

Addressing social and institutional vulnerabilities in the context of flood risk mitigation

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Abstract

There are different perspectives of what constitutes disaster risk. Among the “hazards”-tradition research, more focus is given to modelling hazards, and less effort is made to understand the *vulnerabilities*. Considering vulnerabilities as the inherent characteristics of the place that create the potential to harm, this paper highlights the importance of understanding the vulnerabilities of the place before defining actions for flood risk mitigation (FRM). In this sense, a participatory approach, the Project PLANEJEEE, was developed to understand the social and institutional vulnerabilities of FRM in Campina Grande, Brazil. Data was collected with the collaboration with 199 stakeholders through surveys, workshop and focus groups. The results reflect the analysis of risk perception and coping capacity of communities at risk ($n = 172$), and the institutional context with the involvement with policymakers and local specialists ($n = 27$). Although results confirm that individuals faced severe flood risk cases previously, they still need resources for increasing their coping capacity and their own risk protection. Institutional vulnerabilities are shown with the contrast between challenges and actions for FRM. Findings show that multiple challenges in social and institutional contexts should be systematically addressed to propose actions to reduce flood risk vulnerability, and increase resilience.

KEYWORDS

flood risk mitigation, participatory approach, social and institutional vulnerabilities

1 | INTRODUCTION

The United Nations International Strategy for Disaster Risk Reduction (UNISDR) defines vulnerability as “the conditions determined by physical, social, economic and environmental factors, or processes, which increase the susceptibility of an individual, a community, assets or systems, to the impacts of hazards” (UNISDR, 2021). Different disciplines, in both social and environmental

sciences, search for appropriate definitions of vulnerability with examples of urban planning, disaster management, engineering, economics, sociology and anthropology (Bergstrand et al., 2015; Birkmann, 2007; Cutter et al., 2003). For the Intergovernmental Panel on Climate Change (IPCC), defining what makes a system vulnerable is particularly key for disaster risk reduction (DRR) approaches based on the assumption that hazards only become disasters if they occur in vulnerable contexts

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(IPCC, 2014). This is corroborated by other authors that consider the vulnerability as a series of categories in physical and structural, environmental, social, psychological, and institutional contexts (Alexander & Pescaroli, 2019) that, when combined with exposed elements, will determine whether the event will translate into a disaster (Hazarika et al., 2018; Sharma & Ravindranath, 2019).

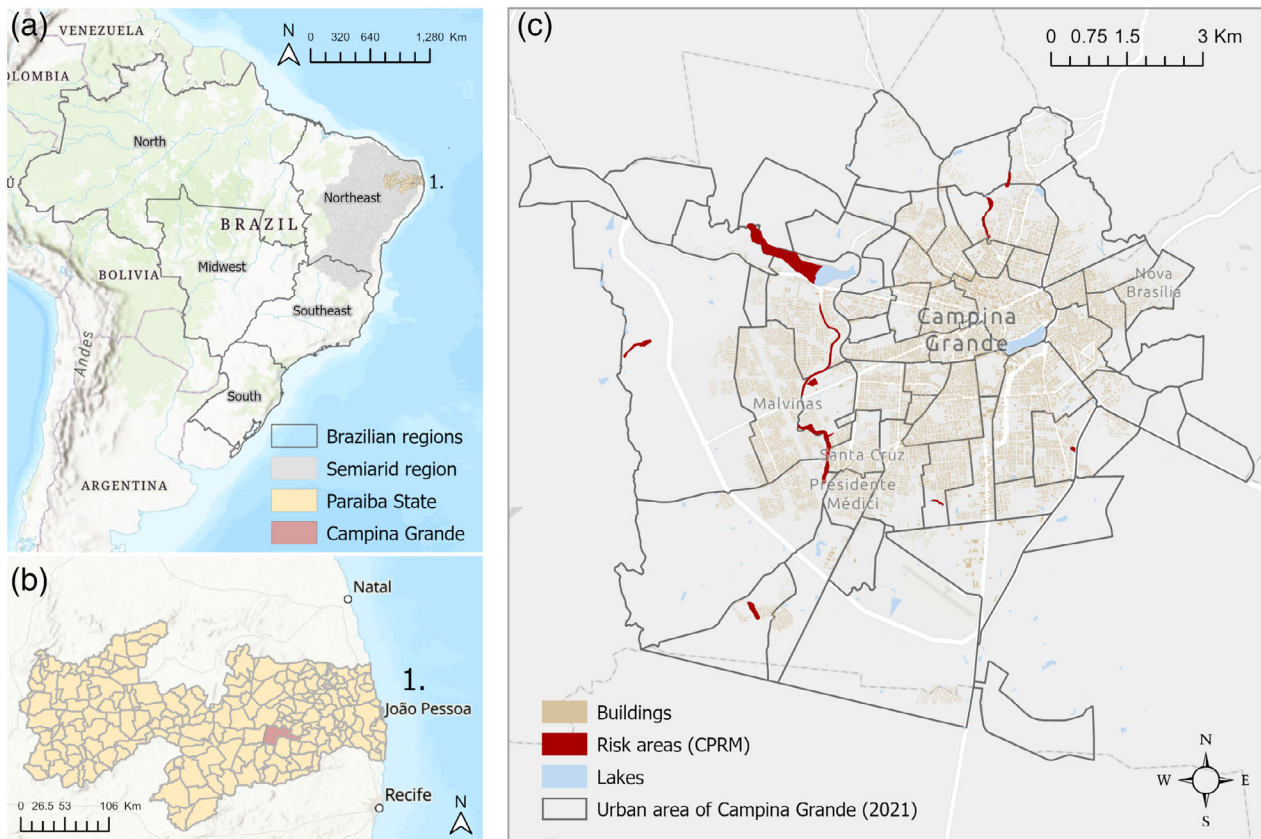
The understanding of vulnerability is essential for flood risk mitigation. Flooding is a hazard widespread worldwide (Hammond et al., 2018; Wang et al., 2018), reaching both developed and developing countries (Danso & Addo, 2016; Miguez et al., 2019; Nguimalet, 2018). The uncontrolled expansion of urban areas makes cities more exposed to flooding. It leads to economic losses and adverse social impacts (Thistlethwaite et al., 2018), including human health and wellbeing (Raymond et al., 2017). However, due to the dynamic nature of risk (Alexander & Pescaroli, 2019; Peduzzi, 2019; UNDRR, 2019), there is a debate of how flood risk (FR) should be contextualised in the studies. There are two main perspectives for addressing FR: (1) the “hazards”-tradition approach, more common among natural scientists and engineers, encompassing the probability of flooding and their consequences, and (2) “social”-tradition approach, among social scientists and planners, considering the hazard as a phenomenon with the potential to harm (i.e., detailed definitions can be seen in Klijn et al. (2015) and Gouldby and Samuels (2009)). For Cutter et al. (2003), the main barrier of the “hazards”-tradition approach lies in placing the origin of disasters in the hazard, instead of vulnerability. In this sense, authors argue that studies in the hazards-research still have a great focus on hazards modelling (Lund, 2015; Peduzzi, 2019), whereas the underlying factors of vulnerabilities are not well addressed, focusing more on the hazard itself (Ajibade & McBean, 2014).

This paper highlights how delineating actions for flood risk mitigation should be accompanied by the understanding of vulnerabilities as they are the “inherent characteristics of the place that create the potential to harm” (Cutter et al., 2008). For Klijn et al. (2012), the proposal of risk reduction strategies should equally consider (1) reducing flood probability, (2) reducing exposure to floods and (3) reducing the vulnerability of people and property. Specifically, the understanding of the three constituents of risk (i.e., hazard, vulnerability, exposure [IPCC, 2014]) may help to identify and select solutions and policy instruments aimed at influencing the development of each constituent (Klijn et al., 2015; Shah et al., 2020). When dealing with policies and urban planning in the context of DRR approaches, Marchezini et al. (2017) discuss how effective governance, institutional

arrangements, warnings, and communication systems are essential to meet the needs of every group, in every vulnerable community, including the needs of young people. For the authors, the ineffectiveness of these measures can be regarded as “institutional vulnerabilities.” Similarly, López-Martínez et al. (2019) argue that institutional vulnerabilities are the vulnerability root cause, involving all the dimensions of vulnerabilities (Birkmann, 2007; Fuchs et al., 2011) and showing how the inefficiency of authorities in charge of hazard management could amplify exposure.

We argue the proposal of actions for FR reduction is also affected by social and institutional constraints of the place. This is explicitly shown in the resilience conceptualisation, covering the “ability to respond to and recover from the impacts of hazards” (Cutter, 1996). However, like disaster and FR, resilience is acknowledged differently in the literature, which leads to several criticisms in the academic discourse (Coaffee et al., 2018; Rezende et al., 2019). In this article, the resilience definition of Cutter et al. (2008) is used, which considers the resilience of a community “as the ability of a social system to respond and recover from disasters, including the inherent conditions that allow the system to absorb impacts and cope with an event, as well as the post-event and adaptive processes that facilitate the ability of the social system to reorganise, change and learn in response to a threat”. In other words, understanding *how* societies perceive, respond, recover, and cope with an event, in pre- and post-events, may help to answer how disaster resilience can be achieved (Cardoso et al., 2020; Norris et al., 2008; Räsänen et al., 2020; Rezende et al., 2019). As such, studies have been focused on comprehending risk perception and coping capacity of communities towards risk mitigation (Chowdhoree et al., 2019; Houston et al., 2017; Lechowska, 2018; Netzel et al., 2021), leading to no consensus of how the measurement should be made (Liu et al., 2018), and what indicators should be used (Danso & Addo, 2016; Lechowska, 2018).

The different social (i.e., risk perception and coping capacity of residents at risk) and institutional vulnerabilities (i.e., government, legislation and institutions) characterise how disaster risk is not a random natural phenomenon but a consequence of human activities and decisions (Peduzzi, 2019). In this regard, this paper argues that due to the dynamic nature of vulnerability over time, the suggestion of actions for risk reduction, especially in the context of FR, should simultaneously incorporate the comprehension of current conditions, including the root causes of vulnerabilities. Findings investigate the social and institutional vulnerabilities according to the perception of stakeholders, including their view of challenges and actions for flood risk



Esri, FAO, NOAA, Esri, HERE, Garmin, METI/NASA, USGS, Esri, HERE, Garmin, FAO, NOAA, USGS, Esri, USGS

FIGURE 1 Geography of Campina Grande—Brazil: (a) location on the semiarid region of Brazil; (b) The location of Campina Grande in Paraiba state and (c) Perimeter highlighting the urban area, neighbourhoods, buildings and flood risk areas according to CPRM.

mitigation (O'Donnell et al., 2017), as well as the risk perception (Lechowska, 2018) and coping capacity (Danso & Addo, 2016) of flood risk communities in the city of Campina Grande, semiarid region of Brazil.

The PLANEJEE Project, named in Portuguese as “PLANEJE Eventos Extremos” (i.e., English translation as “To Plan Extreme Events”), gathered information among residents, policymakers (authorities), and local specialists of the municipality. This article shows how participatory planning can be embedded in the search for risk mitigation solutions in developing countries through this case study. The participatory approach was built with mixed objective and subjective methods, detailed further in this article. The social and institutional contexts are assessed by answering the two research questions:

1. How can social and institutional vulnerabilities in the flood risk context be assessed with stakeholders' collaboration?

2. How do local actors perceive the challenges and solutions for flood risk mitigation?

The article is organised as follows. The case study is presented on Section 2, whilst Section 3 discussed the

conceptual framework, and aspects related to the participatory approach developed in this study. Section 4 shows the analysis of social and institutional contexts with the participation of residents, policymakers, and local specialists, including the discussion of underlying causes of flood risk vulnerabilities. After that, conclusions are presented.

2 | CASE STUDY

Campina Grande is in the Northeast (NE) region of Brazil (Figure 1a), also called as the “semiarid region”. This region encompasses 18% of the national territory, 1262 municipalities (IBGE, 2021), and one-third of the country's population (Lemos et al., 2016). According to the Brazilian Institute of Geography and Statistics (IBGE), the population of Campina Grande is estimated above 400,000 inhabitants (IBGE, 2021). The city is an industrial, technological, and educational centre in Paraiba state, attracting many visitors and residents from surrounding areas (Del Grande et al., 2016).

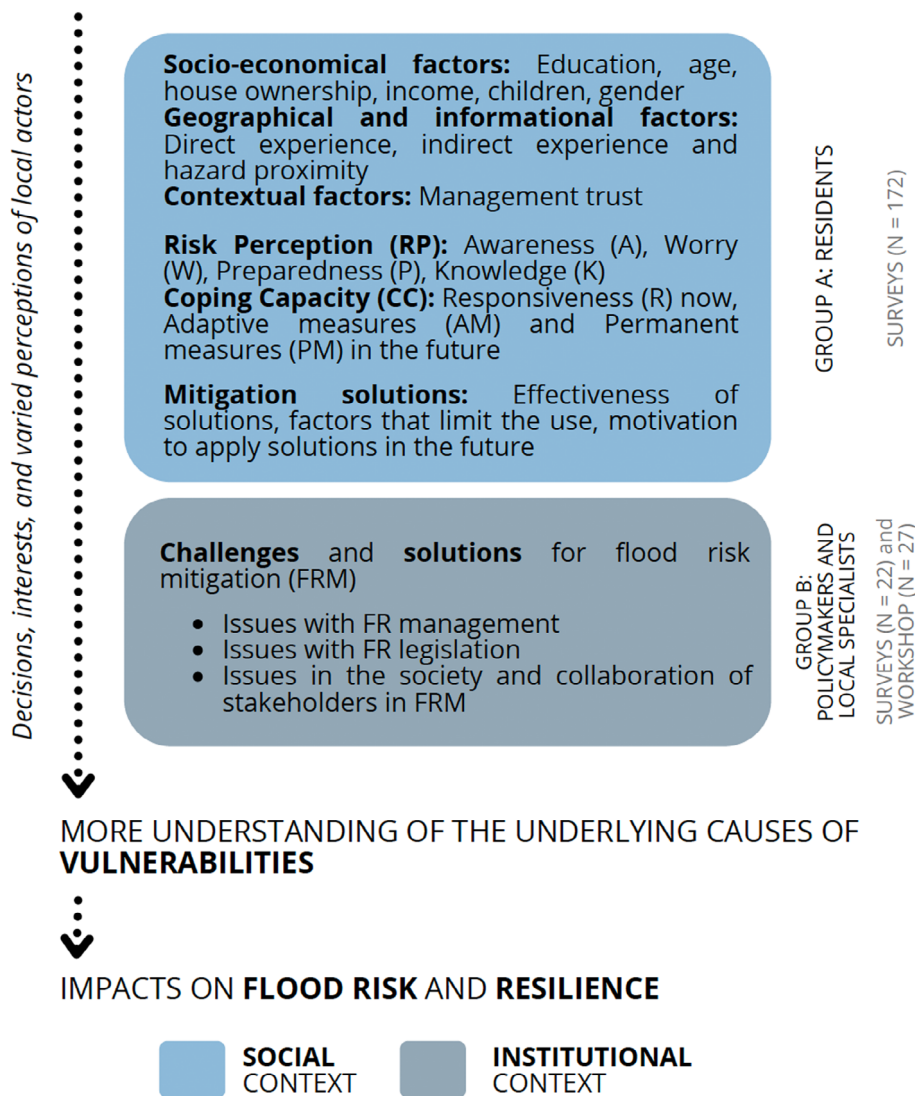


FIGURE 2 The conceptual framework for assessing the social and institutional contexts as the “behaviours and attitudes of local actors” that can influence the generation of vulnerabilities for flood risk mitigation (FRM). Surveys and workshop were used for the participation of groups A and B (i.e., referred to residents, and policymakers (authorities) and local specialists, respectively) during the project PLANEJEEEE in 2019.

Because of the climate of the semiarid region, Campina Grande faces regular periods of water shortage risk (WSR) (Cordão et al., 2020; Rêgo et al., 2017). From 2012 to 2017, the city faced one of the most harmful WSR period of Campina Grande history (Rêgo et al., 2017). However, the city is also susceptible to pluvial flooding risk (Alves et al., 2020). Flood cases are seen in different areas in the city (Figure 1b). Previous studies have been focused on assessing (1) the relation of disordered land occupancy with flood risk (Santos et al., 2017) and (2) impacts generated with the combination of sewage in the drainage infrastructure, creating numerous health impacts in the city (Camelo et al., 2020). Similarly, Campina Grande has management and legislation issues, such as the lack of public participation in water policies, which corroborates to challenges in the institutional context (Miranda, 2017).

3 | METHODOLOGY

3.1 | The conceptualisation of social and institutional vulnerabilities in the context of flood risk (FR)

Definitions of FR, as the relationship between hazard, vulnerability, and exposure (Gouldby & Samuels, 2009; Klijn et al., 2015) and resilience (Cutter et al., 2008) presented in Section 1 were integrated when defining the conceptual framework of the PLANEJEEEE Project, detailed in Figure 2. In essence, Figure 2 shows that understanding the perception of local actors can help comprehend some of the underlying causes of flood risk vulnerabilities (Mondino et al., 2020). As vulnerabilities represent the inherent characteristics of the place and can express themselves in several categories (Cutter

et al., 2008; Alexander & Pescaroli, 2019), they are shown in terms of the institutional and social contexts (Figure 2). The framework shows that understanding the *decisions, interests, and varied perceptions* of local actors (Fernandez, 2021) can facilitate the comprehension about root causes of vulnerabilities, and therefore, can assist in the proposal of actions and solutions for flood risk mitigation (FRM) and resilience (UNDRR, 2019).

The social context of communities in risk is investigated through the concepts of risk perception (RP) and coping capacity (CC) (Figure 2). RP is considered a fundamental factor for understanding the population's responses to hazards, being defined as “an assessment of the probability of a hazard and the probability of the results, most often the negative consequences, perceived by the society” (Lechowska, 2018). For Renn (2004), RP must be seen as a mental or sociopsychological instrument that can enable the prediction of future actions and facilitate the decision of risk reduction solutions. In this study, RP is analysed through the selection of four indicators, which combine the residents' cognitive factors, awareness (A) and worry (W), and behavioural factors, preparedness (P) and knowledge (K), showing how the citizen sees the probability of facing an extreme water event in the future (Figure 2). Whilst RP reflects how individuals and communities perceives risk, the CC is “the ability of people, organisations, and systems, using available skills and resources to manage the adverse conditions of risk or disasters” (UNISDR, 2021). CC represents the citizens' responsiveness (R) to cope with the hazard in the current scenario and the intention to use adaptive (AM) and permanent measures (PM) in the future (Figure 2). The seven indicators of RP and CC were selected through the surveying of indicators used in previous studies (Ajibade & McBean, 2014; Bryan et al., 2019; de Brito et al., 2017; Fuchs et al., 2017; Liu et al., 2018; Marfai et al., 2014; Nguimalet, 2018; Thistlethwaite et al., 2018).

The institutional context is assessed by understanding that it reflects both the context and the process by which governance, formal and informal institutions may be too weak to provide protection against DR (Lassa, 2010). In this regard, more institutional vulnerabilities can indicate the increase of risk, especially when actions and solutions for dealing with the given risk are inadequate, not accepted, or not used by all actors within the territory (Fernandez, 2021). In this study, the institutional vulnerabilities were discussed during the collaboration strategies with stakeholders in the PLANEJEEEE Project, which is described below.

3.2 | The participatory project

The PLANEJEEEE Project developed several engagement strategies with stakeholders, aiming to clarify the *social*

and institutional contexts regarding the flood risk disaster in Campina Grande, Brazil (RQ1). From May to June of 2019, questionnaires were applied with residents, policy-makers (authorities), and local city specialists. Also, informal meetings, a workshop and focus groups were developed with policymakers and local specialists (Figure 2).

Citizens' participation was mainly through door-to-door surveys. First, it is important to highlight that even the city facing FR and WSR, the flood risk was the main goal of the project, and because of this, the location of residents' properties for questionnaire application was based on recurrent flood locations and on the official mapping of flood-prone areas developed by the Geologic Survey of Brazil (CPRM) (Figure 1b) with the support of Civil Defence. A total of 172 residents participated in the project (Figure 3). To investigate the social aspects, questions regarding the socio-economical, geographical, and informational, and contextual questions were included in the questionnaire (Figure 2). Questionnaires were divided into sections to cover RP and CC of residents, as shown in Figure 2. The questions for obtaining the answers of residents for each RP and CC indicator are shown in Table 1, wherein citizens could answer in a scale from “very low” (score 1) to “very high” (score 5) or select the “I don't know” option. Other questions regarding the perception of solutions for FRM were also included. Pearson Correlation, Wilcoxon Z, and Mann Whitney U tests, within the 95% confidence interval were used to statistically analyse the answers with IBM SPSS Statistics 23 software and Python notebooks.

The second part of the PLANEJEEEE Project aimed to investigate the current institutional vulnerabilities of Campina Grande (Figure 2). Initially, informal meetings with policymakers were held to present the project briefly. Later, policymakers and local specialists were invited to participate in a workshop on 18th of June 2019. The invitations were based on their research field (for specialists) or position in the city council (e.g., planning, urban services, engineering, health, education, traffic, GIS, science, and technology), including water companies (AESA—Executive Agency of Water Management and CAGEPA) and their role in the society (e.g., Civil Defence, Municipal Council—CONCIDADE and NGOs). Twenty-seven people attended the workshop. The workshop was developed with the following structure: (1) survey application, (2) general exposition of the PLANEJEEEE Project, (3) the introduction of participants, (4) participants division in four focus groups, (5) the provision of guidance for underlining vulnerabilities, (6) discussion of the main challenges and solutions for water management in the city, (7) presentation of discussions to the bigger group and (8) summary and workshop finalisation.



FIGURE 3 The location for survey implementation with 172 residents of Campina Grande—Brazil. The map highlights four specific flood cases discussed in the focus groups with policymakers and local specialists in the PLANEJEEEE project, referred as I (Conceição), II (Liberdade), III (Jardim Paulistano/Tambor) and IV (Santa Cruz). The location of A, B (Case III), and C, D (Case IV) is shown in the map.

It is important to highlight some details about the engagement strategies. First, the choice of administrating the survey initially aimed to evaluate the answers from stakeholders before the discussions and without any external influence (de Brito et al., 2018). Twenty-two survey answers were collected. Secondly, the division of stakeholders in the focus groups was made to generate a multidisciplinary discussion with a combination of different sectors of the city council and specialists from various

fields. The 27 participants were divided into four focus groups according to the delimitation of flood risk areas by CPRM (Figure 1) and the location of questionnaires applied with residents (Figure 3).

Each focus group had a leader from the PLANEJEEEE team responsible for facilitating and providing guidelines for discussion. Participants received a “baseline” material with maps underlining structural vulnerabilities (i.e., garbage in the street, streets without drainage system)

TABLE 1 Descriptive statistical analyses (mean, SD and CV) for flood risk perception (RP) and coping capacity (CC)

Key indicators	Specific questions	Mean	SD	CV (%)
RP				
Awareness (A)	How do you classify the severity of the floods?	4.4	0.83	18.82
Worry (W)	How likely is flooding going to occur within the next 10 years?	4.3	0.96	22.35
Preparedness or warnings (P)	How likely do you receive warnings before the flooding?	1.7	1.24	73.26
Knowledge (K)	Do you think you can handle flood better with adaptation measures in your home?	4.2	1.35	32.30
CC				
Responsiveness (R, taken adaptive measures)	Which of the following measures would you use in your home to prevent flooding? <i>Elevation of electrical installation, barriers, bombs, sewage valve, and change the elevation of furniture.</i>	1.34	1.23	91.94
Adaptive measures (AM)	Would you make any investment in your home to reduce the risk of flooding?	4.5	1.15	25.40
Permanent measures (PM)	If you had a chance to move home because of flooding, would you?	4.2	1.44	34.08

(IBGE, 2010), physical characteristics (Alves et al., 2018; Tsuyuguchi, 2015) (i.e., elevation, slope, distance to rivers, lakes) and exposure (i.e., population density, number of elders, children) of the study case. Maps with water shortage vulnerabilities (i.e., wells location, rainwater harvesting, and streets with water supply) were also provided because of the dual-disasters context in the city. The mappings were produced with ArcGIS Pro (ESRI), representing the most recent census track information available for the city (IBGE, 2010). Participants were directed to use this information as input to discuss the main challenges and solutions for flood risk mitigation (RQ2).

After the discussions, a representative of each small group was chosen to present the challenges and solutions of the small area (i.e., Cases I to IV of Figure 3) for the bigger group. This was made to enable the other groups to engage with the issues of the entire city. At this point, the groups were able to complement the challenges, actions and solutions of the other groups with their perspectives. Subsequently, the leading researcher of this article presented the overall findings and concluded the workshop. Ten postgraduate and undergraduate Civil Engineering students at the Federal University of Campina Grande (UFCG) assisted in developing the PLANEJEEE Project. Ethical clearance was obtained through the University of Exeter, and an online pilot survey was applied from March to May 2019 with 48 participants.

4 | RESULTS AND DISCUSSIONS

Results and discussions are shown with the analysis of answers obtained in the PLANEJEEE Project. Initially,

the “challenges” for FRM are discussed, aiming to clarify the vulnerabilities in the social and institutional contexts. After that, the “future actions” for FRM are discussed based on findings presented in the PLANEJEEE workshop.

4.1 | The challenges faced in the social context

Table 1 presents the summary of the results of RP and CC. The “awareness” and “worry” indicators had very similar results, which indicate that the citizens classify the severity of past flooding events from “high” to “very high” (Mean—M 4.4) and strongly expect the occurrence of other flooding cases in the next 10 years (M 4.3). The consistency (SD) and variation of response (CV) of these two indicators show that residents overall agree in the high-very high severity of floods and that they will probably face another event in the following years (Table 1). The two indicators are fundamental in the risk perception analysis since they indicate how residents’ experiences with the flood risk events are now and their concern for events in the future.

When asking about how likely they receive warnings before flood risk occurrence, the “preparedness” indicator, their answers show that overall, the residents do not receive many warnings (M 1.7). We asked the same question for specialists and policymakers (group B). The majority answered the residents do not have the necessary risk information (14.3% scored 1, and 47.6% scored 2) with M 2.43 and SD 0.98. Some of the residents (group A) also stated, in a further question, that the only

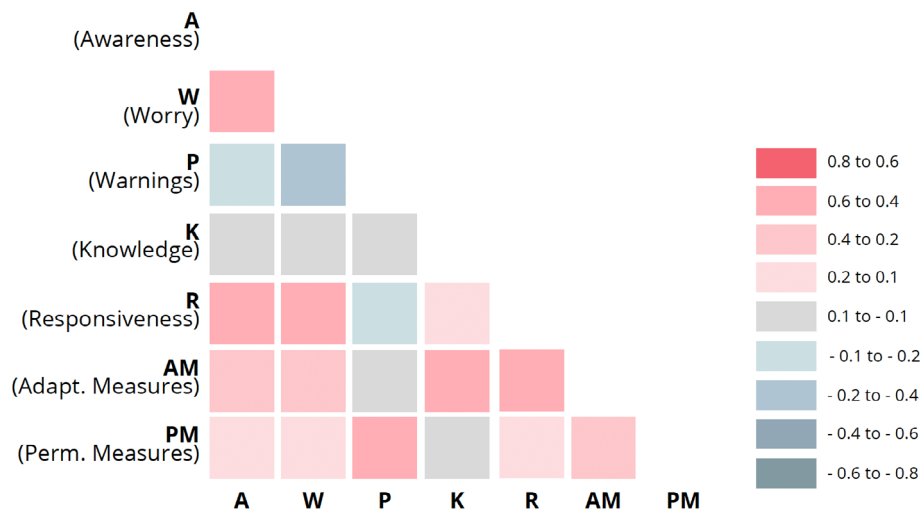


FIGURE 4 Pearson correlations between risk perception (RP) and coping capacity (CC) indicators. “A” refers to awareness, “W” to worry, “P” to preparedness or warnings, “K” to knowledge, “R” to responsiveness, “AM” to adaptation measures, and “PM” permanent measures. Pearson correlations were calculated with python notebooks.

warning they have of the flooding is the rainfall itself (quoting Resident A):

Resident A: “When I realise that it is strong rainfall, I know it (the household) will be flooded.”

In comparison to the “knowledge” indicator, which asked if residents believe that they can handle flood better with adaptation measures in their homes, overall, the respondents affirmed to believe (M 4.2). However, there was less consistency and more variation in the answers, which can indicate different opinions among respondents (Table 1). The knowledge indicator had the objective to analyse their confidence for applying solutions, but not if solutions were already applied. To further analyse if residents had any solution in their households, the CC was evaluated.

Residents were asked what measures they have in place to avoid flooding (i.e., referred to “R, responsiveness”), and their intentions to apply adaptive and permanent measures in the future (i.e., referred to “AM, adapt. future” and “PM, perm. future” in Table 1). “Responsiveness” was analysed by providing five options of solutions recurrent in Brazil (i.e., the elevation of electrical installation, barriers, water pumps, sewage valve, change the height of furniture, Table 1). Residents could select up to the five options provided or include other solutions later in the questionnaire. In this sense, the mean value of this question represents the average number of solutions used in the properties. Results show the mean of 1.34 for taken measures, which indicates that the residents do not have many measures to avoid flooding in place. In this regard, the most common solution seen in the properties was flood barrier, as shown in Figure 3. Residents were also asked what factors limit the application of measures for flooding mitigation in their properties. “Money constraint” received one of the highest scores with M 4.5 and SD 0.72. According to Table 1, the responses for AM and

PM in the future had similar results with a high mean (M) from 4.5 to 4.2, respectively. Those answers indicate that although residents are open to applying adaptive and permanent measures in the future, many do not have measures in place.

Moreover, the Pearson correlation was analysed to understand the correlations between RP and CC indicators. Figure 4 presents the graphical correlations of RP and CC indicators expressing the positive (pink), negative (blue) or non-significant (grey) relationships. As seen, most of the relationships are positive; for example, responsiveness (“adaptation measures taken”) is positively related to “awareness” and “worry”, which indicates that the residents who have more solutions in place are more aware of flood severity and concerned with future flooding events. Likewise, the correlation of “worry” and “awareness” shows that more worried citizens classified the past flood events as more severe. Adaptation and permanent measures in the future are positively related to almost all key indicators. The negative correlations are mainly related to warning (P) indicator. Pearson correlation shows that even though residents do not receive many warnings (P), they still have “adaptation measures in place” (R), indicating that residents apply some solutions to mitigate flood damages even with the lack of warnings from the authorities before the event. The directions of each influence are detailed in Table 2.

The second phase of the influence analysis evaluated relations of social factors of residents (Figure 1) with RP and CC indicators (Table 1), where p values <0.05 are considered as significant. The results in Table 2 indicate that awareness was influenced by direct (M 4.35 p 0.00) and indirect experiences (M 2.7 p 0.00). Residents with direct experiences of floods (i.e., inside their properties or streets) have higher awareness. Still, indirect experiences (i.e., passing through a flooded street when going to

TABLE 2 Final influencing factors of risk perception (RP) and coping capacity (CC)

Key indicator		Social factor with significant influence	<i>p</i> value	Direction of influence in RP and CC (+,–)	
RP	Awareness (A)	Direct experience	0.000	Worry (+)	
		Indirect experience	0.000	Preparedness (–)	
		House ownership	0.028	Responsiveness (+)	
		Hazard proximity	0.037	Adapt. Future (+) Perm. Future (+)	
	Worry (W)	Indirect experience	0.001	Awareness (+)	
		Hazard proximity	0.042	Preparedness (–) Responsiveness (+) Adapt. Future (+) Perm. Future (+)	
		–	<i>Non-significant</i>	Awareness (+) Worry (+) Responsiveness (–) Perm. Future (+)	
		–	<i>Non-significant</i>	Responsiveness (–) Adapt. Future (+)	
	CC	Responsiveness (R, taken adaptive measures)	House ownership	0.003	Awareness (+)
			Age	0.009	Worry (+)
Direct experience			0.000	Preparedness (–) Knowledge (+) Adapt. Future (+) Perm. Future (+)	
Management trust			0.010	Awareness (+) Worry (+) Knowledge (+) Responsiveness (+) Perm. Future (+)	
Adaptive measures (AM)		–	<i>Non-significant</i>	Awareness (+) Worry (+) Knowledge (+) Responsiveness (+) Perm. Future (+)	
		–	<i>Non-significant</i>	Awareness (+) Worry (+) Preparedness (+) Responsiveness (+) Adapt. Future (+)	
		–	<i>Non-significant</i>	Awareness (+) Worry (+) Preparedness (+) Responsiveness (+) Adapt. Future (+)	
		–	<i>Non-significant</i>	Awareness (+) Worry (+) Preparedness (+) Responsiveness (+) Adapt. Future (+)	
Permanent measures (PM)		Education	0.022	Awareness (+) Worry (+) Preparedness (+) Responsiveness (+) Adapt. Future (+)	

Note: Results significant at the $p < 0.05$ level; (+) indicates positive correlation and (–) indicates negative correlation. “*p* value” was calculated with Wilcoxon Z and Mann Whitney U tests, and Pearson correlation was used to evaluate the influence between RP and CC indicators.

work) also influence the awareness factor. This is particularly important because of the positive Pearson correlation where more aware and worried residents have more adaptation measures in place and aim to apply in the future (Figure 4 and Table 2). Other aspects related to geographical and contextual/cultural factors, such as living near the hazard (M 4.30 p 0.04) and owning the property (M 4.35 p 0.03), also influence awareness. Respondents are more aware when they live in a risk

area and own the property, indicating more responsiveness to avoid flooding. The worry indicator also influenced “hazard proximity” (M 4.15 p 0.04) and “indirect experience” (M 3.69 p 0.00) factors. According to the Wilcoxon Z and Mann Whitney U tests, neither preparedness nor knowledge indicators received any substantial influence of social factors (Table 2).

For coping capacity, the adaptation measures taken are influenced by house ownership (p 0.003), age

TABLE 3 Multiple challenges and actions/solutions suggested by stakeholders for flood risk mitigation (FRM) in Campina Grande, Brazil

Scales	Microscale	Challenges	Actions/solutions
Management	Location	Buildings located in risk areas ^{a,b,b+}	Relocate people from risk areas ^{a,b,b+} Map flood-prone vulnerable areas ^{b+}
		Illegal properties in the flood risk areas ^{b+}	Create parks in flood risk regions to avoid urbanisation in the areas ^{b+}
		Buildings near to channels ^{b+}	Develop strategies regarding the social context ^{b+}
		Low income of residents ^{a,b,b+}	
	Maintenance	Lack of inspection by authorities ^{b+}	Clearer maintenance and adoption arrangements ^{a,b}
		Increase of urbanisation ^{a,b}	Effectively plan areas for urban growth in the city ^{b+}
		Problems with design and maintenance of drainage network ^{a,b,b+}	
Government	Lack of interest of government ^b	Increase perception at developer and community level ^{a,b,b+}	
Legislation	Legislation implementation	Comply of legislation ^{a,b+}	Comply of legislation ^{a,b,b+}
		Uncertainty of legislation application ^{b+}	Engagement with stakeholders ^{b+}
	Legislation improvement	Lack of monetary incentives ^{b+}	Development of mandatory standards ^{b,b+}
		Lack of space in legislation ^b	Strengthen the Master Plan ^{b+}
		Lack of funds/budget ^b	Ensure a participatory planning ^{b+} Proposal of mitigation measures in context with other hazards ^{a,b,b+}
Society and collaboration	Risk perception and coping capacity of citizens	Lack of knowledge and awareness of the population ^{a,b,b+}	Improve communication with residents ^{a,b,b+}
		Low flexibility of population ^{a,b+}	Raise perception and coping capacity ^{a,b,b+}
		The social link between residents and the place ^{a,b+}	Promote educational actions with residents ^{b+}
	Engagement and communication of stakeholders	Lack of appropriate risk communication ^{a,b,b+}	Promote a “shared responsibility” campaign in the city council sectors and residents ^{b+}
		Lack of public participation ^{b+}	Promote “capacity-building” for stakeholders ^{b+}
		Lack of communication between stakeholders ^{b,b+}	Promote collaboration between stakeholders ^{b+}

Note: 199 stakeholders were involved in the project PLANEJEEEE. Challenges and solutions discussed in the PLANEJEEEE Project: ^aSurvey for group A (citizens), ^bSurvey for group B (policymakers and local specialists), ^{b+}Workshop and focus groups.

(p 0.009), and direct experience (p 0.000) factors. Answers from all social groups had low mean values for adaptive measures taken (M. 1.34), even the residents with direct experiences. This was clearly seen at the PLANEJEEEE Project because only a few residents had flood barriers or altered the height of electrical fixtures on walls (Figure 3). Residents who own the property have more

adaptation measures (M 1.12) than people that rent the place (M 0.79). Although this conclusion may seem logical, this result is not always evaluated since it depends directly on the residents that will be interviewed (Liu et al., 2018).

Similarly, age appeared to be an essential variable, where the respondents younger than 25 have more

measures applied (M 1.73). To implement solutions in the future, people with less trust in management have fewer plans to use adaptive measures in the future ($p < 0.01$), and literate residents are more willing to take permanent measures (M 4.23 $p < 0.02$). Socio-economic factors, such as income, children, and gender, have not significantly influenced the risk perception and coping capacity indicators. In summary, the responses related to geographical factors (i.e., direct, and indirect experience and hazard proximity), contextual factors (i.e., management trust) and socio-economic factors (i.e., house ownership, age, and education) substantially influenced risk perception and coping capacity (Table 2).

4.2 | The challenges faced in the institutional context

To fully comprehend how institutional vulnerabilities affect flooding risk mitigation, understanding the mitigation policy as an integral part of a broader development context is necessary (Cinner et al., 2018). In this section, discussions of groups A and B were divided into multiple challenges, distributed into key elements such as into management, legislation, society, and collaboration (Table 3).

The main discussions of group B highlighted the challenges related to the “*location*” of properties. Location was also pointed in the risk perception and coping capacity analysis, in which people who live in or near risk areas are more exposed to the hazards and have more awareness and worry (Table 3). Many of these properties are illegal, where the residents build or take ownership regardless of the area where it is located or the necessary legislation to properly construct. Part of these occupations refers to informal substandard occupations, mainly known as “*favelas*” or “*slum areas*”, very typical regions within Brazilian municipalities (Fix & Arantes, 2021). Group B also highlighted the proximity of properties to the drainage channels also corroborates for the severe flooding cases.

Groups A and B suggested the “*social link between the residents and the place they live*” as one of the city’s challenges for flood risk mitigation. When the residents were asked if their households are in a flood risk area, 65% answered “yes,” and 22% answered “I don’t know”. To the respondents who confirmed, we asked the reasons they live in the area and the options “*I don’t have money to move*”, “*I don’t have anywhere else to go*” and “*I got used to the situation*”, were mainly selected with 27.1%, 25.2%, and 24.3% respectively. Residents also affirmed they live in the area because “*the flooding does not reach inside my property*”, suggesting fewer damages in their

houses. Other residents expressed to be financially and emotionally attached to the place where they live. This can be viewed in the answers from the residents B and C:

Resident B: “*I own this house; we like here, and my friends and family are here.*”

Resident C: “*Here I have my family, but I live in a place that I can’t sleep in peace anymore.*”

Groups A and B suggested to “*relocate these communities at risk*” (Table 3). Still, there is a the challenge of mapping areas where the citizens will be safer from flooding, and also the challenge of providing the appropriate investment to make the citizens feel part of the area where they will live. At the same time, group B also suggested that solutions are not always beneficial for all population groups in the same way or to the same degree, which can intensify current inequalities. Concerns about the appropriate manner to relocate flood-vulnerable communities are discussed in other studies, affirming that rebuilding infrastructure can make vulnerable people even more vulnerable (Cinner et al., 2018). Similarly, other studies highlight “*environmental justice*” and “*equity*” as a sensitive topic that can positively or negatively influence the current social conditions (Hendricks & Van Zandt, 2021), vulnerabilities (Vercruyssen et al., 2019) and exposure (Weis et al., 2016). Hence, attention should be directed to the location (Eckart et al., 2017) and to the dynamic character of vulnerability, which could make actions in one location or at one scale undermine the efforts of other locations, people, and scales (Cinner et al., 2018).

Group B demonstrated concerns about the uncertainty of legislation application, arguing that *legislation* is not clear (Table 3). When asked about the critical challenges for applying mitigation strategies in management, the “*lack of space to apply mitigation strategies in policies*” was selected with 27.3% of the votes. Besides, stakeholders believed that if the legislation in place were applied, the number of flood risk issues would be smaller (Table 3). The key reasons for not implementing mitigation strategies when they are already predicted in the legislation were mainly “*costs/budget*”, “*lack of awareness*” and “*lack of interest from local governments*”. Other reasons like “*lack of understanding of what it is*”, “*costs*” and “*maintenance*” were suggested for when the strategies are not yet in the legislation. In the focus groups, group B also emphasised challenges related to the “*weak inspection*” by authorities as well as problems with the “*design and maintenance of drainage structures.*”

Finally, the improvement of “*stakeholders’ collaboration*” was expressly mentioned as a current challenge for FRM by groups A and B. Participation and cooperation are critical aspects of bridging the gap between science and policy (de Brito et al., 2018). Engaging with local

actors in management is considered essential to (i) defining risk mitigation actions and reducing *maladaptation* (i.e., or “bad” adaptation [Schipper, 2020; Schipper et al., 2021]), (ii) to encouraging the adoption of actions by communities (Cheung & Feldman, 2019), and (iii) to improving the RP and CC of residents in the future (Danso & Addo, 2016; Fuchs et al., 2017). In this regard, citizens affirmed they would be keener to participate in management, not only with monetary incentives (M 3.89 SD 1.80) but also if they knew their contribution “was going to be listened” (M 4.41 SD 0.68) and “used in real-management” (M 4.44 SD 0.72).

4.3 | The proposal of solutions for flood risk mitigation

As the Project PLANEJEE also aimed to understand how the stakeholders identify actions for FRM in the city, Table 3 summarise the suggestions of stakeholders A and B for flood risk mitigation. At this section, an overview of the solutions proposed to the cases I to IV (Figure 3) is discussed.

The discussions of actions for “Conceição” (I) and “Santa Cruz” (IV) study cases (Figure 3) focused on the improvement of conditions in official risk areas (i.e., many times seen as “favelas”). Group B highlighted the need for “transforming the place” with sustainable solutions, such as SUDS (Sustainable Drainage Systems), Nature-Based Solutions (NBS) and Green Infrastructure (GI). This reflection was very important for analysing further actions since sustainable solutions are widely recommended in guidelines and legislations throughout the world, but their adoption in developing countries is still low (Almoradie et al., 2020; Ronchi & Arcidiacono, 2018). To understand stakeholders’ perception of flood risk mitigation strategies, a list of solutions was provided to groups A and B. The highest efficiencies in this question were for management actions, such as maintenance of existing measures (M 4.47^a and M 4.33^b) and improvement of awareness and preparedness of citizens (M 4.47^a and M 4.52^b). Both groups scored green solutions with the lowest effectiveness, especially to green roofs (M 2.99^a and M 3.30^b). The mixed perceived effectiveness of the solutions showed that even though groups A and B identified NBS as actions to be implemented in Campina Grande, they still consider these strategies as the least effective when compared with the other options.

The discussions of group B made clear the expectation of obtaining *primary* (i.e., flood reduction) and *secondary* benefits (i.e. heat reduction, wellbeing, access to nature) with actions and solutions for FRM. This is also shown in

other studies, from which, O’Donnell et al. (2017), for example, recommends the promotion of “sustainable solutions” as strategies that can meet numerous policy and strategic objectives of different organisations and departments, in addition to providing benefits beyond the flood risk reduction. Others consider that NBS and GI can assist in reducing vulnerabilities of areas facing risk (Dagenais et al., 2016), as well as it can bring new social services that reduce the possibilities of citizens reoccupying the location and produce more spatial equity (Heckert & Rosan, 2018).

Suggestions were also proposed with regards to the multiple water-related hazards context in the area. The cases of “Liberdade” (II), “Jardim Paulistano/Tambor” (III) and “Santa Cruz” (IV) (Figure 3) considered the implementation of solutions that enabled to achieve benefits for both the water-related hazards. Rainwater harvesting (RWH) was suggested in cases I to IV since the city also faces water shortage risk (Cordão et al., 2020; Del Grande et al., 2016). This topic appears to have great importance for Brazil and other countries with opposite but simultaneous water-related hazards, such as flood and water shortage. In Brazil, drought and flood disasters have severely affected the country in recent decades (Ávila et al., 2016; Lorentz et al., 2016; Marengo et al., 2009). When evaluating stormwater and sewage infrastructure, studies show the inadequacy in terms of basic services (Ultramari, 2013) and infrastructures in the country (Tavares et al., 2018). In 2016, a study from the National System of Sanitation Information of Brazil (SNS) found that 51.9% of the Brazilian population did not have access to appropriate sewage treatment, and the maintenance of network systems is considered of the great challenges for FRM in the country (BRASIL, 2020). The structural, social, and economic vulnerabilities impact directly flood and water shortage mitigation, since the people with the lowest socioeconomic status can be the most vulnerable and live in the areas most at risk. During the PLANEJEE Project, groups A and B also highlighted the need to considering the relationship between the causations behind structural, social and economic vulnerability. For the stakeholders, delineating actions for FRM needs to occur in parallel to the understanding of flood risk causations and vulnerabilities (Table 3).

The complete list of FRM actions and solutions proposed by groups A and B is given in Table 3. In summary, the discussions of the PLANEJEE Project showed a need to propose FRM actions within an urban planning approach, addressing multiple goals and benefits, while adopting adequate governance to tackle issues at city-scale (Table 3). Discussions recognise how actions and solutions towards risk mitigation must be incorporated

within a sustainable urban management, linking vulnerabilities, adaptability, inequalities, equity and risk. Finally, nonstructural actions, such as educational and communication strategies were suggested, especially the encouragement of “*shared-responsibility*”, development of “*educational campaigns*” with citizens, and the improvement of “*collaborative management*.” FRM actions include increasing the knowledge about strategies, especially the green solutions, at the developer and community levels, as an attempt to increase the uptake of mitigation strategies. Besides this, according to group B, the implementation of FRM actions is the result of a collective decision, in which the individuals and communities (34%), management companies (14%) and local authorities (46%) are responsible for.

5 | CONCLUSIONS AND RECOMMENDATIONS

The main objectives of this study were to present how social and institutional vulnerabilities could be integrated into the analysis of flood risk mitigation with a participatory approach (RQ1) and the analysis of how the stakeholders see the main challenges and solutions for flood risk mitigation (RQ2). The objectives were answered with the formulation of a participatory approach in Campina Grande—Brazil, which aimed to provide insights into the underlying causes of flood vulnerabilities, especially looking into social and institutional contexts that may generate vulnerabilities and worsen flood risk impacts and resilience (Figure 2).

The analysis of social vulnerabilities was made through RP and CC, which showed that residents faced severe previous flood risk events in the past (“A”, M 4.4) and have concerns about the future floods (“W”, M 4.3 of Table 2). Other social challenges were seen since residents affirmed to receive inappropriate warnings before the flood (“P”, M 1.7) and only have a few measures in place for reducing flood risk impacts (“R”, M 1.34). When asked about solutions, they agree that solutions in their households can mitigate the impacts from the flood event (“K”, M 4.2), and that they plan to make investments in their properties to reduce flood risk (“AM”, M 4.5). Also, residents would move to another least flood-risk area if they had opportunity (“PM”, M 4.2).

Results have shown that social factors seemed to affect each RP and CC indicator differently (Table 2). The geographical and informational factors (i.e., direct, and indirect experience and hazard proximity) were correlated with “A”, “W”, “R” (Table 2). Socio-economic and geographical factors, especially age, house ownership, and direct experience, influenced the adaptive measures

taken, in which young people, house owners, and people with previous cases of flooding inside their properties had more solutions applied. Contextual factors, such as management trust, influenced the knowledge indicator whereas the socio-economical factor (education) influenced the decision to move house permanently (Table 2). Future research will investigate how these social factors can be incorporated for improving the conditions of people at risk of flooding. Additionally, since the city faces flood and water shortage risks, the evaluation of RP and CC of residents towards the two water-related disasters should be assessed to propose collective actions that can benefit society towards the compound risks, as suggested in the participatory approach.

Through the investigation of institutional vulnerabilities, insights of reasons for the failure of the flooding risk management are provided, such as the issues with maintenance of current infrastructures, lack of interest of the government to mitigate FR, the number of properties located in risk areas, or near to channels, the lack of mappings of either vulnerability or flood-prone areas. For the legislation, stakeholders suggested the lack of clarity of current laws, the lack of reduced monetary incentives, and the lack of appropriate risk communication and collaboration with residents as the main challenges (Table 3). In this regard, stakeholders suggested multiple actions for FRM, which were discussed according to management, legislation, society, and collaboration. When looking specifically into the use of sustainable solutions for FRM, stakeholders appear to aspirate their implementation in the future; however, results show they still consider management and structural strategies as more effective.

In summary, the results presented in this article enabled to discuss how stakeholders can be involved for understanding social and institutional vulnerabilities in the context of flood risk mitigation. The discussions provided in this article provide insights for the dialogue about actions to FRM in the city of Campina Grande (Brazil), but we consider these findings can assist to similar studies in other cities. For this, it is suggested to advance the integration of stakeholders in FRM research, with the inclusion of other participatory techniques, such as the evaluation of which physical and structural factors corroborate more with flood risk and vulnerabilities (de Brito et al., 2018), the inclusion of web and phone applications for engaging with communities at risk (Del Grande et al., 2016), and enabling the development of collaborative mappings for identifying flood risk susceptible and vulnerable areas (Hardoy et al., 2019; Verweij et al., 2020).

Lastly, this article underlines the need for tackling actions for FRM beyond the delineation of hazard-prone

areas, and the characteristics of technical solutions. In fact, results of the participatory approach shows how the understanding of the specificities of the place and current vulnerabilities are linked to the current challenges and should be systematically analysed for proposing actions with FRM in the future.


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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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