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Mapping Household Adaptive Capacity to Climate Change through Sustainable Livelihood Assets in Coastal Urban Communities

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ABSTRACT

Coastal communities are increasingly exposed to climate-related hazards. This study analyzes and maps household adaptive capacity in a coastal urban area in Semarang, using the Sustainable Livelihood Framework to examine how natural, human, physical, financial, and social capital shape resilience. A mixed-methods approach was applied through census-based household surveys, participatory mapping, in-depth interviews, spatial analysis, Spearman correlation to explore capital interlinkages, and AHP weighting to assess the relative importance of livelihood assets. The results reveal contrasting interaction patterns across neighborhood units: human–financial linkages dominate in RT 06/RW 01, while physical–natural interactions are strongest in RT 07/RW 05. AHP results indicate that social capital is the most influential asset, emphasizing the role of organizational participation and community networks. Most households fall into the Moderate adaptive capacity category. By translating household-level assessments into spatially explicit priorities, this study supports community empowerment through strengthened social networks, improved climate literacy, urban farming initiatives, and advocacy for secure land tenure. The findings provide a practical foundation for participatory coastal adaptation planning and offer a methodological reference for climate adaptation research oriented toward community empowerment in the Global South, particularly in Indonesia.

ARTICLE INFORMATION

Keywords:
adaptive capacity; climate change; household-level mapping; livelihood capital interlinkages; sustainable livelihood framework

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INTRODUCTION

Climate change poses a profound and urgent challenge on a global scale. This reality is evident in its effects, which increasingly impact communities across the world. Climate change has caused irreversible damage and loss to terrestrial, freshwater, cryosphere, and coastal and ocean systems, particularly species loss driven by extreme temperatures, and has also impacted food security (Espinola & Roleda, 2025; Li et al., 2026). Furthermore, its impacts can manifest as hydrometeorological disasters, a trend clearly reflected in Indonesia by the growing frequency and intensity of such events. These impacts will be felt more acutely in coastal areas, where sea-level rise threatens livelihoods, infrastructure, and land resources (Fariz et al., 2026). Data from the National Disaster Management Agency (BNPB) in Indonesia between January 1 and May 31, 2023, show that hydrometeorological events accounted for 99.1 percent of all disasters during that period, with wet hydrometeorological events predominating (Hendrawan et al., 2025; Rahmawati & Fariz, 2024). The

rise in these events corresponds with growing community vulnerability, which continues to escalate in line with climate change processes (Birkmann et al., 2022; Fariz et al., 2026). Within disaster management, efforts to strengthen capacity are closely associated with strategies to reduce vulnerability (Cvetković et al., 2021; Sapountzaki, 2022). Communities rely on the assets available to them to secure daily livelihoods and maintain long-term sustainability. These assets consist of natural, human, physical, financial, and social capital (Kamsi et al., 2025; Raza et al., 2025). The Sustainable Livelihood Approach provides an analytical foundation for understanding the interactions of these livelihood capitals in relation to capacity and vulnerability in climate-related hazards (Das & Ansari, 2021). This framework is widely used to examine preparedness and adaptive strategies that enable communities to cope with climate-driven risks (Das & Ansari, 2021; Ramadhan et al., 2024). Adaptive responses differ across communities due to variations in local contexts, resource availability, and hazard characteristics (Marfai et al., 2018; Muccione et al., 2024). Semarang City is a relevant case because it faces climate-related pressures, including flooding, drought, and coastal erosion. These hazards require continuous efforts to strengthen resilience through capacity assessments that inform risk-reduction measures (Martuti et al., 2020; Rahmawati & Fariz, 2024). Tugurejo Subdistrict, located in the coastal zone of Semarang City, faces multiple hazards including drought, tidal flooding, and seawater intrusion, which intensify local vulnerability and require detailed examination of community capacity to adapt and recover (Rahmawati & Fariz, 2024; Setyaningsih et al., 2024).

Various analytical approaches have been used to understand community capacity, such as stakeholder mapping and analysis (Hizbaron et al., 2021) and institutional capacity assessments (Haeril et al., 2022). However, the Sustainable Livelihood Approach is particularly beneficial because it provides a holistic perspective on how communities access, manage, and mobilize various forms of capital (Chapagain et al., 2025; Rahmawati & Fariz, 2024). Previous SLA studies have explored asset-based strategies in highland communities (Mekonen & Berlie, 2021), examined rural livelihood–environment linkages (Mabon et al., 2021), and assessed coastal livelihood initiatives in Indonesia (Saha et al., 2024; Stacey et al., 2019). Assessment of household capacity has been carried out by several studies, though most rely on sampling-based approaches that may overlook variations in adaptive responses among households (Fariz et al., 2022; Namgyal et al., 2025). To address this limitation, the present study applies detailed household-level mapping using the Sustainable Livelihood Framework. This approach offers accurate and up-to-date information on adaptive capacity and supports identification of priority areas and vulnerable groups that require targeted climate adaptation interventions (Fariz et al., 2022; Hazarika et al., 2024; Lizuka, 2020). Through this mapping, community resilience can be strengthened by linking findings to locally relevant strategies, such as infrastructure improvements, livelihood diversification, and social capital enhancement (Mekonen & Berlie, 2021).

While previous household-level Sustainable Livelihood Framework assessments provide valuable insights, they rarely examine the interrelationships among the different livelihood capitals that shape households' actual adaptive choices. This study addresses this gap by examining how natural, human, physical, financial, and social capital interact at the household scale, providing a more grounded understanding of community resilience. Such analysis is particularly important in contexts where sensitive variables, such as household income, are often underreported, and alternative livelihood indicators are needed to support community-based decision-making (Johar et al., 2019). By revealing how livelihood capitals reinforce or compensate for one another, this research offers a practical basis for identifying priority areas for community empowerment, including strengthening social networks, enhancing adaptive skills, and reducing dependency on vulnerable natural resources. In the context of Tugurejo as a coastal urban area exposed to recurrent hydrometeorological hazards, the study supports locally grounded strategies to reduce vulnerability and strengthen household-level

adaptive capacity. These contributions directly align with SDG 1 Target 1.5 on resilience of vulnerable populations, SDG 11.5 on urban disaster resilience, and SDG 13.1 on climate change adaptation, while emphasizing actionable pathways for community empowerment rather than abstract policy targets.

METHOD

This study was conducted in Tugurejo Subdistrict, Tugu District, Semarang City, Indonesia. The details of the study area are presented in Figure 1. The subdistrict is situated on a marine landform characterized by tidal flats along the northern coast of Java, predominantly composed of alluvial deposits. The research focused on two key areas: RT 06/RW 01 and RT 07/RW 05. In the Indonesian administrative system, RT (Rukun Tetangga) and RW (Rukun Warga) are community-based neighborhood units that organize social affairs and facilitate the delivery of basic administrative and public services at the lowest level below the urban ward government, with each RW comprising several RTs. In practical terms, one RT typically consists of approximately 30 to 50 households (Putra et al., 2024), making it broadly comparable to a small neighborhood unit or a cluster of census blocks in many developed countries, rather than a single census block, which often represents only a few dozen housing units with an average household size of two to three persons (Esteve et al., 2024). These locations were selected because they exhibit distinct social and environmental characteristics, allowing for a comparative assessment of household adaptive capacity to climate change.

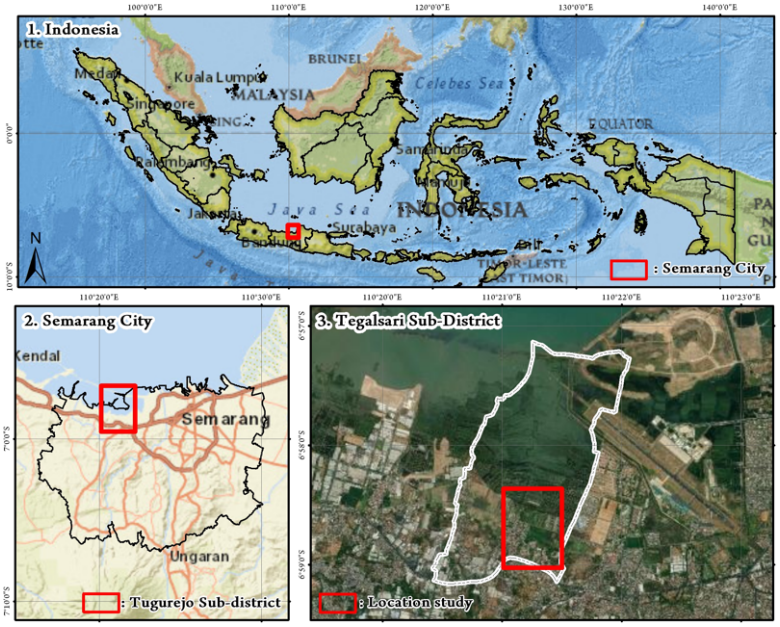

Figure 1. Study Area

A mixed-methods approach was employed, combining quantitative and qualitative techniques. The quantitative component involved direct observation and the distribution of structured questionnaires to all households in the study area to collect numerical data on the five dimensions of the Sustainable Livelihood Assets (SLA). In parallel, the qualitative component consisted of in-depth interviews designed to validate observational and survey findings and to provide a deeper understanding of the local social and environmental context, including existing adaptation strategies. In addition to these techniques, documentation was used as supplementary data to strengthen contextual analysis and corroborate household-level information. This study applied a census sampling technique, in which the entire population was included as research respondents. According to administrative records from the Tugurejo Subdistrict office, the key study areas comprised 85

households: 44 in RT 06/RW 01 and 41 in RT 07/RW 05. The use of saturated sampling was intended to obtain a more representative and accurate depiction of adaptive capacity, given that households may exhibit different responses to hazards (Fariz et al., 2022). This approach aligns with Lizuka (2020), who emphasizes that involving all households yields more current, contextually grounded results in community capacity assessments. The research variables were derived from the five principal livelihood assets or pentagonal assets that influence adaptive capacity and determine access to social and economic structures and processes at the local level. The selection of indicators for each variable was based on field observations and adapted to the characteristics of the study area. The list of indicators was constructed by referring to and modifying several sources, including Fariz et al. (2022), Wu et al. (2023), Zakari et al. (2022), Saputra and Lee (2019), Rahmawati and Fariz (2024), Shah et al. (2022), and Wijayanti et al. (2016).

Table 1. Variables and Operational Definitions

Variable	Indicator	Operational Definition
Natural Capital	Land Ownership	Ownership of land used for residential or productive purposes.
	Pond Ownership	System of ownership and access to aquaculture ponds.
Human Capital	Productive Age Ratio	Comparison between the number of economically inactive individuals and active individuals within a household.
	Community Health	Proportion of individuals with chronic illness and disabilities within a household.
	Education	Highest educational attainment of household members.
Financial Capital	Household Income	Accumulated income generated by household members in productive working age.
	Savings Ownership	Percentage of income allocated as savings.
Social Capital	Organizational Participation	Extent to which household members participate in community or organizational activities.
	Organizational Membership	Household members' responsibilities or roles in coordinating community activities.
Physical Capital	Housing Condition	Physical condition of the house assessed based on building materials.
	Vehicle Ownership	Ownership of private transportation assets.

The analysis comprised several major stages. The first stage involved basic GIS analysis, including the mapping of building footprints through manual interpretation of high-resolution satellite imagery and participatory mapping to delineate RT and RW boundaries. Participatory mapping is a multi-agent practice that empowers communities by compiling their spatial knowledge into cartographic visualizations, thereby bridging the gap between policy and community perspectives and enhancing democratic decision-making (Denwood et al., 2022). The second stage consisted of scoring all indicators within each livelihood asset. Each indicator was evaluated using a Likert scale from 1 to 5, where 1 represents very low conditions, and 5 represents very high conditions. The third stage involved examining the relationships among variables using Spearman correlation applied to raw scores. Spearman correlation was used to identify the direction and strength of associations between livelihood assets. This analysis is particularly important for assessing the relationship between physical and financial capital. Financial data are often sensitive and difficult to obtain accurately because respondents may be reluctant to disclose income or savings. In contrast, physical capital is more easily validated through direct observation, such as housing condition, access to clean water, and ownership of productive tools.

The fourth stage focused on determining indicator weights. Initial weights were identified through a comprehensive literature review and subsequently refined using expert judgment within the Analytic Hierarchy Process (AHP) framework. In climate change adaptation studies, AHP is commonly applied based on the judgments of a small group of domain experts with long-term engagement in the research context, rather than relying on large-scale surveys (Golfam et al., 2019). This approach is particularly relevant given that climate adaptation is highly contextual, shaped by site-specific biophysical, social, economic, cultural, and political conditions (Buffa et al., 2023). Accordingly, the researchers themselves served as the expert panel, as AHP requires numerous pairwise comparisons and is therefore commonly applied using a limited number of highly experienced assessors to maintain cognitive feasibility and judgment consistency (Birgani et al., 2022). In addition, climate adaptation research emphasizes the importance of researcher "insiderness", where long-term engagement and close involvement with local communities enable deeper contextual understanding and more reflective expert judgment (Kitagawa, 2023). From this perspective, the researchers' sustained interaction with the study area justifies their role as an expert panel in the AHP weighting process. The expert judgment process was conducted through a Focus Group Discussion (FGD), which functioned as a structured AHP-FGD approach to facilitate deliberation and consensus-building among experts, thereby reducing inconsistency in pairwise comparisons compared to conventional individual-based AHP applications, as demonstrated by Fariz et al. (2023). The output of this stage was the classification of household adaptive capacity into five categories: very low, low, moderate, high, and very high. The fifth stage involved mapping adaptive capacity. The weighted adaptive capacity values for each household were visualized spatially as thematic maps to illustrate the distribution of adaptive capacity across the study area. These maps were generated based on the building-footprint layer obtained in the earlier GIS analysis. The spatial visualization enabled identification of adaptive capacity patterns and areas that may be particularly vulnerable to the impacts of climate change.

RESULTS AND DISCUSSION

Tugurejo Subdistrict is located in the coastal zone of Semarang City and is recognized as an urban area with complex socio-ecological characteristics. The subdistrict is directly adjacent to the main Semarang Jakarta transportation corridor and is surrounded by industrial centers, including the Candi Industrial Estate (Utami et al., 2024). Land cover in the area is dominated by dense residential settlements and aquaculture ponds, with only limited agricultural land remaining (Kelly-Fair et al., 2022). Within the local governance system, social units such as RTs, RWs, and household-based groups such as Dasa Wisma (Dawis) function as key structures for organizing community and environmental activities. These characteristics align with the definition of an urban area by Tian, et al. (2021), which describes urban settings as spaces demonstrating social, economic, spatial, and ecological integration.

From a biophysical perspective, Tugurejo is subject to strong environmental pressures due to its low-lying coastal plain location, which is vulnerable to tidal flooding, coastal erosion, seawater intrusion, and river flooding (Rahmawati & Fariz, 2024). In some locations, the coastline has shrunk due to coastal erosion and the conversion of mangrove ecosystems into fish farming ponds (Sidiq, 2025). These conditions have encouraged the development of various community-level adaptation initiatives, including participation in the national Program Kampung Iklim (ProKlim), which aims to enhance community-based climate mitigation and adaptation. Observations and interviews indicate that communities in both key areas experience hydrometeorological hazards, including flooding, whirlwind events, and seawater intrusion. These pressures have spurred the emergence of community-based adaptive responses, particularly through Female Farmers Groups (Kelompok

Wanita Tani, or KWT), which focus on household food security and economic empowerment, as shown in Figure 2.



Figure 2. Female Farmers Group (*Kelompok Wanita Tani*/KWT)

Additionally, there are Dawis (Dasa Wisma) groups, which are neighborhood-level women's groups consisting of approximately 10 to 20 neighboring households at the RT or RW level, established to facilitate and accelerate the implementation of Family Welfare Empowerment (PKK) programs. Both groups actively promote urban farming initiatives to strengthen food security and social networks. Within this context, the present study assesses household adaptive capacity using the Sustainable Livelihood Framework to understand the extent to which natural, human, physical, financial, and social capital function as buffers in responding to climate-related threats. Figure 3 illustrates the radar diagram of household assets in the study area.



Figure 3. Capital Conditions in The Study Area

Climate change presents a direct threat to coastal livelihoods, especially for households that depend on natural resources for food, income, and other basic needs. According to Figure 3, the assessment for RT 06/RW 01 shows that human capital is the strongest component, with a score of 3.80 out of 5, largely due to the community's excellent health status. A total of 97.7 percent of households reported no members with chronic illness or disabilities, resulting in a high health indicator score of 4.9. In contrast, natural capital is the weakest component, with a score of 2.07. Pond ownership received the lowest score (1.06) because only 4.5 percent of households work as aquaculture farmers, and even those operate ponds under rental arrangements from pond owners in RT 01/RW 01. A similar pattern is found in RT 07/RW 05, where human capital also registers the highest score (4.02). All households in this area reported no members with chronic illness or disabilities. Education levels are also relatively high, with 65 percent of households having at least a senior high school graduate and 27.5 percent having at least a university graduate. As in RT 06/RW 01, natural capital becomes the weakest asset (score 2.0). Most residents do not own ponds or productive land because the Dawis Kencur II settlement area is located on land owned by PT KAI and

KORPRI, creating land tenure insecurity that limits adaptive capacity. The assessment of livelihood capital in both areas reveals a consistent pattern. Human capital is the highest-performing asset, whereas natural capital is the lowest. These similarities are influenced not only by social and economic conditions but also by structural limitations in access to productive land, shifts in employment due to coastal industrialization, and environmental pressures such as river pollution and coastal abrasion. Interviews indicate that land conversion, corporate land acquisition, and declining pond productivity caused by microplastic and heavy metal pollution have pushed households to shift from land-based livelihoods to more stable industrial work. At the same time, recurring social interactions such as weekly religious gatherings, Karang Taruna (KT), a village-level youth social organization, and the engagement of KWT Sumber Hasil and KWT Wema Mekar strengthen social capital as a vital component in reinforcing community resilience. The results of Spearman correlation analysis are presented in Table 2.

Table 2. Spearman Correlation Analysis

Relationship	Neighborhood Unit 06 / Community Unit 01		Neighborhood Unit 07 / Community Unit 05	
	Correlation Coefficient	Correlation Strength	Correlation Coefficient	Correlation Strength
N – H	-0.092	Very Weak Negative Relationship	0.097	Very Weak Relationship
N – F	0.11	Very Weak Relationship	0.45	Moderate Relationship
N – S	0.203	Very Weak Relationship	0.525	Strong Relationship
N – P	0.324	Moderate Relationship	0.551	Strong Relationship
H – F	0.614	Strong Relationship	0.363	Moderate Relationship
H – S	0.217	Very Weak Relationship	0.043	Very Weak Relationship
H – P	0.364	Moderate Relationship	0.055	Very Weak Relationship
S – F	0.471	Moderate Relationship	0.274	Moderate Relationship
S – P	0.406	Moderate Relationship	0.268	Moderate Relationship
P – F	0.367	Moderate Relationship	0.651	Strong Relationship

The Spearman analysis for RT 06/RW 01 shows that human capital has the strongest relationship with financial capital, with a coefficient of 0.614 ($p < 0.01$). This finding aligns with Pradnyaswari et al. (2021), who argue that community productivity is strongly influenced by the ratio of the productive-age population and overall health status. Households with good health and a high proportion of productive-age members tend to have more stable incomes and savings, which subsequently enhance their adaptive capacity. These results emphasize that demographic structure and health conditions play a central role in shaping household resilience, since income and savings directly support access to healthcare, education, and adaptive infrastructure. In contrast to RT 06/RW 01, the results for RT 07/RW 05 indicate that natural capital has the strongest and most frequent relationships with other capitals. Land and pond ownership display strong correlations with social capital (0.525) and physical capital (0.551). This confirms the argument of Pratomo et al. (2022) that property ownership contributes to long-term household stability and reduces uncertainty related to relocation or spatial changes. The strong link between natural and social capital also suggests that land ownership encourages participation in local organizations such as farming groups, pond management groups, and neighborhood associations, which serve as essential social networks for enhancing resilience (Septanti, 2019). In this sense, land and ponds are not merely economic assets but also gateways to social collaboration that supports climate adaptation.

The correlation between natural and financial capital in RT 07/RW 05 is also relatively strong (0.450), indicating that household income and savings are strongly influenced by land and pond ownership. This finding is consistent with Ningwuri (2017) and Adiansari (2022), who highlight the vulnerability of aquaculture farmers to changes in land tenure status due to coastal industrialization. When pond lands are sold or converted, household income declines sharply, forcing livelihood changes that, in turn, reshape adaptive capacity. The strongest correlation in RT 07/RW 05 appears between physical and financial capital (0.651). This shows that housing conditions, ownership of secondary assets, and the quality of supporting infrastructure are heavily influenced by household economic capability. Households with stronger finances can improve building quality, enhance access to clean water, and strengthen other physical assets that support adaptation to flooding, tidal inundation, and extreme weather. Overall, the Spearman results indicate that although inter-asset relationships vary across areas, the combined influence of land, income, social networks, productive age structure, and health status drives household adaptive capacity. Several studies in Semarang, Indonesia, and Southeast Asia emphasize that social capital such as organizational participation, trust networks, and community leadership constitutes one of the most important indicators of adaptive capacity. Social capital facilitates collective action, information exchange, access to external resources, and shared decision-making, all of which contribute to enhanced climate resilience (Gisevius et al., 2025; Landicho et al., 2023; Saptutyningsih et al., 2020). Human capital also plays a critical role because access to information, training, and education helps individuals and communities recognize climate risks, learn new strategies, and adapt more flexibly (Landicho et al., 2023; Diana et al., 2022). In contrast, physical, natural, and financial capital function more as supporting components because they cannot stand alone without reinforcement from social and human capital (Diana et al., 2022; Prayitno et al., 2025). In the previous subsection, the results of the livelihood capital assessment were still presented as raw scores. The analysis in this stage incorporates weights derived from the Analytic Hierarchy Process (AHP) conducted through a Focus Group Discussion (FGD). The AHP process yielded a Consistency Ratio (CR) of 0.81, indicating that the pairwise comparison matrix is at an acceptable level of consistency. The weights of variables and indicators from AHP FGD are described in Table 3.

Table 3. Weights of Variables and Indicators from AHP FGD

Variable	Weight	Indicator	Weight
Natural Capital	0,03	Land Ownership	0,8
		Pond Ownership	0,2
Human Capital	0,24	Productive Age Ratio	0,27
		Community Health	0,09
		Education	0,64
Financial Capital	0,15	Household Income	0,66
		Savings Ownership	0,34
Social Capital	0,52	Organizational Participation	0,8
		Organizational Membership	0,2
Physical Capital	0,06	Housing Condition	0,34
		Vehicle Ownership	0,66

According to Table 3, the AHP FGD results show that within natural capital, land ownership received a higher weight than pond ownership. This decision reflects the greater liquidity and flexibility of land as an asset, as it is generally easier to sell or transfer than aquaculture ponds, thereby yielding stronger contributions to household adaptive capacity. Within human capital, education

received the highest weight. Education is considered a fundamental factor that enhances adaptive capacity by providing access to more stable employment, improving social status, and increasing the ability to understand information related to climate risks and adaptation strategies. For financial capital, household income received the highest weight because daily or monthly earnings can be allocated more immediately to adaptation needs than savings, which are less liquid. For social capital, organizational participation received the highest weight. Active participation reflects social engagement and expands access to networks, assistance, and resource mobilization during climate-related events. Individuals who hold strategic positions in community organizations, such as RT leaders or neighbourhood coordinators, tend to have stronger adaptive capacity. Finally, within physical capital, vehicle ownership received the highest weight. Vehicles provide direct benefits for mobility, including evacuation and supplementary income activities such as ride hailing. This flexibility makes vehicle ownership an important asset in strengthening household adaptive capacity. The household adaptive capacity to climate change is mapped in Figure 4.

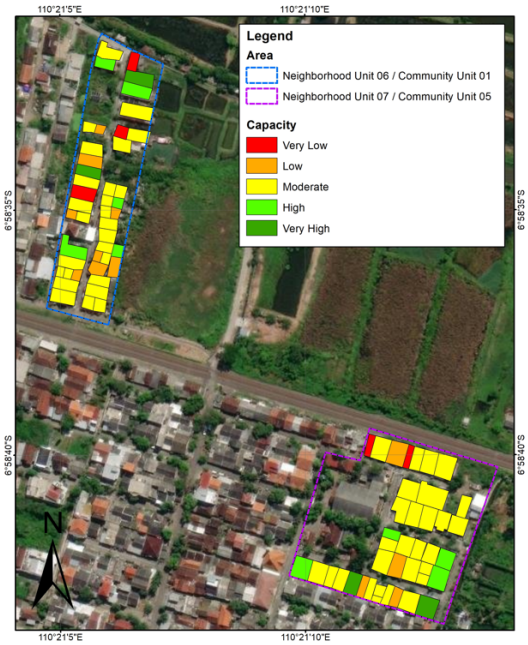

Figure 4. Household adaptive capacity to climate change map

The analysis, as shown in Figure 4, indicates that most households in both areas fall into the Moderate adaptive capacity category, with only a small proportion categorized as Low or Very Low, and an equally limited number categorized as High or Very High. This distribution suggests that, on average, households possess livelihood assets that are adequate yet not sufficiently strong to be considered highly resilient, yet not so weak as to fall into severe vulnerability. Households categorized as Low and Very Low generally exhibit consistently low scores across nearly all asset types, particularly in social capital, which carries the highest weight according to the AHP FGD results. In contrast, households categorized as High and Very High show strong performance across social, human, and financial capital. This pattern suggests that efforts to enhance adaptive capacity in the study area should prioritize households in the Moderate category, enabling them to progress into higher levels of resilience. In contrast, households in the Low and Very Low categories require more protective interventions due to their current vulnerability. In other words, the adaptive capacity structure in RT 07/RW 05 and RT 06/RW 01 reveals a resilience spectrum dominated by the medium

tier, with distinct pockets of vulnerability and clusters of households that already possess substantial resilience.

This study has several limitations, one of which is that the analysis of relationships among livelihood assets relies solely on Spearman correlation. Since Spearman's correlation is descriptive, it cannot capture causal relationships or simultaneous interactions among variables. While this approach is sufficient for identifying patterns of interaction among livelihood assets within the Sustainable Livelihoods Framework, it does not provide insights into which factors significantly determine household adaptive capacity. As a result, the interpretation of findings remains exploratory and does not generate probability estimates for adaptive capacity categories such as low, moderate, or high. Understanding the relationships among livelihood assets is crucial because certain assets may serve as proxies for others that are more difficult to measure. For instance, physical capital indicators such as housing quality, yard structure, or settlement morphology may function as observable predictors of financial or even social capital. This possibility highlights the importance of advancing research that rigorously tests such cross-asset relationships. To strengthen the relevance of household adaptive capacity assessments for community development, future studies could adopt more robust inferential approaches such as those applied by Dyanty et al. (2025), who used binary logistic regression to examine determinants of adaptation strategy adoption. Regression-based approaches, including binary, ordinal, or multinomial models, would enable clearer identification of variables that significantly influence household adaptive capacity. This would support more targeted community empowerment strategies by helping practitioners prioritize interventions based on locally dominant drivers of adaptation. Further methodological development also offers opportunities to test whether physically observable indicators derived from field surveys or aerial imagery, such as building quality, settlement density, or yard size, can serve as proxies for sensitive livelihood assets. If validated, these indicators could support more objective and efficient assessment of financial or social capital through geospatial analysis, reducing reliance on self-reported information that households may be reluctant to disclose. Such approaches would improve the feasibility of household-level assessments while strengthening evidence-informed local planning, particularly in data-constrained coastal settings.

Overall, this study's findings confirm that participatory mapping of household adaptive capacity provides a critical foundation for coastal community development planning. Beyond contributing to academic understanding of livelihood asset dynamics, this study offers a practical scientific reference for assessing climate change adaptive capacity with an explicit empowerment orientation. By integrating Sustainable Livelihood Assets analysis, spatial mapping, and participatory methods at the household scale, the study provides a transferable methodological pathway for climate adaptation research in the Global South, particularly in Indonesia and comparable coastal contexts where vulnerability, informality, and data limitations are prevalent. The empirical evidence generated supports community empowerment initiatives, including strengthening social networks, improving climate literacy, promoting urban farming as a supplementary livelihood strategy, and advocating for secure land rights in vulnerable coastal settlements. By translating household-level assessments into locally relevant priorities, this approach reinforces inclusive and participatory development processes. It contributes directly to SDG 1 on poverty reduction, SDG 11 on sustainable cities and communities, and SDG 13 on climate action by strengthening the long-term resilience of coastal households facing climate-related pressures.

CONCLUSION

This study demonstrates that household adaptive capacity in the coastal urban area of Tugurejo is shaped by a distinctive configuration of livelihood assets, with human capital consistently the

strongest component and natural capital the weakest due to limited land ownership, declining pond productivity, and insecure land tenure. Spearman correlation analysis reveals contrasting interaction patterns across neighborhood units, where adaptive capacity in RT 06/RW 01 is primarily driven by strong linkages between human and financial capital, indicating that household income and savings are closely associated with health conditions and productive age structure, while in RT 07/RW 05 the strongest associations occur between physical and natural capital, reflecting the central role of land tenure and resource access in shaping housing conditions and asset ownership. AHP results further confirm that social capital is the most influential livelihood asset, with the highest weight, underscoring the importance of organizational participation and community networks in strengthening resilience. Spatial mapping of weighted household capacity shows that most households fall within the Moderate category, with smaller clusters of Low and Very Low capacity indicating persistent vulnerability alongside limited numbers of highly resilient households. Nevertheless, this study is limited by its reliance on Spearman's correlation, which is descriptive and does not capture causal relationships or simultaneous interactions among livelihood assets, leading to findings that remain exploratory rather than predictive. Future research should therefore adopt more robust inferential approaches, such as binary, ordinal, or multinomial regression, to identify key determinants of household adaptive capacity and estimate probabilities across capacity classes. Further methodological development is also needed to test whether physically observable indicators derived from field observation or aerial imagery can serve as reliable proxies for sensitive financial or social assets, enabling more objective and scalable assessments. Beyond its analytical contribution, this study provides an applied framework for community empowerment and coastal development planning by translating household-level assessments into actionable priorities and demonstrating the potential of physically observable indicators as proxies for sensitive livelihood assets. As such, the study offers a practical methodological reference for climate adaptation research oriented toward community empowerment in the Global South, particularly Indonesia, and contributes directly to the achievement of SDG 1, SDG 11, and SDG 13 by supporting inclusive, evidence-based strategies to strengthen coastal household resilience.

DECLARATION OF GENERATIVE AI

The authors declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

CONFLICTING INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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