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An approach to understanding the intrinsic complexity of resilience against floods: Evidences from three urban communities of Pakistan

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Abstract

Rapid and unplanned urbanization has resulted in the settlement and expansion of marginalized communities in flood-prone areas. Consequently, the devastating impacts of urban flooding have increased recently, further augmented by the changing climatic patterns resulting in more frequent flooding. However, to effectively enhance resilience at the community level, it is essential first to understand its components and indicators. This study proposed and tested a methodology to assess community resilience against urban flooding – 57 indicators of resilience were identified, which were classified into six domains, namely social, economic, infrastructural, institutional, natural, and psychological. The data was collected through a questionnaire survey in three communities of Rawalpindi, Sialkot, and Muzaffargarh cities in the province of Punjab, Pakistan. The data of resilience indicators were standardized, and an index-based approach was used to assess the community resilience in the six domains. The relative importance of each domain was evaluated through input from field experts translated into weights through the analytic hierarchy process method. Thereafter, overall community resilience was constructed, and statistical methods were employed to compare resilience and its domains. A significant difference in resilience was observed among the selected communities. Recommendations based on relative urgency, complexity, and impact were devised to help institutions make informed decisions to improve community resilience against floods.

Keywords: capacity; climate change adaptation; disaster risk reduction; Pakistan; urban flooding

1. Introduction

Flood is the most common natural hazard that accounts for more than 43% of all natural hazards in the world [1]. Floods, once considered a hazard typical to rural areas, are predominantly becoming an urban event now [2]. Rapid urbanization, particularly in the Global South, has resulted in a concentration of underprivileged and marginalized communities in hazardous locations, thereby increasing urban vulnerability [3]. Urban populations in South Asian countries are at high risk of flooding due to the changing climatic conditions and uncontrolled urbanization and development in/along flood plains [4,5].

Urban flooding is a recurring phenomenon in Pakistan. Both fluvial and pluvial flooding have massively affected the urban population in Pakistan in recent years. Fluvial flooding in 2010 caused economic damages of around 10 billion USD. The floods completely wiped our various key lifeline infrastructure in various parts of the country. Pluvial flooding is considered a major disruptive hazard in urban communities. Almost every year, excessive monsoon rainfall floods many urban centres in Pakistan. Poor land-use planning, inadequate disaster management initiatives, limited corrective measures for existing development, reactive approach of development authorities, inequalities, and rapid population growth are some reasons for increasing urban risks [6,7]. In 2001, floods affected more than 400,000 people of the most deprived communities in Islamabad and Rawalpindi. In 2017, pluvial flooding killed at least 23 people and submerged hundreds of houses in Karachi, the largest city in the country [8]. Heavy rainfall in Lahore (the second largest city of Pakistan) in 2018 took 18 lives and caused massive power outages, damaged roads, and halted social life [9]. Taking into account the changing precipitation pattern in the country and resulting damages in recent years, building resilience among urban communities has become crucial.

Urban resilience is gaining importance in disaster risk reduction and climate change adaptation. In global environment change, understanding resilience in urban settings is vital [10] for reducing vulnerability [11] and mitigating the hazard in urban areas [12]. It is therefore becoming imperative to ascertain the resilience of urban areas which are highly prone to flooding. Urban resilience can be defined as “the ability of a city or urban system to withstand a wide array of shocks and stresses” [13]. An urban system comprises various social, economic, physical, and institutional features that vary across space. Depending on different interpretations and definitions, resilience is often linked with overlapping concepts of vulnerability, risk, and capacity [14]. The multifaceted nature of resilience often complicates a clear urban resilience assessment. Therefore, it is crucial to properly understand ‘resilience’ and develop methods to quantify it to prepare and implement successful disaster risk reduction plans and policies.

In Pakistan, much of the research studies have focused on assessing the vulnerability of rural and urban communities (see, for example, [7,15–22]), while limited studies have focused on exploring, understanding, and determining flood resilience. Among those who investigated resilience, Ainuddin & Routray (2012) developed a community resilience framework for earthquake hazards. They further developed an index to measure community resilience [24]. Shah et al. (2018) measured the resilience of households to flood hazards in rural areas of Khyber Pakhtunkhwa province using an index-based approach on subjective weights for indicators [17]. Jamshed et al. (2019) evaluated the resilience level of post-disaster resettlements in rural areas of Pakistan [25]. Ahmad and Afzal (2019) measured flood resilience through social, economic, institutional, and physical resilience [26]. Sajjad (2021) mapped the spatial distribution of disaster resilience at the district level [27]. All these studies used limited indicators to measure resilience and mainly focused on rural communities. Indicators and dimensions might inherently different for rural and urban areas, as apparent by multidimensional poverty dynamics in them [28]. Moreover, multidimensionality was not sufficiently captured by previous studies. It is pertinent to note that disaster resilience differs significantly between rural and urban areas because of socioeconomic, governance, institutional, and infrastructural aspects [29–31]. This study aims to establish and combine the different domains/dimensions of resilience to understand the resilience against flooding, explore community resilience from a holistic and multidimensional perspective in urban areas, and suggest measures for enhancing resilience.

2. The concept of resilience

Resilience is a broader concept that tries to envelop disaster risk reduction paradigms and climate change adaptation [32]. The word probably emerged from Latin roots, i.e., *resilio or resilire* [33,34]. A seminal study defined resilience as the system's ability to absorb and persist [35]. The more advanced concept of resilience deals with the inter-linkages of human and ecological systems [11]. Folke (2006) systemized different resilience concepts as per their context, focus, and characteristics [36]. A report by Community and Regional Resilience Institute summarizes 46 diverse definitions of resilience [37]. It has the potential to unify the philosophies of climate change adaptation and disaster risk reduction [14].

Operationalizing the concept of resilience is somewhat challenging in disaster risk reduction and climate change adaptation [38]. Resilience is oriented more towards resistance, preservation, and restoration following a hazard in the context of disaster risk reduction [39]. However, climate change scientists see it as coping, responding, reorganizing, and transforming to hazardous events (Intergovernmental Panel on Climate Change, 2014). From the perspective of global environmental change, resilience is embedded in the concept of vulnerability and adaptive capacity. It is also often interrelated with various disaster risks and its components such as vulnerability, adaptive and coping capacity [32,36,41,42]. Cutter et al. (2008) further contended that resilience is a process that leads to adaptation [41]. Moreover, some researchers assert that vulnerability and resilience are interlinked [14,43,44]. The terms resilience and capacity are sometimes interchangeably used in research [11]. However, many scholars emphasize that more research is required to understand resilience and its interdependencies or linkages with other concepts of global environmental change [10,32]. In this regard, assessing resilience becomes integral for developing future disaster risk strategies.

Various frameworks and discourses demonstrate the multifacetedness of resilience. Walker et al., (2002) suggested a framework for the analysis of resilience in social-ecological systems [45], whereas Bruneau et al., (2003) proposed the 4R Model (robustness, redundancy, resourcefulness, and rapidity) to assess resilience [46]. Godschalk (2003) envisioned redundancy, diversity, efficiency, autonomy, strength, independence, adaptability, and collaboration as the main characteristics of resilience [12]. Cutter et al., (2008) proposed a dynamic process, the severity of a disaster, the temporal aspect of hazard, and the influence of external factors. They termed it as the disaster resilience of place (DROP) model [41]. Birkmann's MOVE (Methods for the Improvement of Vulnerability Assessment in Europe) Framework suggested resilience as a component of vulnerability [38]. This framework described resilience in terms of anticipating, coping, and recovering from natural hazards. Against the background of these theoretical and conceptual settings, community resilience can be built through social equity and connectedness, economic wellbeing, physical development, and environmental safety [47].

Several studies have used various dimensions to assess resilience in developing countries. Joerin et al. (2012) used the household survey to assess community resilience to climate-induced hazards in India [48]. Orencio & Fujii (2013) used the analytic hierarchy process (AHP) for assessing resilience in coastal areas of the Philippines [49], while Chan et al. (2014) established disaster resilience indicators for the Tan-sui river basin in Taiwan using Delphi and AHP [50]. Asadzadeh et al. (2015) used factor analysis and analytic network process to measure urban resilience in Tehran, Iran [51]. In contrast, Yoon et al. (2016) used an index-based approach and regression analysis to assess community disaster resilience in Korea [52]. Abenayake (2018) assessed community resilience from an ecosystem services perspective in Sri Lanka [53]. Halkos and Skouloudis (2020) and Halkos et al. (2018) investigated barriers limiting the resilience of small and medium enterprises in Attica, Greece [54,55]. The complexity and multidimensionality involved in assessing resilience are quite clear from these studies.

2.1 The domains of resilience

Resilience has several dimensions and multiple methods of measurement. Key dimensions of resilience are social, economic, physical/infrastructural, institutional, natural, and psychological. Social resilience is associated with social entities and their ability to absorb, tolerate, cope, and adjust to various environmental threats like flooding, storms, earthquakes, etc. Social and power relations, cultural values and social norms, network structures, health, knowledge, and awareness are considered key determinants of social resilience and are imperative for building and maintaining resilience [48,56,57]. Culture has a long-term impact on building social resilience [58]. Economic resilience is considered central to minimize losses resulting from disaster [59]. Employment, wealth, the extent of property losses due to disasters, business disruption, and any other financial aspects are associated with economic resilience metrics [41].

Infrastructural resilience is associated with all the physical features on which urban and rural communities depend. These include lifeline or critical infrastructure, transportation, water and irrigation networks, housing, etc., and their interdependence on each other [41,60]. The increased dependence of societies on critical infrastructure, particularly in the context of natural hazards, has intensified the focus on this dimension [38]. Institutional resilience, on the other hand, is associated with an organization's properties and elements. The institutional capacities are often shaped by political systems, especially in crisis and disasters [61]. It is a critical component for evaluating various factors that can encourage or discourage overall resilience against urban floods [62]. Public participation in awareness campaigns, presence of contingency, zoning and building regulations, emergency services, early warning, access to credit, etc., are the key determinants for institutional resilience to hazards [17,43]. It is a part of disaster governance with strong linkages with social, economic, and political dimensions [63].

A new dimension of resilience, “natural”, has been introduced, mainly dealing with the natural hazard context – for example, frequency, height, and duration of flood events. It indicates how communities are resilient to natural features of space and relevant hazards. Although natural resilience deals more with hazard and exposure, it is known to affect community resilience. Psychological resilience is focused on analyzing individuals' ability and recovery process to deal with shocks and negative effects associated with the risk [64]. In disaster risk research, psychological resilience deals with two domains. The first involves the mental health and development process of individuals after hazard, whereas the second deals with the factors related to disaster preparedness and mitigation at community or individual levels [38]. Therefore, these dimensions can help in understanding the concept of resilience. The political and cultural dimensions are crucial for building resilience in the communities. However, quantifying and analyzing the impact of these dimensions remains a challenge. Therefore, these dimensions were not included in the resilience assessment.

3. Data and methods

This study utilizes primary data to quantify the resilience of flood-prone urban communities. Urban resilience is explored through the lens of social, economic, infrastructural, institutional, natural, and psychological resilience. Indicators for each domain were chosen using an extensive literature review. An index-based approach has been used to aggregate indicators under each domain. AHP method was used to determine the relative impact of each resilience domain to assess the overall community resilience. Descriptive analysis and statistical tests were employed to explain the various indicators and resilience domains. Figure 1 summarizes the methodology proposed and adopted in this study.

Figure 1. A methodological framework to assess community resilience against flooding.

3.1. Data collection

Three cities in the province of Punjab, Pakistan, namely Rawalpindi, Sialkot, and Muzaffargarh, exhibiting a marked variation in population size, have been selected through multistage sampling to test the methodology proposed in Figure 1. Rawalpindi was selected as metropolitan (> 1 million urban population), Sialkot as a city (500,000 to 100,000 urban population), and Muzaffargarh as a medium town (<500,000 urban population). A comparative picture can help to diagnose resilience systems of different communities, showing a spatial variation of the phenomenon as well.

The National Disaster Management Authority (NDMA) of Pakistan has classified these cities as high flood risk areas since they are susceptible to riverine and surface flooding usually instigated by heavy monsoon rains, poor drainage, and protection mechanisms. For the empirical investigation, one community from each city was identified for an in-depth household survey. Using the Cochran sampling formula, with a confidence level of 95% and precision of 0.07, a total of 194 samples were estimated from three communities. Figure 2 shows the location of each community on the map.

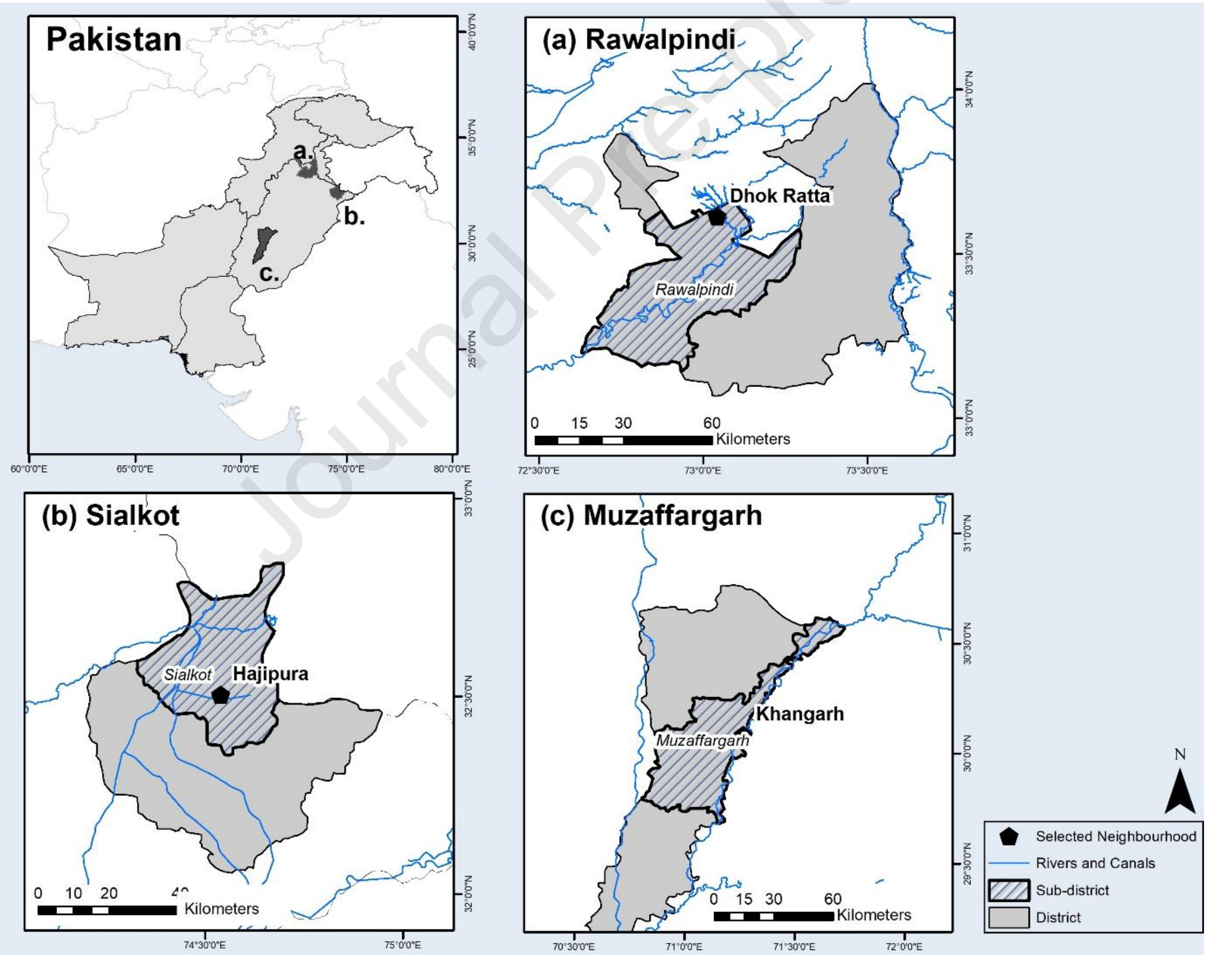

Figure 2. Map of the study area.

A pre-testing of 30 questionnaires was done, 10 in each community, to streamline the questionnaire. After finalizing the questions, the questionnaire survey was conducted on a (randomly selected) household scale. A total of 210 samples were collected, 70 from each community (neighborhood) in Dhok Ratta in Rawalpindi, Hajipura in Sialkot, and Khangarh in Muzaffargarh.

The data of 57 indicators were collected through questionnaire surveys and categorized into six broader domains of resilience: social, economic, infrastructural, institutional, natural, and psychological. To compute the overall resilience, these domains were combined using a weighted sum approach using AHP analysis. In this regard, the opinion of field experts about the relative importance of each domain for the assessment of community resilience against urban flooding was collected through an online questionnaire. This questionnaire was shared among experts from various fields such as disaster management, urban planning, civil engineering, architecture, and others belonging to various industries such as academia, government sector, private sector, and others (Figure 3).

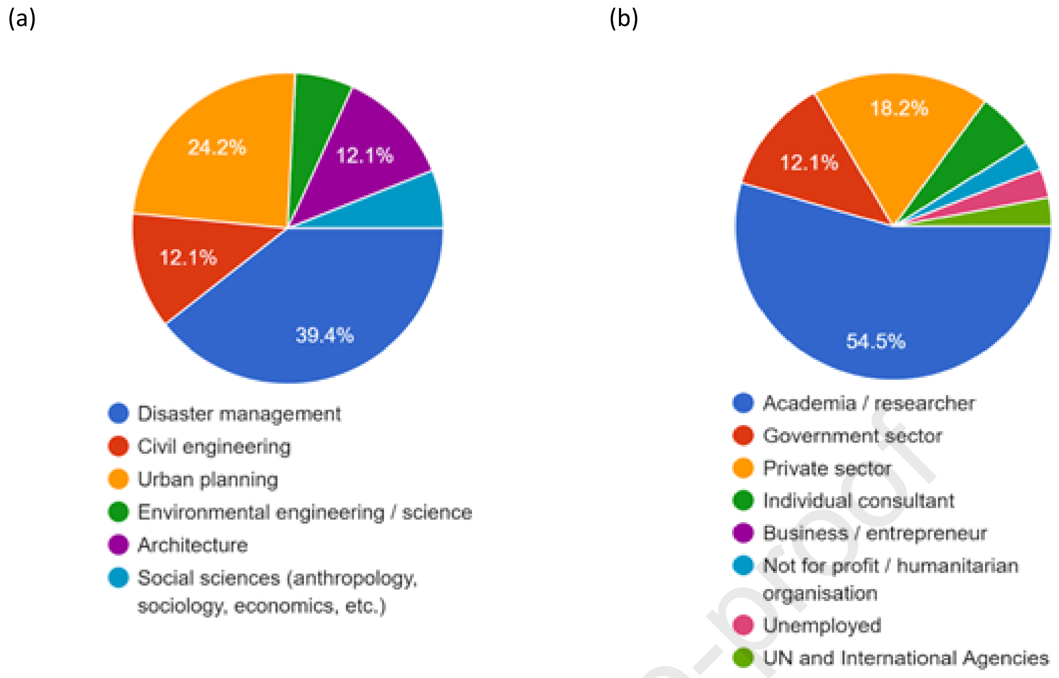

Figure 3. Distribution of field experts' (a) field of expertise, and (b) main work industry contributing to the development of a pairwise comparison matrix to determine the relative importance of each domain for assessment of community resilience against urban flooding.

3.2. Methods

There is a consensus among researchers on using certain indicators for measuring community resilience [48,52,65]. Therefore, the indicators used in this study overlap with some of the ones used previously [7,66,67]. – however, it is important to mention that these studies mainly focused on assessing risk perception, vulnerability, and risk of flood-prone communities. The current study, on the other hand, presents an approach where these indicators are reclassified into six domains to examine community resilience which makes this methodology not only unique but also robust as it enables the analysis of collected data to examine resilience. Social resilience contains 11 indicators, whereas economic and infrastructure resilience included twelve indicators each. Institutional, natural, and psychological resilience had eleven, five, and six, respectively. Table 1 represents indicators used for analysis, along with data description. The transformation value *(TV)* standardization/normalization method was used for index construction of individual resilience domains, as shown in Eq. (1) [68].

Table 1: Resilience indicators and their description (data of each indicator was collected through a household-level questionnaire survey).

DOMAINS OF RESILIENCE		Data Description*
Social Resilience		
SR1	Household size (in number)	Numeric
SR2	Family type	1 = Joint 0 = Single/Nuclear
SR3	Education of the household head	1 = Literate 0 = Illiterate
SR4	Male-female ratio	Numeric
SR5	Household having past experiences with floods	1 = Yes 0 = No
SR6	Community cooperation in disaster response	1 = Yes 0 = No
SR7	Households with swimming skill	1 = Yes 0 = No
SR8	Households with first aid skills	1 = Yes 0 = No
SR9	Households' participation in flood relief activities	1 = Yes 0 = No
SR10	Community meetings regarding flood preparedness	1 = Yes 0 = No
SR11	Time households residing in the community	Numeric
Economic Resilience		
ER1	Employment status of the household head	1 = Employed 0 = Unemployed
ER2	Households with multiple livelihood options	Numeric

DOMAINS OF RESILIENCE		Data Description*
ER3	Average annual household's income	Numeric
ER4	Economic dependency ratio (Number of earners/household size)	Numeric
ER5	Households with family member employed outside flood-prone area	1 = Yes 0 = No
ER6	Households having financial burden (under debt)	1 = No 0 = Yes
ER7	Households owning the house	1 = Yes 0 = No
ER8	Households having any kind of savings (bank, gold, silver, prize bonds, saving certificates)	1 = Yes 0 = No
ER9	Households having land/house outside the flood-prone area	1 = Yes 0 = No
ER10	Households with insurance (health, life, asset)	1 = Yes 0 = No
ER11	Households incurring damages in previous floods	1 = No 0 = Yes
ER12	Households having a private vehicle	1 = Yes 0 = No
Infrastructural Resilience		
IR1	Households living in pacca houses (brick, cemented)	1 = Yes 0 = No
IR2	Age of building (in years)	Numeric (Inverse)
IR3	Height of building (number of storeys)	Numeric
IR4	Households having access to safe drinking water	1 = Yes 0 = No
IR5	Households having access to improved sanitation	1 = Yes 0 = No
IR6	Households getting electricity	1 = Yes 0 = No
IR7	Households having means of communication (television)	1 = Yes

DOMAINS OF RESILIENCE		Data Description*
		0 = No
IR8	Households having means of communication (mobile)	1 = Yes 0 = No
IR9	Households having means of communication (radio)	1 = Yes 0 = No
IR10	Households having means of communication (telephone)	1 = Yes 0 = No
IR11	Perceived quality of road network	1-5 Scale
IR12	Perceived quality of stormwater drainage	1-5 Scale
Institutional Resilience		
INR1	Households' knowledge about flood risk classification	1 = Yes 0 = No
INR2	Warning about last floods received by the households	1 = Yes 0 = No
INR3	Households' level of understanding national warning system	1-5 Scale
INR4	Households' awareness regarding nearest emergency shelter	1 = Yes 0 = No
INR5	Households' awareness regarding evacuation routes	1 = Yes 0 = No
INR6	Households' knowledge of emergency protocols regarding floods	1-5 Scale
INR7	Availability and circulation of emergency plans to household	1 = Yes 0 = No
INR8	Frequency of public awareness programs/drills attended by any household member (in number)	Numeric
INR9	Households that have gone to their local government for assistance in the past 12 months	1 = Yes 0 = No
INR10	Community having land use/zoning laws and households following them	1 = Yes 0 = No
INR11	Households' trust in the government's disaster risk reduction programs and policies	1 = Yes 0 = No
Natural Resilience		

DOMAINS OF RESILIENCE		Data Description*
NR1	Location of the house	1 = Upland 0 = At or below floodplain
NR2	Frequency of flood inside the house	Numeric (Inverse)
NR3	Frequency of flood in the neighborhood	Numeric (Inverse)
NR4	Height of flood measured from residence ground floor (in meters)	Numeric (Inverse)
NR5	Duration of the flood (in days)	Numeric (Inverse)
Psychological Resilience		
PR1	Perceived flood risk	1-5 Scale
PR2	Households' feeling afraid of the flood	1-5 Scale
PR3	Households' believing in the possibility of future occurrence of floods	1-5 Scale
PR4	Households' feeling potential destruction of their houses/assets	1-5 Scale
PR5	Households' readiness to change their lifestyle because of the floods	1-5 Scale
PR6	Households' believing in the capability of controlling/dealing with flood	1-5 Scale

** 1-5 Scale is very low, low, moderate, high, and very high*

$$Transformed\ Value\ (TV) = \frac{X_{ij} - X_{(\min)}}{X_{(\max)} - X_{(\min)}} \qquad (1)$$

The AHP analysis method was applied to the data collected from field experts through an online questionnaire to determine the relative importance of each domain of resilience with respect to the other. The data collected from 33 experts was compiled, and the relative importance of each domain with respect to each of the others was determined using a numerical scale for comparison developed by Saaty (1980 & 2012), as shown in Table 2.

Table 2. Saaty's numerical scale of comparison to determine the relative importance of each criterion with respect to each of the others.

Qualitative judgment	Numeric value
Extreme importance	9 8
Very high importance	7 6
High importance	5 4
Moderate importance	3 2
Equal importance	1

A pairwise comparison matrix was then developed, showing the relative importance of each domain with respect to the other (Table 3). Cells in this matrix contain the numeric value of importance as shown in Table 2, reflecting the relative preference (also termed as judgement) in each of the compared pairs. For instance, if the majority of the experts considered that *social resilience's importance was 'very high' as compared to the psychological resilience*, the social-psychological comparison cell (the intersection of row 'social' and column 'psychological') will contain the value of 7 as shown in Table 3. The opposite comparison, the importance of psychological resilience compared to that of social, will yield the reciprocal of this value (psychological/social = 1/7) as shown in the psychological-social cell in the pairwise comparison matrix (Table 3). The pairwise comparisons thus offer great advantages in the form of (1) simplicity where regardless of how many criteria are involved, the AHP method compares them in pairs; and (2) capability to compare the qualitative judgments systematically.

Table 3. Pairwise comparison matrix developed through field experts' responses to determine the relative weights of each domain for assessment of community resilience against urban flooding.

	Social	Economic	Infrastructural	Institutional	Natural	Psychological
Social	1	3	1	7	5	7
Economic	1/3	1	3	3	3	5
Infrastructural	1	1/3	1	5	1	5
Institutional	1/7	1/3	1/5	1	1/3	3
Natural	1/5	1/3	1	3	1	5
Psychological	1/7	1/5	1/5	1/3	1/5	1

Before computing the domain weights, the numeric values (judgements) need to be tested for consistency. This needs to be done to make sure that the judgements are consistent; for instance, if 'A' is preferred twice as much as 'B' and 'B' twice as much than 'C', then to be consistent, 'A' should be preferred approximately four times as much than 'C'. Suppose the experts assign a value to the A-C comparison that does not correspond to the A-B-C relationship. In that case, a certain level of inconsistency will be introduced in the matrix. Some inconsistency, however, is expected and allowed in the AHP analysis.

In AHP, the consistency of judgements is checked by consistency ratio (CR) through the consistency index (CI) and random index (RI) using Eq. 2 [70].

$$CR = \frac{CI}{RI} \qquad (2)$$

The CI is computed by Equation 3, where λ is the average value of the consistency vector computed through the pairwise comparison matrix, and n is the number of domains being compared. The value of RI is constant, which depends on the number of domains involved in the comparison; for six resilience domains, its value was 1.24 as determined by the RI table [70].

$$CI = \frac{\lambda - n}{n-1} \qquad (3)$$

The CR value higher than 0.1 indicates inconsistent judgments [70]. The value of CR for the pairwise comparison matrix given in Table 3 was computed as 0.094, which indicates that the judgments were consistent. The matrix can be used for computing the weights of resilience domains.

The resilience domain weights calculated through AHP analysis of the pairwise comparison matrix (Table 2) of experts' opinion is shown in Table 4. The results indicate that the expert ranked the domains of social, economic, and infrastructural resilience the highest for assessing community resilience against urban flooding. The psychological resilience domain was ranked the lowest. Therefore, it is evident that social resilience will have the greatest influence, followed by economic and infrastructural resilience, while computing the overall community resilience against urban flooding in this study.

Table 4. Weights and relative ranks of domains of resilience computed through AHP.

Resilience Domain	Weight	Relative Rank
Social	0.375	1
Economic	0.240	2
Infrastructural	0.180	3
Institutional	0.055	5
Natural	0.118	4
Psychological	0.032	6

The domain weights (Table 4) were applied to the rescaled resilience domain values using Equation 4 to compute the overall resilience against urban flooding for each community. The resilience was computed for each questionnaire response (210 responses) and later averaged to obtain the overall community resilience.

$$Overall\ resilience\ against\ urban\ flooding = (0.375 \times Social) + (0.240 \times Economic) + (0.180 \times Infrastructural) + (0.055 \times Institutional) + (0.118 \times Natural) + (0.032 \times Psychological) \quad (4)$$

4. Results and discussion

The analysis shows interesting insights on the urban resilience of households against flooding in Pakistan (Figure 4). In terms of social resilience, a mixed trend was observed among indicators (Figure 4(a)). The average household size was 5.5, with 5.4 in the Rawalpindi community, 5.6 in the

Sialkot community, and 5.4 in the Muzaffargarh community. Most household heads were literate in the sampled population (79.5%), with similarities within all communities.

Past experience with flood events plays a vital role in influencing resilience [71]. Around 78.6% of households had past experiences with floods, which can increase their resilience. Rawalpindi community had the least experience (67%), followed by Muzaffargarh (77%), and highest in the Sialkot community (91%). The lowest resilience was observed in the indicators in family type, swimming skills, first aid skills, community meetings, and community participation. Most of the households living in flood-prone communities were single-family units (89.5%). Overall, only 12.4% of households had swimming skills, with the least in Sialkot (4.3%). Similarly, only 3.3% of households had first aid skills, with least again in Sialkot (1.4%).

Community participation can essentially increase the learning and adaptive capacities of flood-prone communities [72]. Family participation in flood activities was poor in all three communities. Only four households out of sampled population participated in flood-related activities, with none of the households belonging to the Rawalpindi community. Similarly, participation in community meetings about flood preparedness was also limited. Around 12.5% of households participated in flood preparedness meetings, with least in Rawalpindi (3%). Overall, the mean social resilience index for Rawalpindi, Sialkot, and Muzaffargarh communities were 0.23, 0.35, and 0.29, respectively. ANOVA (f-test) shows significant difference among social resilience of three communities (F= 19.623, *p*-value= 0.000).

Again, in economic resilience, a mixed trend was observed among chosen indicators (Figure 4(b)). Income and livelihoods are significant indicators of adaptive capacity and help build long-term community resilience [73]. Most of the household heads were employed (85.7%), with the highest in the Muzaffargarh community (90.0%), followed by Rawalpindi (87.1%) and Sialkot (80.0%). A variable situation was observed for multiple sources for livelihoods. About 70% of households in the Rawalpindi community had a single income source, followed by Muzaffargarh (54.3%) and the Sialkot community (38.6%). Overall, 54% of households had single sources, 39% had two sources, 6.2% had three sources, and 0.5% (only one household) had four income sources. An average monthly income was about 30,000 PKR[1], with an average of 23,528 PKR in Rawalpindi, 42,057 PKR in Sialkot, and 22,992 PKR in Muzaffargarh. Significant variability was also observed in the three communities regarding monthly income (F= 12.640, *p*-value = 0.000).

Few households had a family member working outside the city (7.1%), which can help increase resilience in case of flood occurrence. It was observed that around 33% of respondents had taken a loan, making them less resilient. However, in the communities of Rawalpindi, Sialkot, and Muzaffargarh, around 55%, 16%, and 27% of households, respectively, were financially burdened. The majority of households had house ownership (80%), which varied individually. The highest house ownership was observed in Muzaffargarh (97.1%), followed by Sialkot (88.6%) and Rawalpindi community (54.3%). Interestingly, the majority of households reported no savings (65.7%), with the highest percentage in the Rawalpindi community (90.0%). When asked about land/property assets outside the city, a majority reported that they had no assets outside their community (81.4%), with the highest in Rawalpindi (94.3%), depicting low economic resilience.

Insurance can support build community resilience against climate change-induced disasters [74]. Only about 30% of the households had insurance, with the least observed in Rawalpindi (2.9%), and followed by Muzaffargarh (30.0%) and Sialkot (55.7%). The extent of past damages can tell the household’s repair and maintenance costs due to flooding, where about 59% suffered damages, with the highest in Muzaffargarh (88.6%), followed by Rawalpindi (52.9%) and Sialkot (35.7%). Households were asked about private transport, which can be liquidated into finance when needed.

[1] 1 Pakistani Rupee (PKR) = 0.0062 United States Dollar (USD) (July 2019)

About 93.3% of households had private means of transportation, where the highest was in Rawalpindi (100%), trailed by Muzaffargarh (70%) and Sialkot (44.3%).

Overall, the mean economic resilience index for Rawalpindi, Sialkot, and Muzaffargarh communities were 0.32, 0.51, and 0.40, respectively. The ANOVA (f-test) showed a significant difference among three communities regarding economic resilience (F= 19.623, *p*-value= 0.000). This implies that the highest economic resilient community belonged to the medium city (Sialkot) and then Muzaffargarh and Rawalpindi.

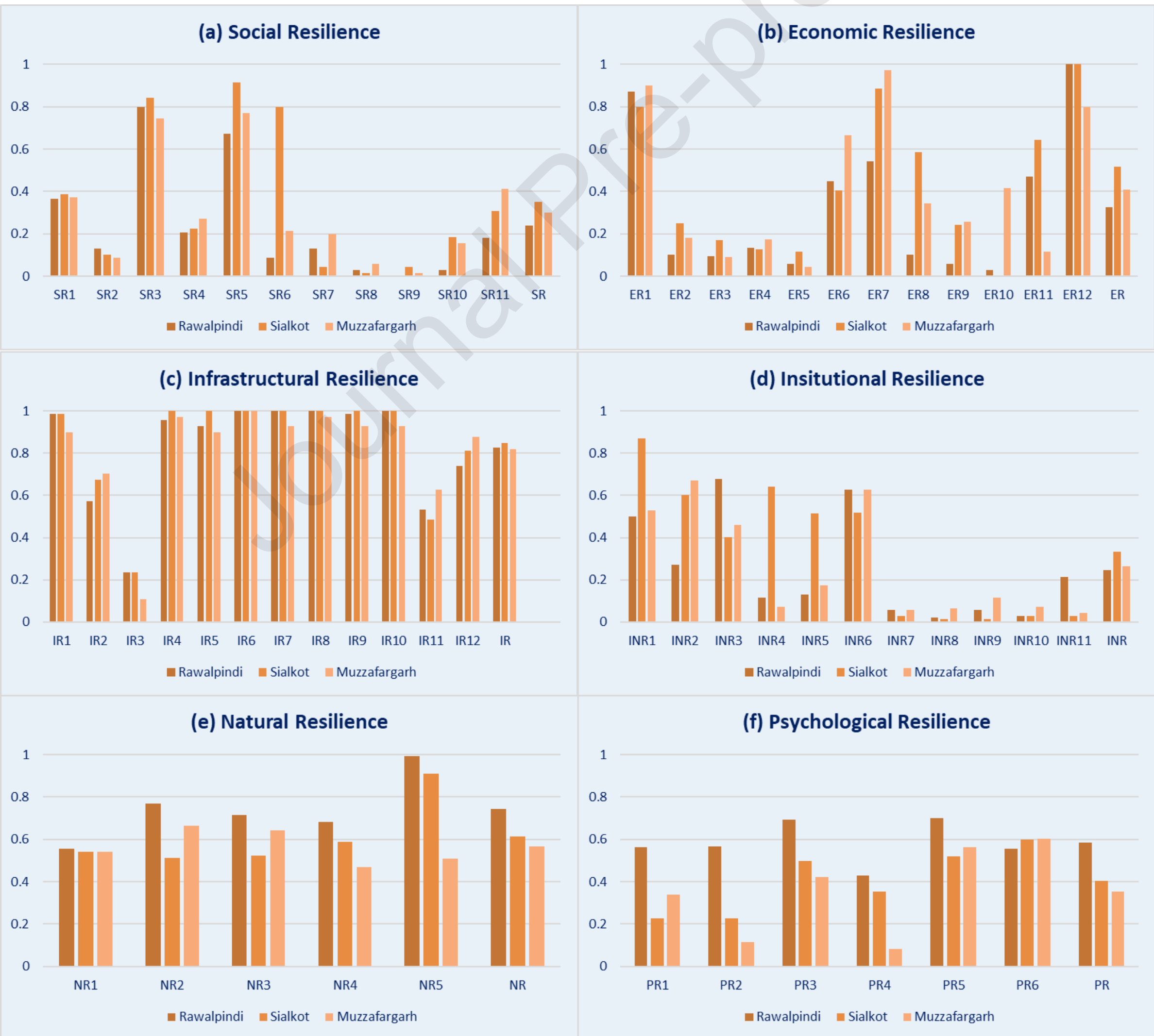

Figure 4. Descriptive statistics of indicators of resilience* classified into six domains**: (a) social, (b) economic, (c) infrastructural, (d) institutional, (e) natural, and (f) psychological.

** Description of each indicator can be seen in table 1*

*** SR is the 'mean' social resilience, ER is the 'mean' economic resilience, IR is the 'mean' infrastructural resilience, INR is the 'mean' institutional resilience, NR is the 'mean' natural resilience, and PR is the 'mean' psychological resilience.*

In terms of infrastructural resilience, a positive picture was observed (Figure 4(c)). As selected communities were within cities, the majority of respondents' houses were made of bricks and cement (95.7%). In terms of building age, the average value for all buildings was around 14 years, 12 years in Muzaffargarh, 13 years in Sialkot, and 17 years in Rawalpindi. However, f-test showed a significant difference among the communities (F= 7.333, *p*-value = 0.001). More individual storeys of the building can help in increasing urban flood resilience against floodwater height. The majority of the houses were single-storey buildings (62.9%) in the sampled population, followed by double (35.7%) and triple-storeyed buildings (1.4%). This trend was observed in all selected communities.

Regarding infrastructural amenities provision in flood-prone communities, a better position was observed. The majority of the households had a provision of safe drinking water/improved water sources (97.6%), improved sanitation (94.3%), and electricity (100%). All of the Sialkot community respondents had these three facilities, while the unavailability of amenities was observed in only a few households in Rawalpindi and Muzaffargarh communities. Regarding means of communication, a positive trend was observed. The majority of respondents had access to television (97.6%), mobile phones (99.0%), radio (97.1%), and landline telephone (97.6%). The minority who did not have access to these mediums were mostly from the Muzaffargarh community. When asked about perceived road and storm drainage quality, the mean value was around moderate and good for each. Overall, the mean infrastructural resilience value for Rawalpindi, Sialkot, and Muzaffargarh communities was 0.82, 0.84, and 0.82, respectively. ANOVA (f-test), however, showed a significant variation among these communities regarding infrastructural resilience (F= 3.075, *p*-value= 0.048).

Institutional resilience explored the relationship between local institutions and exposed communities. Firstly, households were asked whether they knew that National Disaster Management Authority (NDMA), Pakistan, has classified their city at high flood risk [75]; around 37% of households did not know about it (Figure 4(d)). In the Rawalpindi community, half of the respondents did not know that their vicinity is declared a high flood risk area. This implies poor risk communication by the institutions to the public.

Regarding early warning communication during the last flood event, around 48.6% replied that they did not receive the warning. Rawalpindi community had the highest percentage where households did not receive the warning (72.9%), followed by Sialkot (40%) and Muzaffargarh (32.9%). Regarding the understanding of early warning, a significant difference among communities was observed ($F = 18.483$, p-value= 0.000). The majority of the respondents in the Rawalpindi area had moderate to a good understanding. In contrast, moderate to low and moderate to very low were observed for Sialkot and Muzaffargarh communities, respectively.

Regarding awareness about nearest evacuation shelter and evacuation routes, a majority did not know about shelter (72.4%) and routes (72.9%). Muzaffargarh community had the highest percentage of no knowledge regarding the nearest shelter (92.9%), followed by Rawalpindi (88.6%) and Sialkot (35.7%). However, in terms of no knowledge about evacuation routes, the highest percentage belonged to Rawalpindi (87.1%), followed by Muzaffargarh (82.9%) and Sialkot communities (48.6%). When asked about understanding emergency protocols and procedures, significant variability was observed among the communities ($F= 4.440$, p-value= 0.013). The majority of the respondents were inclined towards high understanding (67.6%).

Regarding the circulation of emergency plans to the community, only 4.8% of households had the plan available with them. A similar picture was detected in individual communities. This again implies poor risk communication by local authorities. In terms of attending public awareness campaigns and flood preparedness drills, the majority of the households (95.7%) have not participated in any such program. Most of the respondents did not visit local institutions to seek advice or help (93.8%). This implies distrust among flood-prone communities and local institutions. Effective institutional mechanisms, such as land-use planning and development regulations, can increase resilience [76].

In terms of building control and zoning regulations, around 95.7% of households believed that institutions could not control urban development in flood-prone areas, with similar responses in individual communities. Lastly, in terms of confidence between communities and local institutions, the majority of the respondents showed distrust between them (90.5%). The highest mistrust was observed in the Sialkot community (97.1%), followed by Muzaffargarh (95.7%) and Rawalpindi (78.6%) communities. Overall, the institutional resilience index was the lowest among all domains of resilience. The mean institutional resilience index for Rawalpindi, Sialkot, and Muzaffargarh communities was 0.24, 0.33, and 0.26, respectively. ANOVA (f-test) also indicated a marked variation among these communities in terms of institutional resilience ($F= 11.598$, p-value= 0.000).

Natural resilience shows how geophysical and hazard factors affect household resilience. Regarding the physical location of the house vis-à-vis the plinth level of the house, it was observed that about 55% of the houses were constructed above the floodplain, with similar conditions prevailing across three communities (Figure 4(e)). Overall, only 15.7% of the households did not experience floods inside their houses. But this percent fell to 4.8% when asked about floods outside the house. Regarding frequency of floods inside house and in neighborhood, a significant difference (p-value = 0.000) was observed i.e., $F= 17.049$ and $F = 14.293$ respectively.

The height of the flood indicates the resistance to flooding water. The highest floodwater was observed at 2.44 m (8 ft) in the three communities. However, the ANOVA test shows that a significant variation exists among communities in terms of floodwater height (F = 10.292, *p*-value = 0.000). The duration of floodwater in the neighborhood implies drainage from the subjected community. In Rawalpindi, the flood's maximum duration was one month; in Sialkot two months, and four months in the Muzaffargarh community. Statistical tests affirm a significant difference (F = 93.292, *p*-value = 0.000), and a high F-value shows huge variance among the three communities. Overall, the mean natural resilience index for Rawalpindi, Sialkot, and Muzaffargarh communities was 0.74, 0.61, and 0.56, respectively. ANOVA (f-test) showed a major difference among three communities regarding natural resilience (F= 14.815, *p*-value= 0.000).

The psychological resilience domain suggests risk perception influencing the overall community resilience against natural hazards. Overall, around 58% perceived flood risk as low and very low, 17% as moderate, and the rest 25% as high (Figure 4(f)). This implies poor risk perception by more than half of the respondents in a high flood risk area. This risk perception, however, significantly varied among the three communities (F= 28.880, *p*-value= 0.000). When asked about the level of fear against urban flooding, around 80% of households responded that they had moderate to low levels of fear. This implies the fatalistic attitude of respondents. However, individual communities had different viewpoints, with a high level of fear in Rawalpindi marked at 52%, only 3% in Sialkot, and 4.3% in Muzaffargarh. This stark difference can be attributed to Rawalpindi's flood experience back in 2005, whereas other communities have faced floods in 2010 and 2014.

Similarly, a significant difference was also observed regarding perception about the likelihood of future flood occurrence (F= 21.444, *p*-value= 0.000). About 60% of Rawalpindi respondents opined high chances of flood occurrence. In terms of adapting to a new lifestyle to combat flooding, a significant difference was observed among communities (F= 13.211, *p*-value= 0.000). The majority of the Rawalpindi community (about 70%) were ready to modify their lifestyles. However, no significant difference was seen regarding perceived coping against floods. Overall, the mean psychological resilience index for Rawalpindi, Sialkot, and Muzaffargarh communities was 0.58, 0.40, and 0.35, respectively. Moreover, ANOVA (f-test) also showed significant variability among the three communities about psychological resilience (F= 63.218, p-value= 0.000).

The resilience in each domain in the three communities was obtained by averaging the index values, as shown in Figure 5. Social resilience was one of the lowest among all constituents of community resilience. It was more or less the same in all the communities, with comparatively higher social resilience in the Sialkot area. This can be attributed to a relatively higher percentage of literate persons, social cohesion, and past experiences with floods. In the Rawalpindi community, limited past experiences with floods were also noticeable, impacting community resilience. These past experiences and inherent behavior are closely associated with culture, and hence resilience building. Variability was observed in terms of economic resilience. Here again, medium city (Sialkot) surpassed other cities due to more sources of livelihoods and higher income levels.

The highest urban resilience was observed in the infrastructure domain. Almost all households in the study area had access to basic amenities like electricity, gas, water, and television. The worst condition was observed in the institutional resilience domain. This could be due to the unavailability of emergency plans to communities and institutions' inability to restrict urban development in flood-prone areas. Results imply poor linkages and distrust among institutions and communities. Moreover, no local institution is officially designated or responsible, and floods are being managed on an ad-hoc basis. Institutional resilience must be reactive and dynamic enough to accommodate political changes and instabilities, especially in developing countries like Pakistan. In terms of natural resilience, Rawalpindi was deemed relatively more resilient, possibly because the community was prone to less frequent pluvial flooding as opposed to more frequent riverine flooding in Sialkot and Muzaffargarh communities.

Regarding psychological resilience, Rawalpindi households had a higher average as compared to Sialkot and Muzaffargarh. A comparative look in Figure 5 shows that despite variations, constituents of urban resilience are low, except infrastructural resilience. This is quite understandable as Pakistani developmental policies are mostly geared towards infrastructural development compared to socioeconomic development.

Overall, community resilience was calculated after incorporating weights developed through AHP analysis. The Sialkot community emerged as the most resilient, followed by Muzaffargarh and Rawalpindi (Figure 5(d)). The mean values for Rawalpindi, Sialkot, and Muzaffargarh were 0.33, 0.42, and 0.37, respectively. ANOVA (f-test) showed a significant variation among the three communities in terms of overall community resilience (F= 56.404, p-value= 0.000). In the light of increasing extreme events, average urban resilience values are still very low. Therefore, urgent attention is needed to increase community resilience by initiating effective strategies to reduce disaster risk in flood-prone areas of Pakistan.

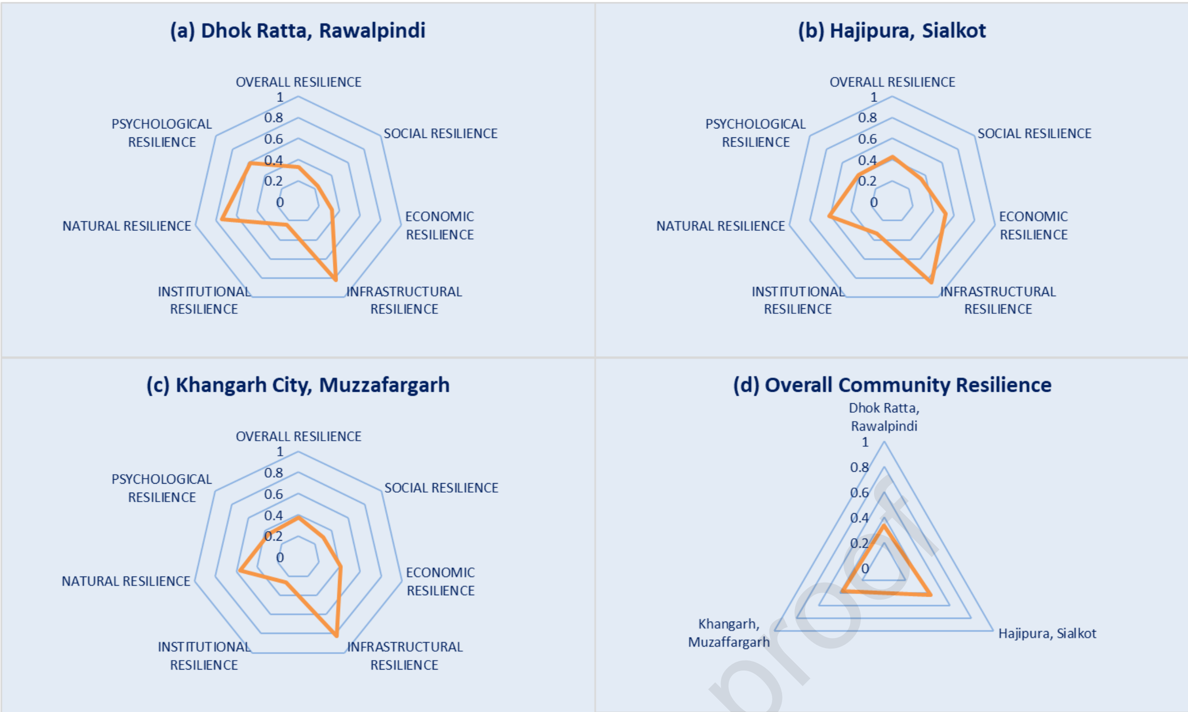

Figure 5. Resilience in each domain in (a) Dhok Ratta, Rawalpindi, (b) Hajipura, Sialkot, and (c) Khangarh, Muzzafaragarh communities, and (d) overall resilience of the three communities against urban flooding.

5. Conclusions and recommendations

Resilience is a holistic phenomenon, cross-cutting across various disciplines and fields of disaster management and climate change adaptation. This study tries to increase the understanding of the diverse and multidimensional concept of urban resilience. The study quantifies the urban resilience of flood-prone communities through empirical investigation. A step-by-step methodology is outlined for aggregating, weighting, and indexing the construction for urban resilience. The AHP weighting method was successfully utilized to methodically compute and quantify the relative importance of various disaster resilience components. The proposed methodology can be replicated for other natural hazards by choosing relevant indicators.

Of all the domains of resilience examined in this study, social resilience was marked as extremely important by most of the local experts. This can be attributed to the reliance of communities on social networking and capital and distrust of local institutions in urban flooding. This research also revealed the bleak picture of disaster management institutions, where a community has limited access to risk information and other related documentation. The research also concludes that urban resilience varies spatially, as a significant difference was observed among the three communities examined in this study (Dhok Ratta, Rawalpindi; Hajipura, Sialkot; and Khangarh, Muzaffargarh). This calls for enhancing resilience through adopting various strategies and measures for effective flood risk reduction and climate change adaptation.

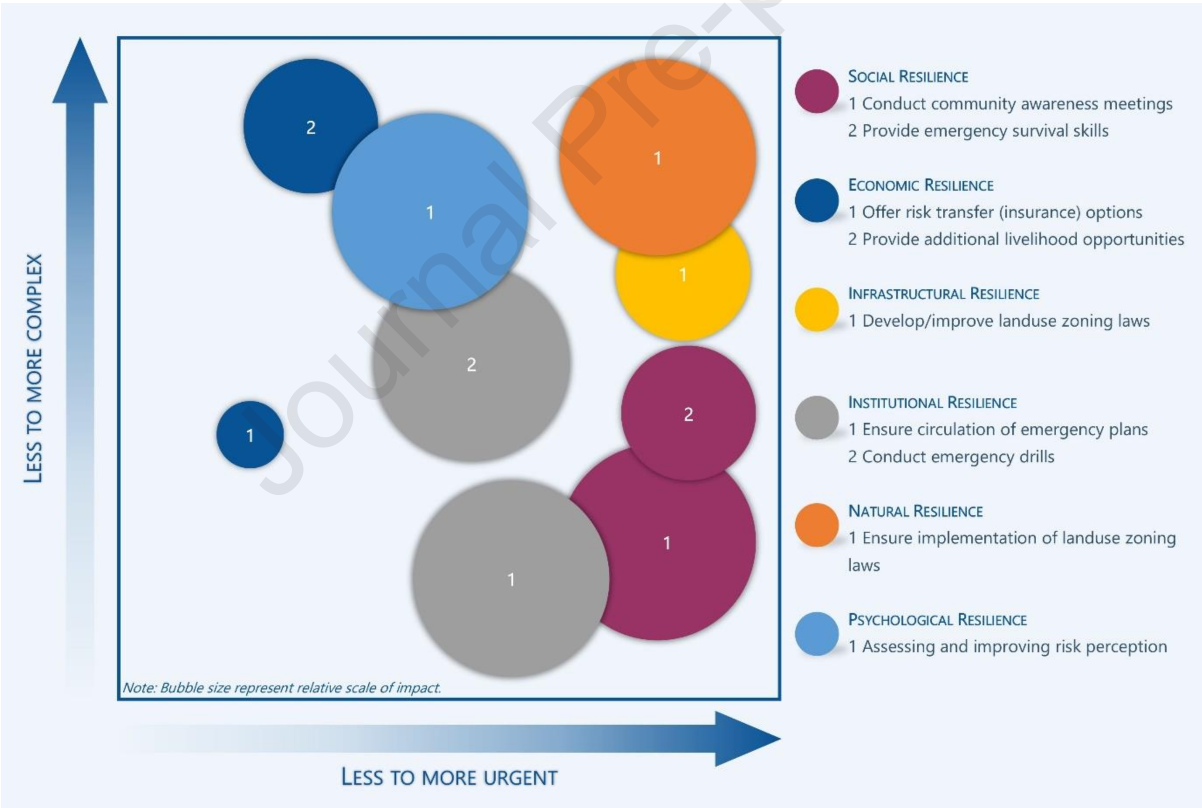

Figure 6. Relative urgency, complexity, and impact of various resilience strengthening recommendations.

The findings of this study unveil the shortcomings and assist in suggesting potential actions for increasing urban resilience. Figure 6 highlights recommendations/strategies for increasing resilience regarding their relative urgency, complexity, and impacts. Social resilience can very much be enhanced through conducting community awareness meetings among the flood-prone urban communities. This strategy is urgently required and with little complexity, but a larger impact makes it very practical.

Another recommendation is to teach communities emergency survival skills, which can save lives in a flood situation. It is direly needed to develop and evolve zoning restrictions with changing climate and disaster risks for increasing infrastructural resilience. The same goes for ensuring the implementation of such regulations and rules for minimizing flood risk. Although the development and in-situ execution of zoning ordinances are difficult in a multifaceted urban environment, the resultant impact is huge. Institutional resilience can be increased through effective risk communication by ensuring the circulation of emergency plans to communities. Similarly, drills and awareness campaigns are also needed. The suggested actions with a low level of relative complexity and high impacts make them the priority agenda for the concerned institutions for effective flood risk management.

Devising and implementing policies, however, remains crucial for the sustainable impacts of any reformative measures. The institutions alone probably could not reform their practices in the absence of strong, relevant, up-to-date, and scientifically backed policies and guidelines. Understanding the public risk perception and determining how to improve risk communication by the concerned institutions is vital for effective flood risk management. This study provides a potential mechanism to successfully translate the key resilience items, based on their effectiveness and complexity, into policy design and implementation.

Results also point out poor risk perception among flood-prone communities. However, increasing risk perception is complex, as a multitude of factors influences the decision-making of individuals, groups, or communities regarding potential external threats. However, the pay-offs for assessing and improving risk perception are vast as it predicts the community's inclination and culture towards adopting precautionary measures against floods. By implementing these strategies and embedding a culture of prevention, institutions and communities can effectively reduce flood risk and adapt themselves to climate change. For future studies, political and cultural domains may be added to the resilience index. The methodology can be strengthened by replicating the index for other natural hazards as well.

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Declaration of interests

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