PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 22 ISSUE 5 (2024), Page 209 – 223

FLOOD VULNERABILITY IN JAKARTA COASTAL SETTLEMENT: A STUDY AT KALIBARU SUBDISTRICT, NORTH JAKARTA, INDONESIA

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Abstract

The efforts to alleviate slum settlement in the coastal areas of Jakarta are required to consider the sustainability of flood disaster protection measures. This is essential for reducing vulnerability issues, particularly in Kalibaru Subdistrict with the highest flood risk. The vulnerability issues refer to aspects of community exposure level, sensitivity, and adaptive capacity as main indicators of coastal areas due to climate change. Therefore, this study aimed to analyze the vulnerability of slum settlement in coastal area of Kalibaru Subdistrict, North Jakarta. A quantitative method was used to measure vulnerability level of settlements to flood using statistical and scoring analysis. The results showed that vulnerability level of settlement to floods was within the moderate category. The adaptive capacity serving as a significant element, was influenced by collective actions, cooperation, and mutual assistance in addressing disaster threats. This showed the need to optimize both physical and non-physical aspects of slum settlement eradication interventions.

Keywords: Flood Vulnerability, Coastal Settlement, North Jakarta

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INTRODUCTION

Coastal settlement is the most vulnerable area to flood risks due to the dynamics of anthropogenic activities causing an increase in sea levels on temporal and spatial scales (Glavovic et al., 2022). In a socio-ecological system, the interaction between humans and their environment forms local capital, determining the vulnerability to flood (Yuliastuti et al., 2023). Flood vulnerability is considered significant for community of slum settlement due to limited access to infrastructure and social protection (Adegun, 2023; Pu et al., 2024). According to UN-Habitat (2018), slum settlement is an inadequate housing area consisting of dwellings made of low-quality materials and lacking proper infrastructure.

A total of 40% of the area in Jakarta is below sea level, particularly in North Jakarta, which directly borders the sea (World Bank, 2011), causing high vulnerability to flood. Generally, Jakarta is located on a low, flat alluvial plain with 13 rivers that cause major flood during heavy rains (World Bank, 2011). The condition of coastal settlement is influenced by land subsidence and high poverty rates (Bott et al., 2021; World Bank, 2011). Based on the Regulation of the Governor of DKI Jakarta Province Number 90 of 2018 concerning the Improvement of Settlement Quality in the Framework of Integrated Area Arrangement, North Jakarta has 80 slum RWs that need to be improved to enhance the quality of settlements. The slum upgrading includes fostering the environment physical, social, cultural, and economic aspects to meet the need for decent housing and reduce vulnerability.

In the Medium-Term Regional Development Plan of DKI Jakarta for 2017-2022, nine priority RWs (neighborhood units) have been identified for intervention. Among the priority RWs, six are located in Kalibaru Subdistrict, which is predicted to face a high risk of flood by 2040 (Rahayu et al., 2020). Therefore, slum upgrading aims to enhance access to urban infrastructure and improve flood hazard anticipation. The anticipated redevelopment of slum areas, with consideration of flood risks, is expected to enhance community resilience significantly.

Based on the description, this study aimed to analyze vulnerability of coastal slum settlement to flood after upgrading. Previous reports have shown the relationship between flood vulnerability in slum settlement and disaster aspects, focusing on increasing adaptive capacity through social resilience (Parvin et al., 2023; Yeboah et al., 2021) as well as enhancing infrastructure and local community sensitivity (Elghazouly et al., 2024; Yu et al., 2016). Moreover, this study examined vulnerability of coastal settlements to flood through three components, namely exposure, sensitivity, and adaptive capacity. The results were expected to fill the literature gap and serve as a reference in implementing efforts to improve the quality of settlement in coastal slum upgrading to mitigate flood vulnerability.

LITERATURE REVIEW

Vulnerability is perceived as the integration between physical events and the characteristics of the population, leading to risk exposure and limitations in community capacity to respond to threats (Dolan, 2004; Yahia Meddah et al., 2023). Previous studies have shown that vulnerability of coastal areas due to climate change refers to three leading indicators, namely disaster exposure, sensitivity, and adaptive capacity (Borbor-Cordova et al., 2020; Mondal et al., 2020; Astuti et al., 2021; Sarker, 2022; Meddah et al., 2023). These indicators represent the interdependent relationship between community and the surrounding elements, including environmental, social, and economic aspects that affect vulnerability level of coastal areas to flood disasters (Salata & Yiannakou, 2020)

Exposure comprises external pressures, including the characteristics of flood disasters, such as frequency, depth, and duration (Babanawo et al., 2022). Sensitivity is defined as the internal conditions of a system that influence vulnerability, including the socio-economic conditions of community and the physical conditions of the environment (Borbor-Cordova et al., 2020). The socio-economic components of sensitivity include the number of family members (Atiglo et al., 2022; Babanawo et al., 2022) and income levels (Astuti et al., 2021; Owusu & Nursey-Bray, 2019). Meanwhile, the physical environmental components include infrastructure and access to essential services (Bernard et al., 2022; Borbor-Cordova et al., 2020). Adaptive capacity shows the resilience or ability of community to prepare for, avoid, and recover from disaster risks (Dolan, 2004). Table 1 shows the 14 indicators for assessing flood vulnerability in coastal slum settlement.

Table 1: Flood Vulnerability Indicators

Indicator	Description	Sources
Exposure		
Flood Frequency (FB)	The frequency of flood experienced by the community in the past year	(Anh et al., 2018; Borbor-Cordova et al., 2020; Damte et al., 2023)
Flood Dept (KLB)	The depth of flood is measured from the ground surface to the water surface. Greater flood depth correlates with higher levels of damage.	(Anh et al., 2018; Babanawo et al., 2022; Hadipour et al., 2020)
Flood Duration (DRB)	The time they are required for floodwaters to recede. Longer flood duration correlates with higher levels of damage.	(Anh et al., 2018; Babanawo et al., 2022)
Sensitivity		
Number of Family Members (JAK)	Larger family size correlates with higher vulnerability	(Atiglo et al., 2022; Babanawo et al., 2022).
Household Income (TPD)	Lower monthly household income correlates with higher vulnerability	(Astuti et al., 2021; Owusu & Nursey-Bray, 2019)

Indicator	Description	Sources
Clean Water Access (KAB)	Access to safe water sources free from pollutants	(Astuti et al., 2021; Linh & Huan, 2022)
Sanitation (STS)	Access to adequate sanitation facilities	(Bernard et al., 2022)
Drainage Network (KLD)	Limitations and poor quality of drainage infrastructure that can cause flood	(Owusu & Nursey-Bray, 2019)
Waste Management (FPSH)	Access to waste collection services	(Adegun, 2023; Borbor-Cordova et al., 2020)
Adaptive capacity		
Education (TPT)	Higher education correlates with a better understanding of flood risks and improved flood mitigation and adaptation efforts.	(Hadipour et al., 2020)
Information Media (MI)	The availability of information media can provide opportunities for preparedness, early warning, and emergency information.	(Babanawo et al., 2022; Owusu & Nursey-Bray, 2019).
Family Cooperation (KJK)	Mutual assistance among family members for better flood mitigation and adaptation efforts	(Sadeka et al., 2020; Tammar et al., 2020)
Gotong royong (GTR) and Neighbor Cooperation (KJT)	Mutual assistance among community members for better flood mitigation and adaptation efforts	(Pazhuhan et al., 2023; Sadeka et al., 2020; Tammar et al., 2020)
Outreach Activities (PKPE)	Activities aimed at increasing community capacity to deal with disasters, thereby enhancing environmental awareness and preparedness for flood	(Astuti et al., 2021; Yahia Meddah et al., 2023).

Source: Literature review

STUDY METHODOLOGY

Study Area

Study area was Kalibaru Subdistrict, Cilincing District, North Jakarta City, DKI Jakarta Province. Kalibaru Subdistrict is recognized for distinctive topography, which is situated below sea level. The predominant cause of flood in this area is the occurrence of high-intensity rainfall. After the completion of the coastal embankment as part of the National Capital Integrated Coastal Development (NCICD) project in 2018, there has been a significant reduction in the incidence of tidal flood. Based on settlement conditions, Kalibaru Subdistrict is among the 10 subdistricts with the highest number of slum RWs that are vulnerable to pluvial and coastal flood risks (BPS, 2017; Rahayu et al., 2020). This subdistrict comprises 15 RWs, with one RW being uninhabited and managed by a business entity engaged in port and logistics services.

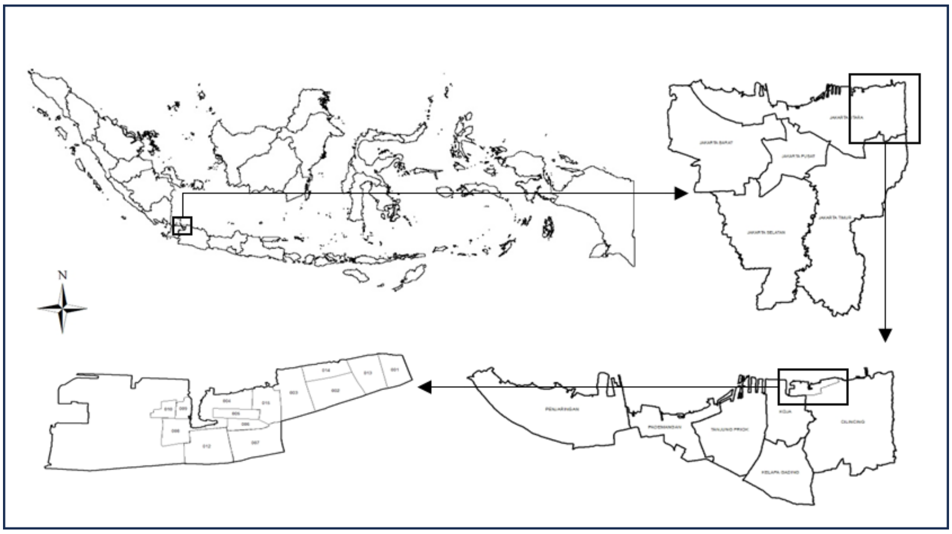

Figure 1: Location of Study Area

Data Resources
This used a quantitative method with a mixed-methods methodology. Data were collected through questionnaires and interviews with community leaders between March-April 2024. The study included 208 respondents selected through purposive sampling. The respondents were either the household head or their designated representatives residing within the Kalibaru Subdistrict, specifically sourced from six RWs identified as priority areas for slum upgrading initiatives. These RWs include RW 1, RW 6, RW 7, RW 10, RW 12, and RW 13.

Analysis Method
Data analysis was conducted using Structural Equation Modeling (SEM) and the scoring method. In SEM analysis, flood vulnerability indicators and the three dimensions were validated using second-order Confirmatory Factor Analysis (CFA). The model developed in this study was reflective (Figure 1), indicating a causal relationship between the indicators and their dimension variables (Kurniawan et al., 2018). The CFA method used two testing models, namely the measurement and the structural.

The measurement model was tested to identify the validity and reliability of variables and their indicators. Several criteria in the model included (1) The Cronbach's alpha value must be greater than 0.7 to measure internal reliability consistency, (2) The composite reliability (CR) value, where a higher value indicates more excellent reliability (Hair et al., 2019). However, a CR value between 0.6 and 0.7 could be acceptable, and values between 0.7 and 0.9 were considered good, while those greater than 0.90 indicated redundancy (Hair et al., 2022). (3) The average variance extracted (AVE) value should be greater than 0.5

(Hair et al., 2022). (4) The outer loading value must be above 0.7 to show the correlation of indicators representing the dimension (Hair et al., 2019). However, in exploratory studies, values between 0.5 and 0.6 are considered sufficient (Kurniawan et al., 2018).

Testing the structural model to assess the significance of the relationships between variables refers to (1) The coefficient of determination (Adjusted R square), where a higher R square value indicates a better model. (2) Goodness of Fit (GoF), which is obtained through the square root of the product of AVE and R square. The GoF is considered good when it exceeds 0.38. (3) The T-statistic must be greater than 1.96, and (4) the Significance (p-value) must be less than 0.05.

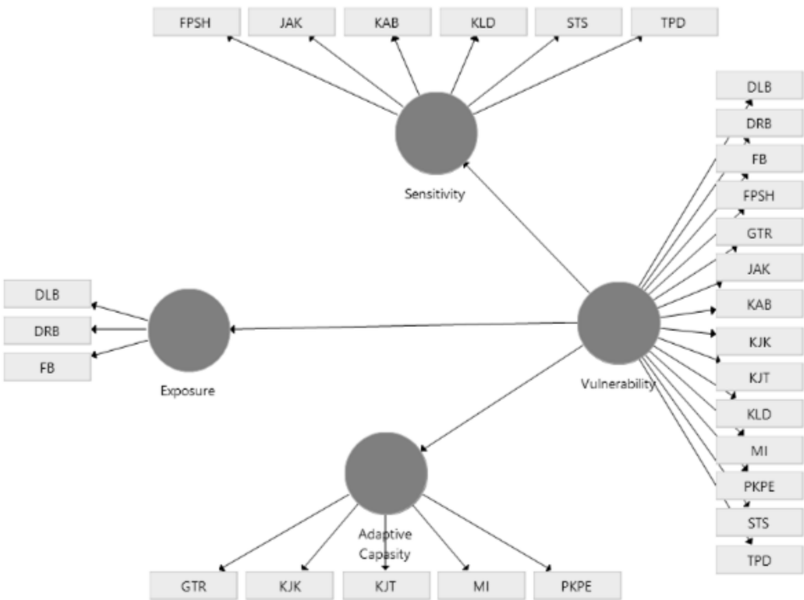

Figure 2: Model Structure
Source: Smart PLS output

The second-order CFA analysis obtained the outer loading values as weights to assess flood vulnerability. The level of flood vulnerability was analyzed using a scoring method derived from the sum of the exposure, sensitivity, and adaptive capacity indexes. Moreover, the index for each dimension of vulnerability was calculated by multiplying the outer loading with the acquired value. The flood vulnerability results were classified into three categories, namely high, medium, and low.

Flood Vulnerability Index = $\sum(f_e * n_e) + \sum(f_s * n_s) + \sum(f_{ca} * n_{ca})$ …..... (1)

ANALYSIS AND DISCUSSION

The measurement model was tested to obtain valid and reliable indicators. In the initial iteration, the Cronbach's alpha, CR, and AVE values of sensitivity and vulnerability variables did not meet the criteria. However, adaptive capacity only met CR threshold, and exposure variables fulfilled the requirements. Table 2 shows the outer loading values from the first iteration, indicating that there are still low outer loading values (<0.7). This shows that eliminating indicators with lower values needs to consider their influence on other values. Outer loading values between 0.4 and 0.7 should be regarded to avoid affecting the validity of dimensions (Hair et al., 2022). Therefore, indicators with outer loading values below 0.4 are eliminated (Hair et al., 2022).

Table 2: Result of Outer loading Iteration 1

Indicator	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
DLB	0.846			0.483
DRB	0.869			0.521
FB	0.698			0.408
JAK		-0.308		-0.14
TPD		0.216		0.013
KAB		-0.421		-0.127
STS		0.033		0.04
KLD		0.815		0.815
FPSH		0.583		0.257
TPT			0.099	0.096
MI			0.292	0.279
GTR			0.894	0.789
KJK			0.748	0.645
KJT			0.878	0.782
PKPE			0.722	0.661

Source: Smart PLS Output

Table 3 shows the outer loading values from several iterations, where all indicators have values that meet the threshold. The constructs of exposure, sensitivity, adaptive capacity, and vulnerability satisfy the required thresholds. Exposure shows a Cronbach's alpha value of 0.729, CR 0.84, and AVE 0.636. Meanwhile, sensitivity has a Cronbach's alpha value of 0.701, CR 0.769, and AVE 0.36. Adaptive capacity shows a Cronbach's alpha value of 0.833, CR 0.889, and AVE 0.669. Vulnerability shows a Cronbach's alpha value of 0.713, CR 0.832, and AVE 0.577.

Table 3: Result of Outer Loading in Measurement Model

Indicator	Exposure	Sensitivity	Adaptive Capacity	Vulnerability
DLB	0.815			
DRB	0.899			0.332
FB	0.688			
KLD		0.602		
FPSH		0.954		
GTR				0.872
KJK			0.784	0.798
KJT			0.892	0.896
PKPE			0.685	

Source: Smart PLS Output

Structural model testing refers to the R square value indicating the magnitude of latent constructs on their dimensional constructs, where a value indicates a better model (Hair et al., 2019). In this study, adaptive capacity had an R square value of 0.805 (n>0.67), indicating that the variable was a robust model predictor and could explain vulnerability by 80.4%. Exposure was a variable with moderate explanatory power, and an R square value of 0.355 (n>3.3), explaining vulnerability by 35.2%. Meanwhile, sensitivity was a weak model predictor with R square value of 0.014 (n<0.19) and an explanatory power of 9%. The measurement and structural models were validated through GoF value obtained from the square root of AVE and R square multiplication. Based on the results, GoF value was 0.379 (n>0.36), exceeding the prescribed threshold.

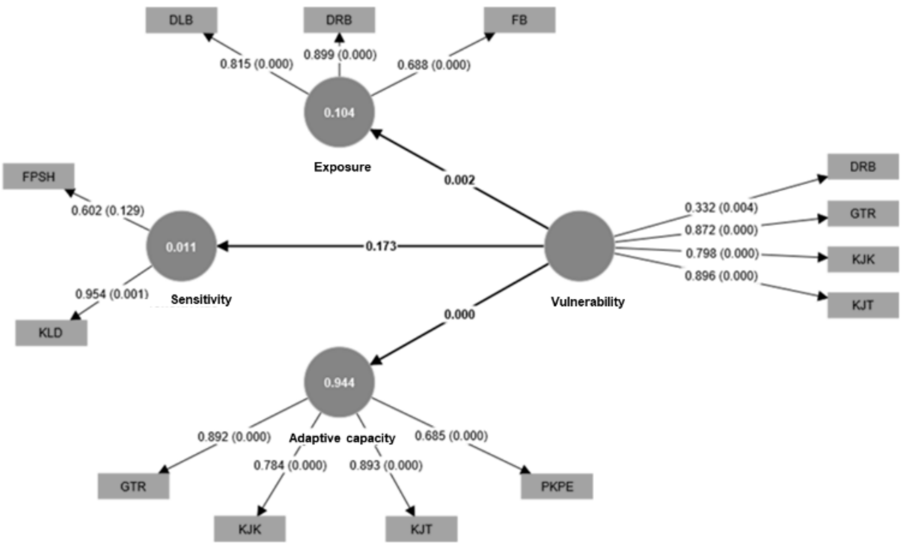

Figure 3: Result of Structural Evaluation Model
Source: Smart PLS output

As shown in Figure 3, the analysis results indicated that only two variables were significant in measuring vulnerability, along with four valid and reliable indicators. These indicators comprised exposure consisting of flood duration and adaptive capacity including family cooperation, neighbor cooperation, and *gotong royong* or mutual assistance. Based on the results, adaptive capacity variable was dominant in determining vulnerability of settlement to flood, as majority showed significant factor loading values.

The exclusion of indicators related to exposure, sensitivity, and adaptive capacity variables was influenced by the empirical conditions of the Kalibaru Subdistrict. Regarding frequency and depth, exclusion indicators were from variations in experiences among respondents. Similarly, the exclusion of indicators of clean water, sanitation, and waste collection services was attributed to differing respondent perceptions.

Results of the interviews showed that there were households lacking access to piped water, as major needs were fulfilled through well, water kiosks, and *nyelang*. Water kiosks represented a program for areas without piped water access, serving as a source from tanks routinely filled by tanker trucks. Meanwhile, *nyelang* referred to piped water purchased from neighbors using hoses. Some respondents also raised concerns regarding the water quality, as there was an indication of turbidity and foul-smelling characteristics.

Figure 4: The Condition of Settlement Infrastructure
Source: Author's Documentation

Adequate sanitation facilities equipped with septic tanks were lacking for some respondents, leading to the direct discharge of waste into water channels. This was attributed to unavailable access to waste disposal services to community, causing reliance on informal waste collection methods. The drainage system in Kalibaru Subdistrict was considered a critical component of settlement. Consequently, the drainage system was among the aspects targeted for improvement under slum upgrading program to enhance the quality of living conditions. After the settlement upgrading, the drainage conditions were assessed to have improved, thereby mitigating flood in several areas.

The exclusion of media information indicators could be due to some respondents not receiving information about flood threats. Similarly, regarding indicators of outreach and educational activities, some respondents expressed infrequent or nonexistent participation.

Table 4: Result of Flood Vulnerability Levels in Kalibaru Subdistrict

Vulnerability Indicator	Outer loading	Score	Result
DRB	0.332	538	178.616
KJK	0.798	629	501.942
GTR	0.872	617	538.024
KJT	0.896	615	551.040
Total			**1,769.622**

Source: Author's Calculation

Table 4 shows the vulnerability level of coastal settlement in Kalibaru Subdistrict to flood obtained using a scoring method through the multiplication of the loading factor results by respondent assessments. Based on the analysis, the calculation showed a vulnerability value of 1,769.622. This study categorized vulnerability into three classes, namely high (07.076-1,714.74), moderate (1,714.75-2,522.41), and low (2,522.42-3,330.08). Based on this classification, coastal settlement in the Kalibaru Subdistrict were considered moderately vulnerable to flood. As shown in Figure 5, there were three RWs with low vulnerability, two RWs had moderate, and one was high.

Based on the flood vulnerability assessment scores obtained, the majority of community in the six locations had higher scores for GTR (mutual assistance) and KJT (neighborhood cooperation) compared to DRB (flood duration) and KJK (family cooperation) indicators. This showed that participation in community cooperation and neighborhood cooperation activities during flood was considered more vital or significant in reducing vulnerability. Meanwhile, family cooperation had lower assessment scores because some respondents mentioned that family members who could assist did not reside at home due to employment outside the community.

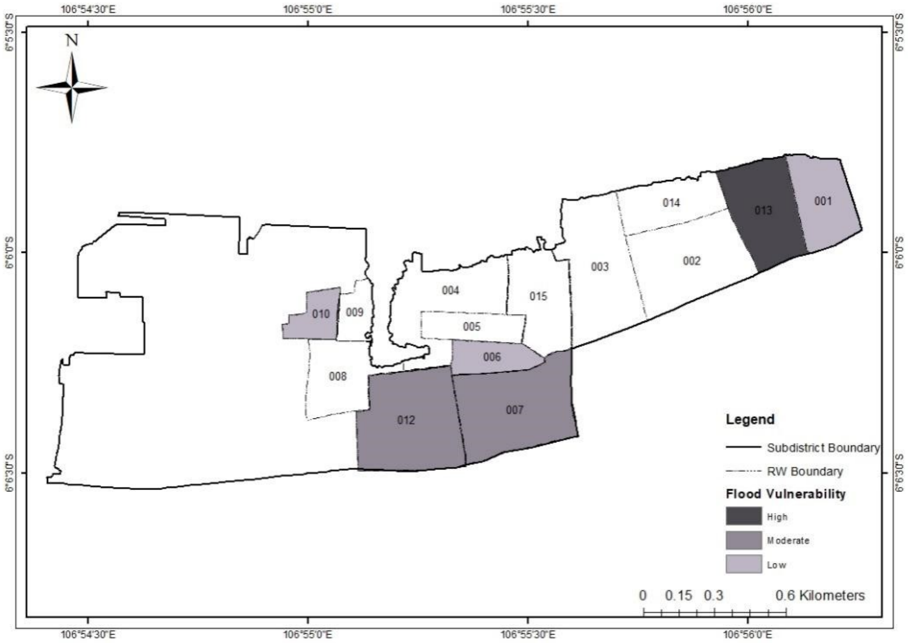

Figure 5: Flood Vulnerability in Kalibaru Subdistrict According to Neighborhood Units (RWs).

The results showed the role of social capital in accessing aid from social community (Chen et al., 2021), forming collective actions to respond to flood impacts by accelerating community and infrastructure recovery (Fatemi et al., 2021) and reinforcing each other to enhance their capacity to cope with disasters (Azad & Pritchard, 2023). The influence of adaptive capacity on vulnerability to flood was affected by the socio-economic conditions of community (Mruksirisuk et al., 2023). The Kalibaru Subdistrict community was diverse, with various cultural influences affecting perceptions of flood threats. This diversity led to differing willingness to enhance flood resilience (Soetanto et al., 2017). Strong social norms, cooperative abilities, and solidarity facilitated access to social capital (Wannewitz & Garschagen, 2024). Chong and Bin Kamarudin (2023) also stated that close social connections could enhance community ability to cope with disasters such as flood. Therefore, improving the quality of settlement included enhancing physical aspects and strengthening community resilience during disasters. Community resilience was considered crucial for better understanding both natural and built environments (Sulaiman et al., 2019), and for enhancing the community's ability to adapt to changing conditions, endure, and recover swiftly from disasters.

CONCLUSION

In conclusion, this study explored flood vulnerability levels in Kalibaru Subdistrict, which was within the moderate category. The classification of levels produced was closely related to indicators of adaptive capacity that predominantly determined flood vulnerability. These results showed that the social relationships formed within community were crucial in addressing the disaster risks. The analysis showed that the physical environmental components did not significantly influence the determination of flood vulnerability at the study location despite settlement planning efforts. This was attributed to the community differing perceptions of environmental conditions and the ease of access to basic urban services.

The increased flood risk due to climate change was predicted to escalate, with coastal settlements expected to experience significant impacts. Besides settlement planning aimed at improving infrastructure and essential services, enhancing social capital also required attention to mitigate vulnerability to flood.

ACKNOWLEDGEMENT

This research was funded by School of Environmental Science, Universitas Indonesia, Grant No. PKS-0311/UN2.F13.D1/PPM.00.04/2024.

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Received: 12th June 2024. Accepted: 6th September 2024

