a checklist for cities to gauge the degree to which they are resilient to the impacts of natural hazards**. The list has 85 metrics (each with a suggested 5-point scoring system) relating to UNISDR's 'ten essentials.**	The organization, infrastructure, response capability, environment, and recovery of cities.	The framework tracks resilience across the following aspects: **research, organization, infrastructure, response capability, environment, and recovery.**	**The model is less applicable to rural communities of the developing world.**
	Community Resilience Measurement Tool (CRMT) Zurich Flood Alliance, 2017	Index	Measures flood resilience based on a **'systems approach'** to understanding the factors that **enable communities to withstand flood-related shocks** and stresses. It combines an assessment of the **5 capital assets with resilience properties of those assets.**	The following capitals: human (e.g.skills and health); social (e.g., strong relationships and cooperation); natural (e.g., land productivity and water); physical (e.g., infrastructure and equipment); and financial (e.g., level and diversity of income)enhance the resilience of communities to floods.	Uses a systems approach to **understand complex relationships, unlike linear approaches that deal with cause-and-effect relationships.**	Much of the socio-economic data (e.g., strong relationships and cooperation) **is not available in most countries of the Global South.**

Practical/Operational/Implementation aspects were missing in most of the frameworks. Cutter et al. stated that despite efforts to assess the dimensions of community resilience, the main challenge is to develop standard metrics to measure resilience (Cutter et al., 2010). Keating et al. (2017) highlighted the urgent need for the development of flood resilience measurement tools, giving rise to a better understanding of the resilience of key components, the improvement of resilience measuring skills, and the comparison of resilience changes over time. Keating et al. (2017) also mentioned, ' It is necessary to implement all the theories into action after assessing the community's resilience (Keating et al., 2017). Dejene and Birhanu et al. highlighted that studies are required to develop a theoretically as well as practically justified weighting approach that can allow consistent delineation of the relative importance of the resilience indicators (Bulti et al., 2019). Most of the frameworks consider the context of

Western countries. The reasons behind flooding in South Asian countries are totally different from those in Western countries. That is why there is a need to understand the vulnerability of the context to operationalize any framework to measure resilience. Further, Ali and George (2022) highlights the drawbacks of the current indices/ frameworks related to community resilience.

Most of the frameworks have emphasized different Capitals/Dimensions. According to the literature, the major capitals for community resilience are Social, Natural, Financial, Institutional, and Human. Few frameworks have given us a list of indicators to ensure resilience to urban floods; few indicators are relevant to urban floods as they have different characteristics. For example, the Zurich Community Resilience Measurement Framework talked about 88 different sources of resilience. In this framework, we can find indicators like the Basin Management Plan and Watershed management under the physical capital, which are irrelevant in Urban flooding. In Dhaka's context, the reasons behind the urban flooding are mainly heavy rainfall and poor capacity for stormwater management. So, it is clearly understood that the theoretical frameworks need to be contextualized. The indicators that we can find from the literature should be validated by the community people, experts, and stakeholders from the different sectors. Thus, we can make a practical indicators list to measure the flood resilience of a community and improve its resilience accordingly.

3. URBAN FLOODING SITUATION IN DHAKA

3.1 Background

Dhaka is also experiencing several socio-economic problems, such as rising inequality, poverty, inadequate social security, and corruption. Water logging, traffic congestion, improper solid waste disposal, black smoke emission from vehicles and industry, air and noise pollution, and water pollution from industrial discharge are also very common problems in the city (Taufiq, 2021). In recent times, water logging has become one of the main causes of apprehension, damaging infrastructures, disrupting daily lives, and demolishing vegetation and aquatic habitats. Several initiatives undertaken by WASA (Water and Sewerage Authority) and the two City Corporations to improve the existing condition have failed due to the absence of proper urban design and planning, landscape architecture, and, most importantly, lack of coordination between project activities and stakeholders (Subrina & Chowdhury, 2018). Dhaka city suffers from drainage congestion and water logging, especially during the rainy season. It creates an unhealthy environmental situation and causes inconvenience to the residents of the urban area, including damage to infrastructure, loss of business, and spreading of diseases. It has been identified that improvement of the drainage system is one of the highest priority needs in urban areas for a better and sustainable environment and livelihood. Figure1(a) shows the geographical location of Dhaka city and Figure 1(b) shows the map of Dhaka Metropolitan City.

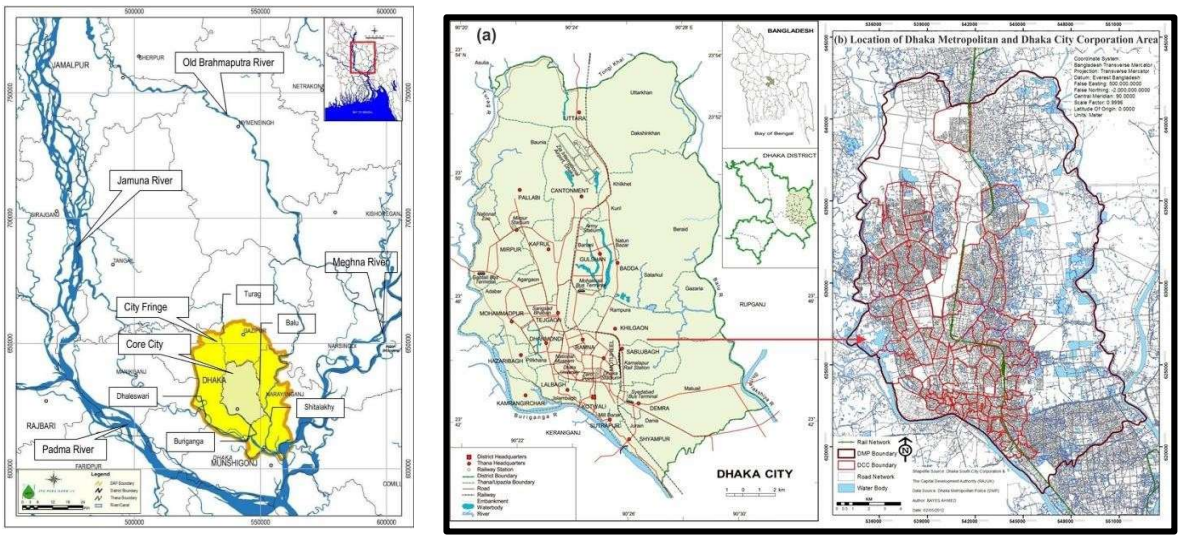

Figure 1(a). Geographical location of Dhaka City, **1(b).** Map of Dhaka Metropolitan City

Bangladesh, like most other countries, prefers to choose structural measures for flood control. However, with the current trend of flooding, the costs of implementing these measures are increasingly prohibitive. A review of flood mitigation literature suggests that non-structural measures such as land use control, flood plain management, flood forecasting and warnings improvement, and resettlement of flood-prone communities are more economically efficient. In addition, community awareness is also an important ingredient in successful flood preparedness measures.

3.2 Urban Flooding Hotspots in Dhaka

The engineering department of Dhaka North City Corporation (DNCC) created a waterlogging hotspot map on 1 June 2021, the day when the city of Dhaka had significant rainfall and waterlogging. At least 103 locations where waterlogging persists for extended periods of time are indicated on the map. The locations most impacted include Uttara-1, Kaola, Mirpur-14, Kalyanpur, Paikpara, and Hatirjheel. As the relevant authorities have identified at least 156 locations prone to waterlogging due to rainfall, two municipal corporations in the capital city of Dhaka are attempting to handle the current monsoon by tackling the waterlogging problem with short- and mid-term remedies. However, engineers working for city corporations and urban specialists predict that the issue of waterlogging will persist in the future.

According to an internal report, construction of drains and canals to help drain rainwater has been completed in 2022 at 44 out of the 136 waterlogging hotspots in the capital. However, drainage infrastructure in 63 other areas will not be completed this year, and it is only at the planning stage in another 29 areas. Figure 2 shows the urban flooding hotspots in Dhaka city.

 ISSN: 2185-8322

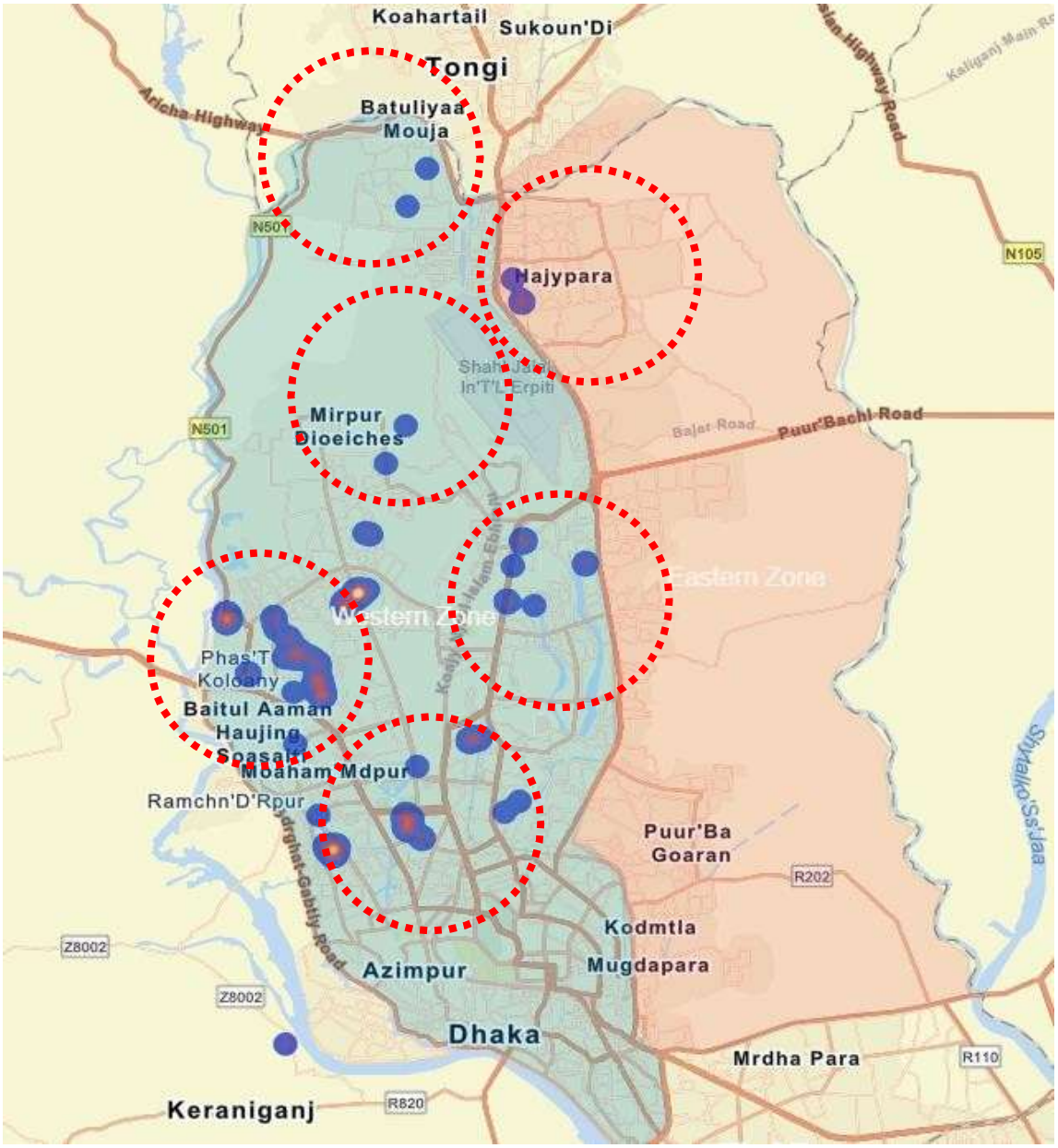

Figure 2. Urban flooding hotspots in Dhaka City

3.3 Selection of Study Area

After analyzing the Dhaka detailed area plan DAP, Digital elevation map, waterlogging hotspot map, and the existing literature, we have chosen the Kallyanpur zone as our study area. The study area shares adjoining borders with Goranchatbari to the north, Central Dhaka to the east, and Old Dhaka to the south. The Western Embankment along the left bank of the Turag River protects the area from river flooding. Kallyanpur is a key contributor to Dhaka's economy, featuring a variety of manufacturing and processing factories, commercial activities, offices, clinics, and schools.

We have chosen two different communities for our data collection within this study area. The Figure 3 shows the satellite images of our two different communities. Community 'A' consists of Kazipara and Shewrapa. And Community 'B' consist of Darussalam, Paikpara, Kallyanpur, Shahalibag, Pirerbag etc.Population density is also high in both these communities. The causes of the urban flooding in this community are insufficient drainage, structural faults in drainage designs, and a lack of coordination between responsible authorities.

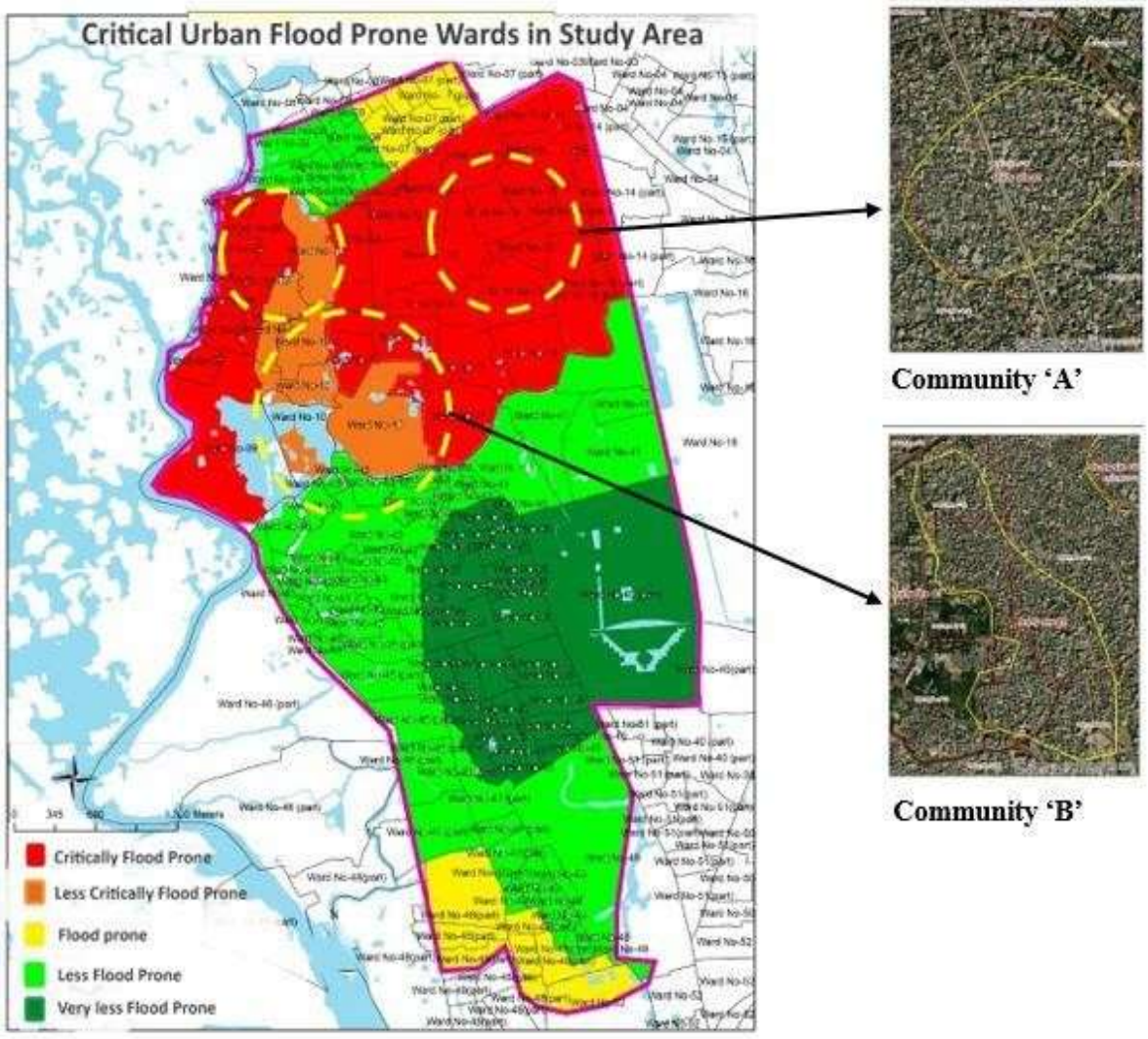

Figure 3. Selection of the community

This community also faces water scarcity during summer. Some respondents talked about rainwater harvesting, which can effectively solve urban flooding and water scarcity. When DNCC took responsibility for the drainage system, the urban flooding situation improved as they cleaned the existing drainage of this area before the monsoon. About 88% of land use in the study area comprises residential, restricted areas, manufacturing and processing activity, education and institution, transportation networks, and water bodies. More than three-fifths of the land of this area will have been zoned for either residential use or the transportation network by 2050, RAJUK has mentioned in the Dhaka City structure plan. Land cover maps show that the built-up area is almost 72% and the non-built-up area is about 18%. Two types of drainage

areas are available- (i) Natural Drainage and (ii) Man-made Drainage. The whole area's drainage system consists mainly of pipes, box culverts, khals, and lakes.

4. MATERIALS AND METHOD

4.1 Method

We have chosen the qualitative method for this study for the primary data. Qualitative methods offer a holistic view of urban flood resilience by exploring the social, cultural, and contextual factors that influence vulnerability and adaptive capacity. For secondary data, we have gone through the existing maps, reports, journal papers, and articles from the newspapers. To identify the practical indicators, we did a household survey by creating a questionnaire. The households that were directly affected by flooding or waterlogging in the last 10 years are considered the observation units for the household survey. The cluster sampling method was mainly used to select the observation units. The wards were considered as clusters in this study (Haque et al., 2022). We have chosen two different communities for our data collection, Community 'A' and Community 'B.' Community 'A' consists of two different wards, Ward 13 and Ward 14. In this community, areas are known as Kazipara and Shewrapa. Community 'B' consists of Darussalam, Paikpara, Kallyanpur, Shahalibag, Pirerbag, etc, which are under three different wards, wards 10, 11, and 12. A total of 60 samples were taken for data analysis. There are 30 samples from community 'A' and 30 from community 'B'. To understand the inherent causes behind urban flooding in these communities, we have done focus group discussions and participant observation and also incorporated expert's opinions (Haque et al., 2022). It will help to understand the gaps between the theory and implementation context of Community resilience. After collecting the primary data, we went for a content analysis to obtain the correct understanding of the whole context. It also helps to extract unique elements and prepare initial categories (Graneheim, 2004). Conceptual flowchart of Indicators Finalization Process has been shown in Figure 4**.**

4.2 Questionnaire Survey and Informal Interviews

The main source of primary data was a Questionnaire Survey and Informal Interviews with community members. The questionnaire was designed in such a way that it would track down the problem from the inception and the impact of the urban flooding in the locality. A total of 60 samples were collected by using the cluster sampling technique. With cluster sampling, the researcher divides the population into separate groups according to geographical location. Then, a simple random sample of clusters is selected from the population. Two important parameters were fixed while choosing the respondent. Those who had resided in the locality for more than 10 years were chosen for the interview. Thus, we can document some exclusive insights from their existing knowledge and past experiences. The respondents were selected in different

urban flooding-prone areas within the study area with different professions. It also covered people's perceptions of community resilience.

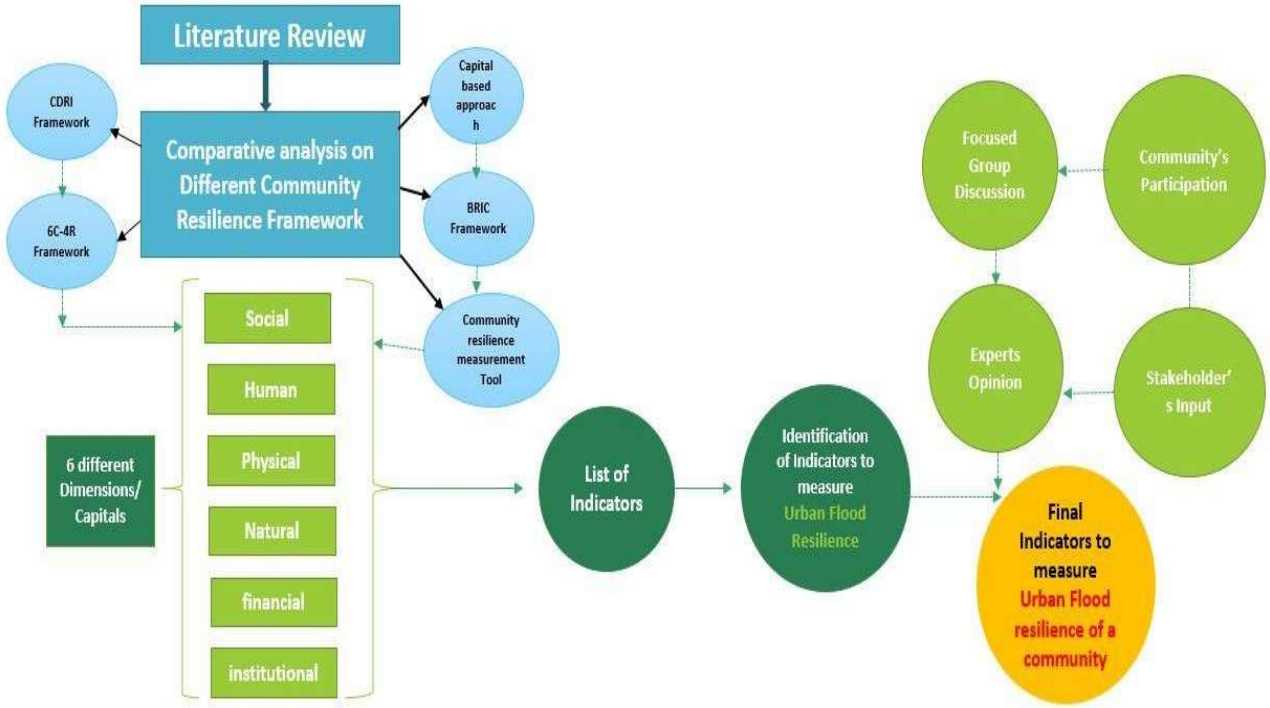

Figure 4. Conceptual flowchart of Indicators Finalization Process

4.3 Focus Group Discussions

Organize focus group discussions with community members and experts to facilitate group interactions and generate rich insights. Discuss specific aspects of urban flood resilience, such as community preparedness, communication, and social cohesion. Encourage participants to share their experiences and opinions, leading to a broader understanding of the issues.

4.4 Participant Observation

Engage in participant observation by spending time in flood-prone areas of Dhaka to observe daily life and flood-related practices. Document how communities prepare for, respond to, and recover from flooding events. Identify informal practices and coping strategies used by residents.

4.5 Experts Opinion

Expert judgment procedure is a method very often used in the area of risk assessments of complex systems or processes to fill in quantitative data. It provides exclusive insights into

expert knowledge, structural contexts, and change processes of action systems. The aim of the expert interview is to discover the unknown, a person's "insider knowledge" (Liebhold et al., 2005). The evaluation of the expert interviews is intended to highlight the joint knowledge of the experts on a specific topic and to integrate them into theoretical discourses.

To achieve community flood resilience we need to establish a relationship between Theories, Community people and the responsible authorities. Then we can come up with an integrated framework with some practical indicators to measure urban flood resilience of a community. Figure 5 represents Conceptual diagram to improve flood resilience of a community.

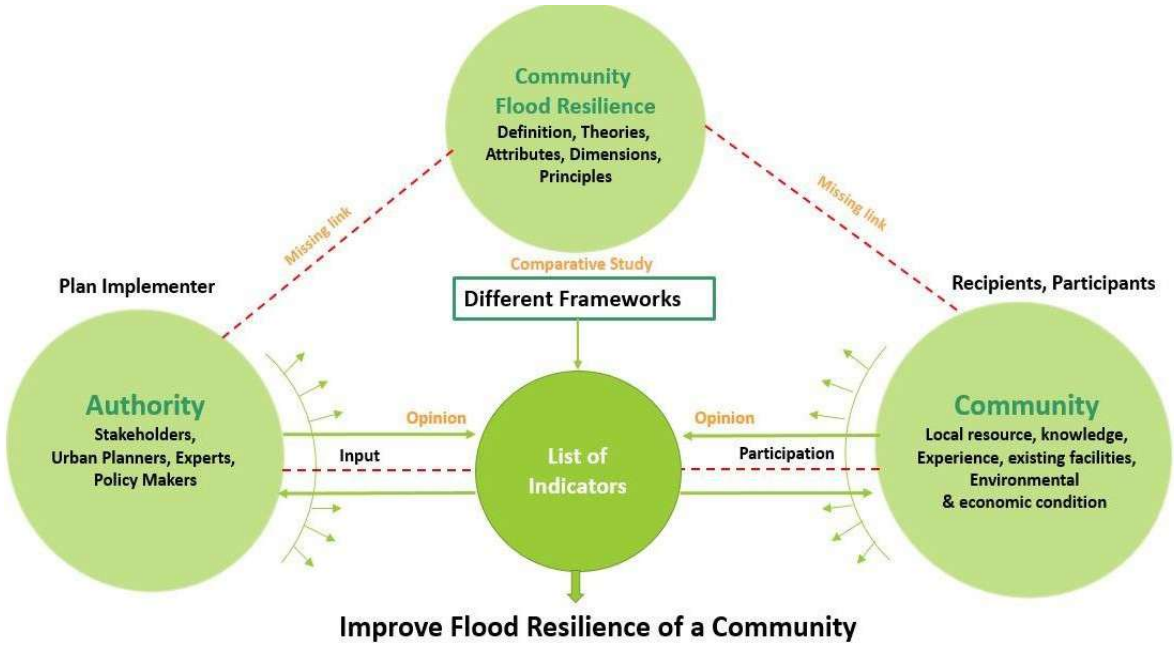

Figure 5. Conceptual diagram to improve flood resilience of a community

5. RESULTS

5.1 Feedback from Community

Kallyanpur zone is a significant waterlogging hotspot in Dhaka during monsoon season. While doing the survey, we found significant insight from the communities. And the insights are different as the community's urban fabric is also different. When we analyzed the land cover map of the Kallyanpur zone, we found that the built-up area within Ward 13 14 is almost 90%, which is alarming. Population density is also high in these wards. Community 'A' consists of these two wards. The causes of the urban flooding in this community are insufficient drainage, structural faults in drainage designs, and a lack of coordination between responsible authorities. This community also faces water scarcity during summer. Some respondents talked about rainwater harvesting, which can effectively solve urban flooding and water scarcity. When

DNCC took responsibility for the drainage system, the urban flooding situation improved as they cleaned the existing drainage of this area before the monsoon.

On the other hand, the people of Community' B' gave some interesting feedback. A major cause of urban flood in this locality is poor solid waste management, the poor capacity of a drainage system, and encroachment in natural drainage. They highly emphasized physical factors and Institutional factors. This community's people do not have knowledge of waste segregation or rainwater harvesting; in fact, they have never heard about the community resilience concept. So, public awareness is comparatively poorer in this community than in Community 'A'.

Both communities emphasize the community's participation in the decision-making process. They think if a community can participate in their development process, it will help them become more responsible and more conscious of the community's sustainable development.

They also talked about the community's development budget. Some respondents mention the disaster development budget. The community should be considered as a body, and the government should allocate a development fund/budget for the community/ward, thus ensuring the community's financial stability.

In Table 2, we have documented the insights and remarks of the community. We have converted their feedback into indicators and then categorized them into different dimensions/capitals, such as physical, financial, environmental, institutional, and social. These indicators are also categorized into sub-dimensions like infrastructure and maintenance, resource and knowledge, development budget, governance, and social crisis.

5.2 Feedback from the Experts

In the expert's opinion, we interviewed government officials, town planners, the director of planning, the chief engineer of Dhaka City Corporation North, the Ward Councillor, Architects, and experts from different academic fields. We prepared a brief questionnaire for the experts to incorporate their experience and knowledge and to visualize community resilience from their lens. Questions that were asked were like-

1. What are the main **reasons behind urban flooding** in Dhaka?
2. What are the **major obstacles** while trying to mitigate urban flooding?
3. Do you think the **community resilience** concept can improve the urban flood situation in Dhaka?
4. According to you, what is **Resilience**?

5. What are the main **characteristics that a flood-resilient Community** should have?

6. According to you, what are the main **gaps & issues while implementing a framework** to measure the resilience of a community?

7. What are the **practical indicators** that should be considered while implementing a framework?

8. What are the **significant variables** that should be considered while trying to improve the flood resilience of a community?

9. In your opinion, what is the **role of a community**? How should a community behave in this mitigation process?

10. Score/Rank the **dimensions of Community resilience** according to its importance.

Table 2. Community remarks and their corresponding indicators

Locality	Remarks	Indicators	Sub- dimension	Dimension
Kazipara, Shewrapawa	Needed level up of road, 2-3 hours Rainfall then waterlogging	Road Maintenance	Infrastructure	Physical
Paikpara, Darussalam	Overflow of Drain during monsoon, Poor maintenance of drainage	Drainage Capacity	Infrastructure Maintenance	Physical & Institutional
Tollarbag, Shahalibag	Personally employed sweepers to clean drains during waterlogging	Development Budget	Development budget	Financial
Kazipara, Shewrapa Paikpara, Kalyanpur	Water scarcity, rainwater can be preserved for household work	Rainwater Harvesting	Resources & Knowledge	Social
Kazipara, Darussalam, Tollarbag, Shah Ali Bag	Lack of Public awareness, Campaign, and training session	Public awareness	Resources & Knowledge	Social
Kazipara, Shewrapara	Poor infrastructure and heavy traffic during waterlogging.	Traffic Congestion	Infrastructure, Social Crisis	Physical & Social
Kazipara, Darussalam, Tollarbag, Shah Ali Bag	Lack of interaction between Responsible authorities	Interaction between Responsible authorities	Governance	Institutional
Paikpara, Tollarbag, Darussalam	Consideration of the community's opinion	Community engagement	Resources & Knowledge	Social

Experts have given importance to Physical, environmental, and Institutional Dimensions/Capitals to improve community resilience to urban floods in Dhaka. They have also suggested significant indicators to consider while implementing a resilience framework.

Table 3 represents the twenty indicators that we have finalized after analyzing the feedback from the community and experts. Table 3 summarizes the community's thoughts and perspectives on urban flood mitigation and community resilience concepts. We have also incorporated experts' opinions into this table.

Table 3. The list of 18 practical indicators

	Factors/Indicators	Dimensions	Sources
1.	Guidance and Instruction.	Institutional	Expert's Opinion
2.	Co-ordination across related institutions	Institutional	Expert's Opinion, Stakeholder's Input, Field Survey
3.	Insufficient documents to support a Framework	Institutional	Expert's Opinion
4.	Interaction between community and responsible stakeholders	Institutional	Expert's Opinion, Field Survey
5.	Campaign & training	Institutional	Expert's Opinion, Field Survey
6.	Emergency infrastructures	Physical	Expert's Opinion
7.	Capacity & Maintenance of Drainage	Physical	Expert's Opinion, Field Survey
8.	Waste Management	Physical	Expert's Opinion, Stakeholder's Input, Field Survey
9.	Community Development Budget	Financial	Expert's Opinion, Stakeholder's Input, Field Survey
10.	Public awareness	Social	Expert's Opinion, Stakeholder's Input, Field Survey
11.	High Dependency of the Community members on Government reliefs, actions, and decisions.	Social	Expert's Opinion, Stakeholder's Input, Field Survey
12.	Representative from Community	Social	Expert's Opinion, Field Survey
13.	Community Participation & opinion	Social	Expert's Opinion, Field Survey
14.	The interest of the community in adopting a new strategy	Social	Expert's Opinion, Field Survey
15.	Rainwater harvesting	Human	Expert's Opinion, Field Survey
16.	Open spaces and soakable greens	Natural	Experts Opinion
17.	Encroachment in Natural Drainage	Natural	Expert's Opinion, Field Survey
18.	Knowledge about Community Resilience.	Human	Expert's Opinion, Field Survey

6. DISCUSSION

Eighteen indicators were finalized after analyzing the feedback from the community and experts as these indicators are suggested by the local people, local stakeholders, and experts; that's why these indicators are more effective, relevant, and practical. 'Institutional' Capacity/Dimension of a community obtained the highest score according to a scale of importance from the experts. On the other hand, the community emphasizes 'Physical' capacity/dimension, which refers to Capacity & Maintenance of Drainage, waste management, and drainage capacity. From our field survey, group session, in-person interview, and experts' opinions, we have identified some significant factors that should be considered while planning to improve a community's urban flood resilience. Below, we have briefly described our identified practical indicators and their significance.

- **Interaction between community and responsible stakeholders**

In our interview session, both communities' people complained against responsible authorities as they could not reach any of them due to problems like waterlogging, drainage overflowing in their locality, waste management crisis, etc. The community should have smooth access to communicate with responsible stakeholders of their locality. Mohammad Sanaullah, a local participant from the area of Pirer Big, Mirpur, mentioned the unimaginable sufferings they faced last year because of poor drainage management. Once, they forwarded this issue to the ward commissioner, but they did not get any positive response or proper solution even after 4 months. First, DWASA monitored Dhaka's drainage management. Currently, this role has been shifted to Dhaka City Corporation. The fact is no one is admitting the negligence and failure of their role. The intervention is always delayed because of less interaction between the community and responsible stakeholders.

- **Co-ordination across related institutions**

Coordination problems may occur when several institutions are required to act together to achieve certain objectives, and the problems may worsen if the various institutions' activities, operations, and areas of jurisdiction overlap. So, it is highly important to maintain a balanced partnership between different organizations and stakeholders. Coordination and cooperation among local authorities, NGOs, INGO, and donor agencies significantly enhance community flood resilience. (Chowdhooree & Islam, 2018). After studying the urban flood history of Dhaka, it is visibly shown that lack of coordination across relation institutions was one of the major reasons.

- **Insufficient documents to support a framework**

Experts mentioned that insufficient documents to support a framework are an important indicator of improving a community's intuitional resilience. The earliest detailed study to prepare a Master plan for flood protection and internal drainage of Dhaka city was undertaken by the Department of Public Health Engineering (DPHE) in 1968. The study covered an area

of 75 sq. km and included the construction of an embankment around the city, pump stations, and other internal drainage facilities. In 1978, DPHE reviewed the 1968 Master Plan and prepared a flood control and drainage works plan. A Study on Stormwater Drainage System Improvement Project in Dhaka City was carried out by JICA (JICA, 1991). Another study was done under FAP8 in 1991. After that study, IWM performed a study in 2006 regarding the drainage Master plan of Dhaka city. However, Dhaka WASA does not have a complete guideline or master plan regarding drainage. So it is important to make necessary documents like a guidelines flow chart of the responsibilities of different actors who directly work for the city's development.

- **Guidance and instruction**

Proper guidance and instruction are very important when we are planning to implement any toolkit or framework within a community. Lack of coordination, lack of instruction, and guidance often create numerous problems, one of which is a failure to meet project deadlines and the other being overlap and duplication of activities. This causes many development projects to remain incomplete in the middle stage. When a deadline is missed, the project's cost increases, creating chaos, confusion, discord, and fiction among various departments, leading to inefficiency and ineffectiveness in the activities of the organizations involved (Chowdhooree & Islam, 2018; Ishtiaque et al., 2014; Taufiq, 2021).

- **Campaign and training**

The community's capacity can be increased by improving its social and political resilience. Numerous campaigns and training sessions need to be conducted to improve local people's technical knowledge. Responsible authorities can initiate different campaigns and sessions to increase public awareness of waste management and waste segregation.

- **Emergency infrastructures**

Emergency infrastructures like early warning systems, communication, water supply, food supply, electricity supply, energy, etc., should be protected and preserved; thus, it can help local people restore their homes efficiently after the flood.

- **Capacity and maintenance of drainage**

According to 80% of respondents, poor performance of operation and maintenance of drainage systems is one of the main reasons for waterlogging. Poor maintenance, Lack of Institutional coordination, lack of public awareness, etc., are the main reasons for the poor capacity of drainage systems. The lack of a comprehensive and planned maintenance program, equipment types, adequate budget, staffing, proper monitoring program, and institutional setup to effectively operate and maintain the drainage network are some other reasons behind this issue. Poor solid waste management is the main problem in maintaining stormwater drainage. Municipal agencies (DCC in the Dhaka City area) are responsible for solid waste

management, but DCC totally failed to manage solid waste within the study area due to a lack of sufficient resources and equipment for drain cleaning.

- **Waste management**

One of the main causes of Dhaka's waterlogging is the city's careless waste management. It is currently difficult to clean the streets and sewers at the rate that garbage is dumped into them due to unprecedented urban congestion, extreme population density, rapid population expansion, and uncontrolled urban migration. Dhaka is the world's most densely inhabited metropolis, with 47,400 inhabitants per km^2 (UN Department of Economic and Social Affairs, 2018). As per Kazi's (2002) report, this city produces between 3500 and 4000 tons of solid trash daily, or around 0.5 kilograms per person. About 8,52,390 tons of trash were produced overall in 2016–17 (Ishtiaque et al., 2014; Taufiq, 2021). Since most seasonal fruits and vegetables become available during the rainy season, waste creation increases. (Hossain et al., 2022; Taufiq, 2021)

Negligence complaints in duty against DNCC and DSCC staff and sweepers are common. Although nearly 4,000 tons of daily household garbage is generated in Dhaka, the DNCC and DSCC only report 500 tons or less. Such disparity clearly indicates that citizens' complaints are not irrelevant. Citizens also do not follow the rules; many dump garbage, ignoring designated spots and waste bins.

- **Community development budget**

It is at the community level where the effects of disasters are felt the most and also where the physical, social, and economic risks can be most adequately assessed and managed. A disaster management fund can be allocated for the community, which will be monitored and supervised by the disaster management committee at the ward level. That will ensure the maximum utilization of the fund and other resources in an emergency and will strengthen the community's financial capacity.

- **Public awareness**

Public awareness can significantly improve Dhaka city's urban flooding situation. The carelessness of the community towards waste disposal, rules and regulations, and responsibilities cause waterlogging in the rainy season. Public awareness can improve a community's social resilience.

- **High dependency of the community members on government reliefs, actions, and decisions**

High dependency on government relief action and decisions is also an important indicator to improve the urban flood resilience score of the community. Currently, a community-based disaster risk reduction approach is being considered all over the world. Community-based disaster risk reduction is a process in which communities at risk of disasters are actively

engaged in the identification, analysis, treatment, monitoring, and evaluation of disaster risks in order to reduce their vulnerabilities and enhance capacities. (ADPC, 2006).

- **Representative from community**

There should be a community representative who can communicate with other stakeholders when needed.

- **Community participation and community's opinion**

Flood preparedness will not be effective without the participation of the vulnerable communities. The prime component is to involve the vulnerable community in the disaster mitigation process. Involvement of the community in resource identification, capabilities, coping mechanisms, and existing facilities towards vulnerability assessment will be more effective in planning a sensible and practical system that will be more suitable for the needs of the community. That's why researchers and experts from relevant fields in Bangladesh highly emphasized 'Community Participation,' particularly to improve the urban flood situation in Dhaka. The community's opinion should be considered in the policy-making and flood management process. The most crucial benefit of an engaged form of community decentralization, however, relates to the establishment of trust between citizens and the state (Stark & Taylor, 2014). Numerous frameworks focus on community participation and the decision-making process to improve social resilience. Considering Dhaka's present urban flood scenario, experts also emphasized the community's opinion and the bottom-up approach.

- **Interest of community to adopt new strategy**

Government officials and experts are complaining about the community as they are not very interested in adopting new strategies. The government took the initiative to ban the regular use of polythene in 2002. The ban's effect did not last long. After a short recess, polythene again became available in the market. Cheap and readily available, most people like to reuse polyethylene bags. In 2016, Dhaka's city corporations installed 6,000 waste Bins to implement a waste disposal law, but carelessness among Citizens led the project to a fiasco. People throw garbage here and there instead of the bin.

- **Open spaces and soakable greens**

Open spaces and soakable green can improve the stormwater system of a community. In Dhaka's context, it's challenging to find open spaces for plantations and greenery because of the city's unplanned urbanization. So, to improve the natural capacity of the community, they can increase greenery by building roof gardens. They can utilize their setback space to plant different vegetable plants.

- **Encroachment in natural drainage**

Kallyanpur main khal, Kallyanpur branch khal, Ramchandrapur Khal, and Katasur Khal are the main khals within the study area. All of the canals are almost encroached with waste materials. Kallyanpur' Ka' Khal khal is almost captured by a section of grabbers, who have captured both sides of the Khal, one of the most important points of passing out sewerage water from the capital, again and built structures due to lack of monitoring by authorities. Waterlogging in the residential areas of Kallyanpur, Shyamoli, and the surrounding areas has been a regular feature for the last couple of years.

A Shyamoli resident said during the survey that prolonged waterlogging with sewerage water had an adverse impact on the lives and health of the people there. According to a 2007 Dhaka Wasa survey, the 2.2km Kallyanpur main canal was 18-36m wide. Encroachment by land-grabbers has narrowed the width of the key drainage route down to 10-12m in places.

- **Knowledge about community resilience**

70% of respondents are not aware of the 'Resilience' concept. The community should know resilience, waste segregation, and rainwater harvesting; thus, they can utilize their resources best and strengthen their capacities.

- **Knowledge about rainwater harvesting**

According to data, Dhaka's total water demand is 2,240 million liters per day (MLD), whereas supply is 2,150 (MLD). This supply is derived from surface water to the extent of 13% and groundwater resources to the extent of about 87% (DWASA Annual Report, 2011-2012). The groundwater table is constantly dropping because of the massive extraction from the subterranean water supply. The pace at which groundwater is being depleted at the moment is 3.52 meters per year (DWASA Annual Report, 2011-2012). This massive city will be without clean drinking water due to the rapid depletion of the water table, which will cause southern salinity water to seep into the groundwater reservoir. Water flooding in September damaged several roads and telephone lines in Dhaka city and affected 250 schools and 681 textile industries, according to a study by the Water and Sewerage Authority (DWASA) (Tabassum et al., 2013). The city had 38 mm of rain in three hours on 22 May 2006, which led to a serious water logging issue. Another method to lessen Dhaka's water logging issue and water constraint is rainwater collection. A straightforward method for gathering and preserving rainwater for human use is called rainwater harvesting (Tabassum et al., 2013). The world has been using rainwater gathering as a source of water for agriculture and domestic needs for ages.

7. CONCLUSION

This paper has assessed the current urban flood situation of two different communities in the Kalyanpur area and tried to identify practical indicators to improve their urban flood situation.

In order to enhance Dhaka's urban flood scenario, we have shed light on the literature on resilience and the notion of community resilience in this study. Resilience is a multifaceted phenomenon and must not be overly generalized (Jamshed et al., 2023). In order to develop community resilience and improve each food resilience factor, targeted, contextualized, and tailored interventions are needed.

After doing a survey, it has been seen that the institutional, physical, and financial capacities of the Kalyanpur area are very poor. We have come up with twenty practical indicators that should be considered while implementing any framework or strategy. Mainstreaming flood management is crucial to ensure the city's resilience. Ward authority is not empowered to prepare a development plan at a local level; however, in their discussion with the city corporation, the Disaster risk reduction aspect should be included. The community's opinion should also be included in the management process. Community preparedness in the study area is extremely low and requires immediate attention and action. From the experience of past disasters, we learned the importance of self-help and mutual help. The community-based early warning system has been very effective here, and the number of casualties has declined dramatically. Institutional capacity is the most important dimension in Dhaka's resilience; that is why the government should take the necessary steps to strengthen the community's instructional capacity to improve its urban flood resilience.

Future research might address some of the shortcomings of this study. First, the study was carried out in a comparatively narrower region with a reduced sample size due to temporal and financial constraints. The study was based on literature, participation of the community's people, and expert opinions. Nonetheless, the involvement of local stakeholders may have shed light on additional resilience-related topics that this study might have overlooked.

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