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Research Paper

Enhancing Smart and Adaptive Coastal Living: A Case from Pekalongan Regency

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Abstract

This research analyzes the dimensions influencing the adaptation efforts of communities affected by tidal flooding toward the implementation of Smart and Adaptive Coastal Living in Pekalongan Regency. This study employs a scoring analysis with total of 12 (twelve) indicators from 4 (four) dimensions: infrastructure, connectivity and communication, economic diversification, and marine ecosystem protection. From the score calculations obtained, it is known that the most dominant dimension is economic diversification with an achievement index of 0.541, while the dimension with the lowest contribution is infrastructure with an achievement index of only 0.159. Regarding the achievements in the context of Smart and Adaptive Coastal Living, community adaptation tends to fall into the non-smart adaptive category because the available infrastructure is inadequate and the conditions of the community do not support the presence of smart innovations in the implementation of this concept. Among the twelve existing variables, the highest contributions to achievements at this level arise from the initiatives of coastal communities (K_3) and alternative employment (AE). Both indicate a willingness to adapt to a living environment that continuously faces pressures resulting from flood disasters.

Keywords: Adaptation; Coastal; Smart; Settlement; Tidal Floods.

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1. Introduction

As an archipelagic country, Indonesia possesses a cluster of islands interconnected by oceans with a very extensive coastline with various types of natural resources, tourism potential, and disaster risk (Khakhim et al., 2013). Coastal areas experiences pressure from natural activities due to climate change and are impacted by human activities, where such activities result in land subsidence. One of the ongoing effects is tidal flooding, which poses a threat to coastal cities worldwide (Rudiarto et al., 2020). Tidal flooding generates a multiplier effect and is a primary cause of deteriorating livelihoods for coastal communities, jeopardizing socio-economic sustainability (Rudiarto & Pamungkas, 2020). It has caused damage to homes, roads, bridges, and household items, motivating communities to adapt, both in group adjustments and individual responses. The tidal flood occurs gradually, leading migration to be regarded as a last effort, in the early stages, communities prefer to adapt (Buchori et al., 2022).

One of the factors contributing to the increasing level of disaster risk in coastal areas is climate change. Coastal cities in Indonesia are faced with the dual obligation of rapidly urbanizing while also adapting to climate-related disasters include droughts, storms, routine flooding, storm surges, water pollution, tsunami, sea level rise, and erosion (Diposaptono, 2003; Gaborit, 2022). Suroso & Firman (2018) mention that climate change is believed to affect the characteristics of climate parameters, which will ultimately result in increased surface temperature hazards, changes in rainfall patterns, and an increase in the frequency and intensity of extreme weather events, as well as rising sea levels, which are further exacerbated by environmental degradation. The impacts on coastal communities include a decline in the production of fish and shrimp farms owned by farmers, threats to coastal settlements, and damage to mangrove ecosystems (Khakhim et al., 2013). Not only that, the high rainfall also contributes to increased water flow towards river estuaries. Obi et al. (2021) state that river siltation and intensive rainfall result in runoff that exceeds the capacity of existing drainage facilities, leading to flooding.

There are significant challenges in linking these coastal dynamics with management and policies being implemented. Indrasari & Rudiarto (2020) reveal that development planning in a region must adhere to the principles of sustainable development, one of which targets resilience against disasters, including the communities residing within it. Integrated Coastal Zone Management (ICZM), Disaster Risk Management (DRM), and climate adaptation are holistic, transversal approaches for the sustainable utilization of coastal resources and regional planning (Segura et al., 2024). Therefore, the preparation of planning and policies must ensure that communities can face disaster risks by considering aspects that contribute to resilience, including social, economic, cultural, environmental, and spatial factors (Rudiarto, 2022). ICZM as an effort for coastal management with all its components using the principles of integration, starting from physical, ecological, biological, social, economic, political, cultural, as well as defense and security aspects to create a balance in coastal development in order to remain sustainable (Yonvitner et al., 2019). Moreover, disaster management also needs to involve local community knowledge as it is considered effective in controlling and managing floods in coastal areas, including technical knowledge for flood control, forecasting flood magnitude, community safety, food security, and flood emergency preparedness (Obi et al., 2021).

In addressing tidal flooding issues, additional adaptive measures are required as alternatives for the local government, particularly in order to reduce the risks associated with climate change. Solutions can be implemented through adaptation strategies that encompass wide-ranging and holistic disaster risk management, which includes the management of river basins, ICZM, conservation of natural resources, as well as addressing social vulnerabilities and governance (for instance, community-based early warning systems and data collection) (Obi et al., 2021). The variety of available measures can be developed as follow-up actions or optimization after identifying what initial steps have been undertaken at present.

The assessment of aspects of community life, especially those related to adaptation to tidal flooding and their contribution in supporting the concept of Smart Coastal Living, is based on the desire to solve problems and create a more livable, innovative, and sustainable residential environment. Previous studies certainly form the basis for this research, as many have analyzed the adaptation of communities on the northern coast of Java to tidal flood disasters, with many research locations being the same, namely the coast of Pekalongan Regency. However, previous studies certainly have limitations. The novelty of this research is in the selection of the Smart City concept, specifically focusing on the Smart Living dimension, which has never been addressed in studies related to adaptation to tidal flooding, even though this dimension is the one most closely associated with everyday life, including how community adaptation is highly related to residential activities. Most previous research has focused more on the forms of adaptation and the effectiveness of the adaptation carried out, without analyzing the level of quality of life and the habitability of the residences.

This research aim to analyze the dimensions influencing the adaptation efforts of communities affected by tidal flooding towards the Smart and Adaptive Coastal Living implementation. This is supported by the trend of sustainable development and the concept of 'Smart Cities' which encourages us to grow and innovate in our way of life. One of these innovations is the implementation of a smarter and more sustainable lifestyle in adapting to disasters. We can observe many innovations that have been carried out by disaster-affected communities in navigating through the changing conditions around them. This certainly supports the transition towards the development of Smart Cities focusing on the dimensions of Smart Living, Smart Environment, and Smart Society. The complexity of the existing issues drives the author to assess the level of adaptation carried out from the perspective of smart living dimensions.

The urgency of addressing climate change impacts on coastal settlements is well-supported by evidence from multiple studies. Coastal areas face significant threats due to rising sea levels, coastal erosion, flooding, and extreme weather events, which are exacerbated by ongoing urbanization and population growth (Serrao-Neumann et al., 2014). These impacts have profound social, economic, and environmental consequences, making adaptation strategies critical for ensuring resilience and sustainability.

2. Smart and Adaptive Coastal Living (SACL) Theoretical Framework

In this study, the authors utilizes various literature as an important step in determining the research variables. The relevance between the concept of disaster adaptation and the dimensions of Smart Living contributes to the understanding of the focus of this research, enabling readers to view the community as its primary user (Figure 1). Before determining the research variables, an analysis of the relevance between the concept of disaster adaptation and the dimensions of Smart Living has been conducted. The focus of the research is on disaster adaptation and the dimensions of Smart Living, thereby viewing the community as the main users. Consequently, regional policies must center around the community and encompass issues such as disaster risk reduction, response to disasters, livability, and the provision of services and information for the community. The observed concept of adaptation focuses on the responses, both conscious and unconscious, of coastal communities to shocks caused by tidal flood disasters through long-term approaches or initiatives aimed at reducing high-risk areas and carrying out post-disaster recovery, which tends to follow socio-economic pathways and is supported by financing, policy changes, and the provision of infrastructure from the government, thereby forming a resilience action (ACF International, 2013; Handayani et al., 2019; Jumatiningrum & Indrayati, 2021; Gaborit, 2022).

From here, a significant concept emerged known as SACL which is a concept aimed at realizing a higher quality of life for coastal communities by implementing adaptive solutions to confront environmental changes caused by coastal disasters, in order to create an efficient and sustainable living. It contains four main dimensions that have been explained in Figure 1.

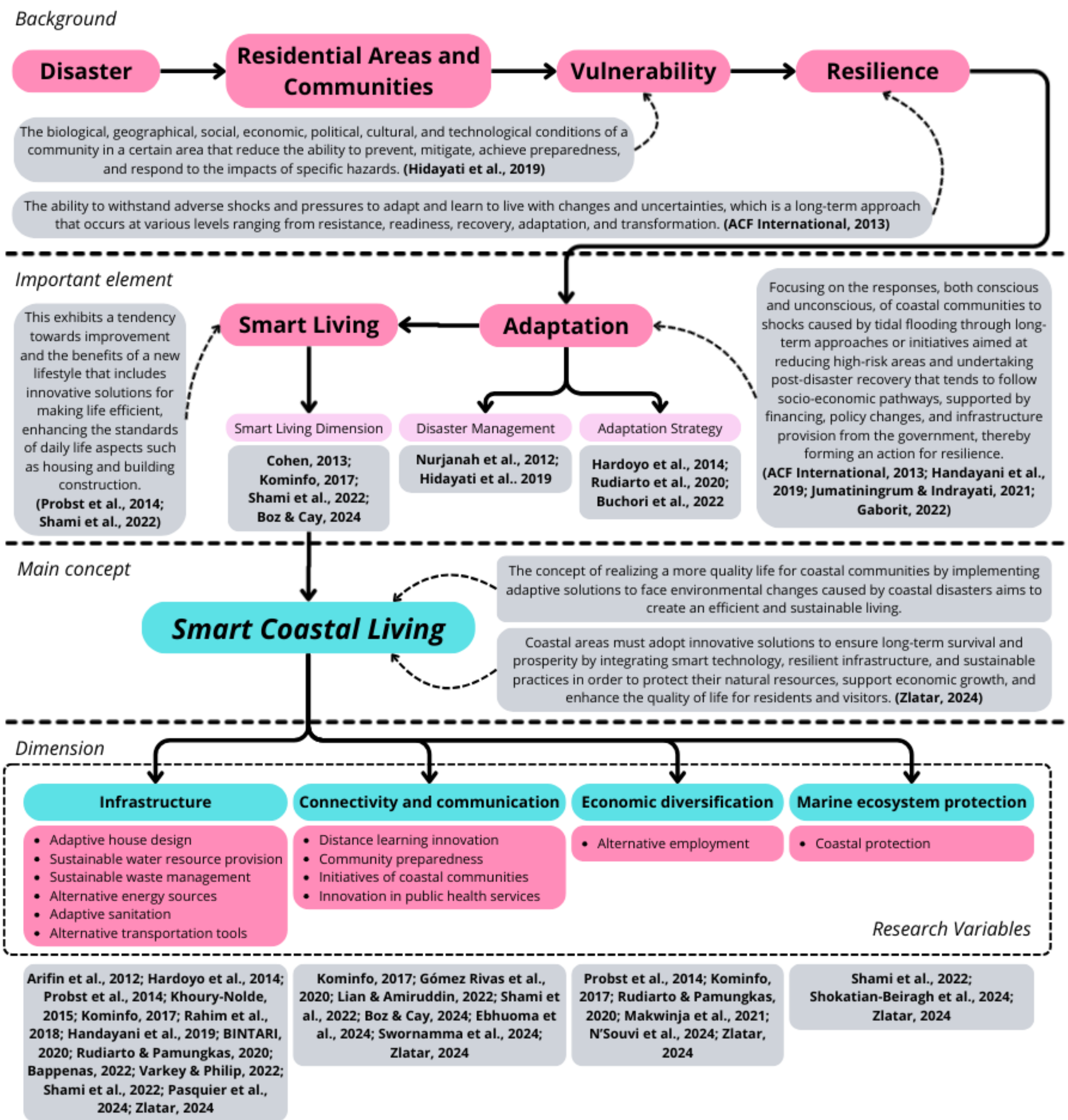


Figure 1. SACL Theoretical Framework
Source: Analysis Results, 2025

3. Methods

3.1. Study Area

Pekalongan Regency is part of the northern coast area that is very vulnerable to flood disasters, with the potential for physical and economic losses from floods classified as high (Muktiali & Setiadi, 2022), so the impact of tidal flooding felt by the coastal community directly impact the decline in their economy and quality of life. Homes and fishponds in the area north of the dam/long storage are still affected by the tidal flooding due to the overflow of water, which leads to an increase in the water body in the northern part of Wonokerto District (Rudiarto et al., 2018; Fandari & Nindita, 2021). The plan for the relocation of settlements by the Pekalongan Regency Government is not supported by the residents' desire to move, as most of them are fishermen who feel burdened when living far from their means of livelihood and do not have the funds to purchase land and construct new houses elsewhere. Therefore, they prefer to survive and adapt to the tidal flooding. More coastal communities are choosing to adapt and live harmoniously with flooding and other coastal disasters rather than relocating to safer areas (Hamdani et al., 2022).

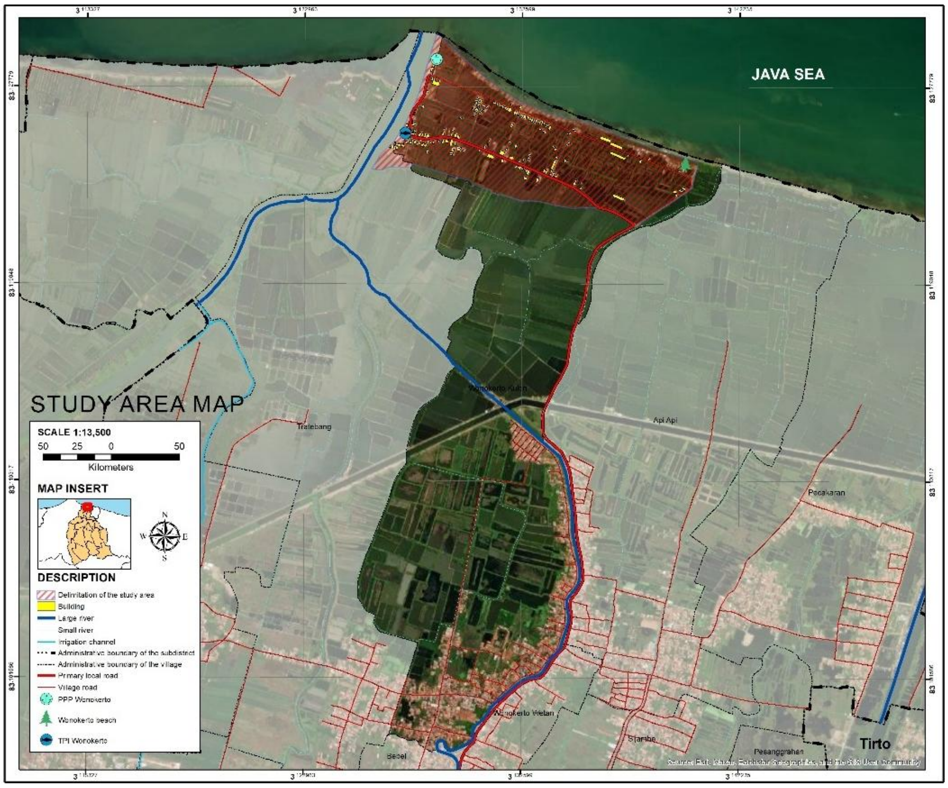


Figure 2. Study Area Map
Source: Spatial Planning Policy of Pekalongan Regency, 2020-2040; Observation, 2025

This research focuses on the settlements in Dukuh Pantairejo, Wonokerto Kulon Village, Wonokerto District, Pekalongan Regency. Pantairejo is the only settlement located to the north of the long storage dam and is frequently inundated by tidal flooding (Figure 2). Pantairejo consists of 199 households and 641 individuals. The coastline of Pekalongan Regency, which stretches 8.22 km (Badan Informasi Geospasial, 2022), has long been affected by tidal flooding since 2002. Wonokerto District, includes Pantairejo within it has experienced tidal flooding since 2010, which has increasingly worsened each year due to the malfunctioning water pumping machines, land subsidence, as well as the increasing abrasion from sea water and the logging of mangroves along the coast (Fandari & Nindita, 2021). The high rainfall due to climate change contributes to the increased runoff that flows toward the river estuary. The prevalence of illegal constructions on riverbanks, combined with high sedimentation and accumulation of waste, renders the rivers in Pekalongan Regency unable to accommodate this runoff, resulting in overflow onto land and causing tidal flooding.

3.2. Data Collection

The implementation of data collection, both primary and secondary data, is conducted through several methods. First, the authors distributed the questionnaires to 45 respondents who are residents of Pantairejo, representing 22.6% of 199 households, with characteristics that tend to be homogeneous, both in terms of economy, daily activities, and flood adaptation efforts uses a simple random sampling system. There are 4 (four) dimensions and 12 (twelve) research variables related to flood adaptation (Table 1). In addition, field observation is carried out by observing the existing physical objects in the study area as supporting data in assessing the implementation of Smart and Adaptive Coastal Living. The authors also conducted interviews with the government and involved parties, as well as document reviews, to explore the existing hexahelix collaboration as a support for improving the quality of life and adaptation to tidal flooding.

Table 1: Assessment Variables of SACL

Dimension	Variable	Indicator	Score Scales
$SACL_1$ - Infrastructure	I_1 - Adaptive house design	– The existence of floating/stilt houses – Efforts to raise the floor – The presence of embankments/retaining walls around the house	0-20 (Non-smart adaptive)

Dimension	Variable	Indicator	Score Scales
		– Special measures to prevent water from entering the house	21-40 (Basic smart adaptive)
	I_2 - The provision of sustainable water resources	– The existence of rainwater harvesting – Alternative sources of clean water that are non-well – Water consumption efficiency	
	I_3 - Sustainable waste management	– The existence of 3R waste management	41-60 (Moderately smart adaptive)
	I_4 - Alternative energy sources	– The existence of available alternative energy sources – The efficiency of electricity consumption.	
	I_5 - Adaptive sanitation	– The existence of adaptive toilets.	61-80 (Smart adaptive)
	I_6 - Alternative modes of transportation	– The existence of alternative non-land means of transportation – Alternative routes for community mobility when the road is submerged in flash floods	
$SACL_2$ - Connectivity and communication	K_1 - Distance learning innovations	– Existence of a distance learning system – Ownership of distance learning support devices	81-100 (Highly smart adaptive)
	K_2 - Community preparedness	– The existence of an early warning system – The existence of a community of people – Methods of disseminating disaster information in the community – Other preparedness measures	
	K_3 - Coastal community initiatives	– Community participation in environmental cooperation	
	K_4 - Public health service innovation	– The existence of telemedicine services	
$SACL_3$ - Economic diversification	AE - Alternative employment	– The existence of non-fishery livelihoods as an alternative income	
$SACL_4$ - Marine ecosystem protection	CP – Coastal protection	– The existence of coastal protection activities	

Source: Arifin et al., 2012; Cohen, 2013; Hardoyo et al., 2014; Probst et al., 2014; Khoury-Nolde, 2015; Kominfo, 2017; Hidayati et al., 2019; BINTARI, 2020; Gómez Rivas et al., 2020; Rudiarto & Pamungkas, 2020; Jumatiningrum & Indrayati, 2021; Makwinja et al., 2021; Bappenas, 2022; Lian & Amiruddin, 2022; Varkey & Philip, 2022; Shami et al., 2022; Boz & Cay, 2024; Ebhuoma et al., 2024; N'Souvi et al., 2024; Pasquier et al., 2024; Shokatian-Beiragh et al., 2024; Swornamma et al., 2024; (Zlatar, 2024); Analysis Result, 2025

The context of smart in this research does not solely hinge on technological sophistication, but is viewed more from the aspect of how adaptive the community is in responding to coastal disasters. In the efforts undertaken by the community, there is certainly an influence from individual willingness and capacity, which in turn shapes an outcome that can be assessed as effective or not in disaster management. The increasing number of initiatives to create alternative actions indicates that the community has the desire to seek solutions to the problems they face. Similarly, the rising capacity of individuals, whether in the form of environmental awareness, knowledge, or insight, can also affect the outcomes achieved. The scoring is adjusted according to the respondents' answers on the questionnaire, where each answer has a representation level from SACL, which are then adjusted to the index range of 0-1 (Table 2), dividing it according to the levels of community adaptation efforts to tidal flood disasters in coastal areas, with the results as follows:

Table 2: Achievement Score and Level of SACL

Score	Index	Category	Interpretation
81-100	≥ 0,81	Highly smart adaptive	The adaptation efforts have been very good, intelligent, and sophisticated.
61-80	0,61 – 0,80	Smart adaptive	The efforts to adapt to coastal disasters are becoming more innovative and smarter.
41-60	0,41 – 0,60	Moderately smart adaptive	Adaptation efforts for coastal disasters are beginning to develop with new alternatives.
21-40	0,21 – 0,40	Basic smart adaptive	There have been conventional adaptation efforts to coastal disasters.
0-20	< 0,21	Non-smart adaptive	Adaptation efforts are either nonexistent or are limited in scope.

Source: Analysis Results, 2025

The researcher conducted validity and reliability tests on the instrument prior to processing data from the distributed questionnaires to determine the accuracy and precision of the data. Validity is an index that indicates whether a measuring instrument truly measures what it is intended to measure, whereas reliability is an index that indicates the extent to which a measuring instrument can be trusted or relied upon (Sugiono, 2005). Validity and reliability tests were conducted on the $SACL_1$ and $SACL_2$ dimensions. Based on the results of the validity tests that have been conducted, 13 questions in the $SACL_1$ and 8 questions in the $SACL_2$ were declared valid because their correlation values (calculated R) ≥ 0.294 or *p-value* < 0.05, so all questions could be used in the subsequent analysis (Table 3).

Table 3: Validity Test Results

Dimension	Item	R-Calculated	R-Table	P (sig.)	Description
$SACL_1$	Q_1	0,636	0,294	0,000	Valid
	Q_2	0,624	0,294	0,000	Valid
	Q_3	0,633	0,294	0,000	Valid
	Q_4	0,646	0,294	0,000	Valid
	Q_5	0,645	0,294	0,000	Valid
	Q_6	0,645	0,294	0,000	Valid
	Q_7	0,623	0,294	0,000	Valid
	Q_8	0,548	0,294	0,000	Valid
	Q_9	0,539	0,294	0,000	Valid
	Q_{10}	0,633	0,294	0,000	Valid
	Q_{11}	0,690	0,294	0,000	Valid
	Q_{12}	0,554	0,294	0,000	Valid
	Q_{13}	0,427	0,294	0,003	Valid
$SACL_2$	Q_{14}	0,752	0,294	0,000	Valid
	Q_{15}	0,762	0,294	0,000	Valid
	Q_{16}	0,759	0,294	0,000	Valid
	Q_{17}	0,448	0,294	0,002	Valid
	Q_{18}	0,733	0,294	0,000	Valid
	Q_{19}	0,730	0,294	0,000	Valid
	Q_{20}	0,458	0,294	0,002	Valid
	Q_{21}	0,773	0,294	0,000	Valid

Source: Analysis Results, 2025

In the reliability test, the research is considered reliable if the obtained Cronbach's Alpha value is greater than 0.60, in accordance with reliability criteria (Sugiyono, 2005). T Based on the results of the reliability test, all research instruments showed a Cronbach's Alpha value greater than 0.60. These findings indicate that each question in $SACL_1$ and $SACL_2$ in the instrument has good internal consistency and is able to measure the construct reliably (Table 4). Therefore, the instruments used in this study are considered reliable and can proceed to the next stage of analysis.

Table 4: Reliability Test Results

Dimension	Cronbach's Alpha	N of Item	Description
$SACL_1$	0,838	13	Reliable
$SACL_2$	0,797	8	Reliable

Source: Analysis Results, 2025

Although $SACL_3$ and $SACL_4$ were not subjected to statistical validity and reliability tests because each consists of only a single question item, the question items can still be used in the research. This is because the questions were formulated based on a clear theoretical foundation and have undergone conceptual consideration and assessment (content validity) as well as adaptation to field conditions, thus being deemed capable of representing the construct being measured. Therefore, the items in both dimensions are considered appropriate and can be used as measurement instruments in this study.

3.3. Methods and Analysis

This research utilizes a quantitative approach to achieve objectivity and neutrality, measuring using numerical data, employing survey and experimental strategies, conducting measurements and observations (Muhajirin et al., 2024). This approach involves the distribution of questionnaires to a sample of local residents living in Pantairejo, followed by scoring analysis with weighting on the attainment of the Smart and Adaptive Coastal Living dimensions related to flood adaptation. Through this numerical analysis, the level of achievement of the dimensions in question can be determined. Field observations and document reviews support this research in terms of exploring and assessing the success of existing development programs on improving quality of life and adaptation to tidal flooding.

Scoring is conducted by summing the scores from each statement answered by the respondents using the basic scoring formula with the Likert scale. There are 4 (four) answer scales that serve as measures of the attitudes, opinions, and perceptions of respondents towards a social phenomenon (Sugiyono, 2017). The reason for selecting 4 answer scales is to eliminate the middle value (odd-numbered choices) which is usually more frequently chosen by respondents who feel indecisive or uninterested in answering. Below is the formula for the Likert scale that is used:

$$S_i = \sum_{j=1}^{n} X_{ij} \tag{1}$$

where: S_i = Total score of respondent -i
X_{ij} = Score of respondent - i answer to statement -j
n = Number of statements in the questionnaire

The next step is to normalize the scores obtained into an index ranging from 0 to 1 to facilitate the comparison of achievements among different variables or dimensions. The lowest index, which is 0, indicates that the community is neither intelligent nor adaptive, while the highest index of 1 interprets the community as being the most intelligent and adaptive. The method used is Min-Max normalization, which is carried out to interpret the index after scoring is completed. Min-Max Normalization is a normalization method that changes the range of data values to between 0 and 1 using the following formula (Izonin et al., 2022):

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \tag{2}$$

where: X' = Normalized value
X = Variabel score
X_{min} = The smallest score that can be obtained by the variable
X_{max} = The largest score that can be obtained by the variable

4. Results and Discussions

The stages of analysis of the adaptation of the community of Dukuh Pantairejo to flooding disasters in supporting the implementation of the SACL concept in the coastal areas of Pekalongan Regency have been conducted by exploring 4 dimensions of SACL with 12 key variables that are considered to contribute positively both to the adaptation process and the implementation of the concept, namely: 1) infrastructure (I_1-I_6); 2) connectivity and communication (K_1-K_4); 3) economic diversification (ED); and 4) protection of marine ecosystems (ME).

4.1. Infrastructure

An adaptive house exemplifying efforts to cope with tidal flooding is the stilt house/floating house (Varkey & Philip, 2022; Pasquier et al., 2024). Unfortunately, this type has yet to be found. The adaptations made primarily involve raising the floor level. 53.3% of the houses in Dukuh Pantairejo are still not higher than the surrounding ground level, making it a priority to address in order to enhance the safety of both the household and its occupants. In addition to raising the floor, there are also embankments around the house that can prevent water from entering. However, the reality is that a significant portion of the houses in the study area remains highly susceptible to tidal flooding due to the absence of embankments around them (53.3%), leading to minimal protection and increasing the likelihood of water intrusion into the homes. No specific efforts were made to prevent water from entering; their solution to secure the belongings was more about creating a higher platform/place to temporarily place those items.

For the variable of sustainable water resource provision, we consider rainwater harvesting as a best practice that can serve as a standard for smart adaptation. Unfortunately, this innovation has not yet been found at the study location. The community solely relies on the village's pump well. Nearly half of the total residents of Pantairejo (48.9%) prefer to wait for water supply from this well when it experiences functional issues. Only 31.1% of the community takes the initiative to store water in specific pools/tanks for reserves or to source water from other possible locations, such as the nearest village Api-Api (20.0%).

In the variable of sustainable waste management, the 3R (Reduce, Reuse, Recycle) approach has not been implemented yet, as the people of Pantairejo still dispose of waste in illegal sites or burn household waste independently near their homes. They have not considered healthier waste processing alternatives that do not generate pollution and could contribute to their income. Unmanaged waste poses a potential risk of contaminating coastal environments, reducing fish catch, and increasing the risk of diseases. Similarly, alternative or renewable energy sources such as wind turbines, solar power, or other technologies and smart innovations have yet to be established in Dukuh Pantairejo. The dependency on PLN electricity remains at 100%. Furthermore, the awareness to save electricity is still lacking, as evidenced by the dominance of 24-hour electricity usage without restrictions (44.4%).

In the variable of adaptive sanitation, adaptive toilets are established as a baseline for smart innovation (BINTARI, 2020). Unfortunately, this innovation has not yet been realized as sanitation remains a significantly poor aspect in this region, as some members of the community still have to bathe and defecate in rivers or makeshift toilets. This contrasts with the variable of alternative transportation tools which have been found in the study area, where 37.8% of the population owns boats or canoes as supporting transportation means for their mobility as fishermen or during floods (Figure 3). This is facilitated by the existence of navigable river routes. For those without boats or canoes, they can still traverse areas that are not affected by floodwaters.

Figure 3. The boat/jukung owned by the community of Pantairejo
Source: Observation, 2025

From the scoring calculations (Table 5), a final index of 0.159 was obtained, indicating that the infrastructure in the Dukuh Pantairejo area is still inadequate and unsuitable as a form of settlement service that must adapt to tidal flood disasters on a daily basis.

Table 5: Analysis of Variables in the Dimension of Infrastructure

Indicator	Percentage	Score	Index	Average Index
I_1 - Adaptive house design				**0,263**
Existing designs of community houses		**45**	**0,000**	
a. **The house is still in the form of a landed house**	**100.0%**	45		
b. The house is already in the form of a floating house	0.0%	0		
Raising the floor of the house to prevent it from being inundated by tidal flooding		**138**	**0,689**	
a. The floors of the house are entirely level with the height of the ground surface outside the house	17.8%	8		
b. We are currently planning to raise the floor of the house	4.4%	4		
c. Some floors of the house are elevated to prevent water from entering the house	31.1%	42		
d. **The entire structure of the house is now significantly elevated above the ground level outside the house**	**46.7%**	84		
The presence of embankment around the house		**94**	**0,363**	
a. **There are no embankments around the house.**	**53.3%**	24		
b. Create incidental embankments during tidal flooding	0.0%	0		
c. There are embankments in certain areas that serve as entry points for water	31.1%	42		
d. Build embankments around the house	15.6%	28		
Special efforts to prevent water from entering the house		**45**	**0,000**	

Indicator	Percentage	Score	Index	Average Index
No response	**100.0%**	45		
I_2 - Provision of sustainable water resources				**0,101**
Rainwater harvesting as an effort to provide water for household needs		**45**	**0,000**	
a. **Not practicing rainwater harvesting**	**100.0%**	**45**		
b. Already practicing rainwater harvesting	0.0%	0		
Alternative sources of water supply when the existing well is not operational		**86**	**0,304**	
a. **Simply waiting for the existing well to become operational again**	**48.9%**	22		
b. Storing well water in several ponds/tanks for supply	31.1%	28		
c. Purchasing clean water from outside Pantairejo	0.0%	0		
d. Sourcing water from other feasible locations	20.0%	36		
Special efforts for water consumption efficiency		**45**	**0,000**	
No response	**100.0%**	**45**		
I_3 - Sustainable waste management				**0,000**
Waste management 3R (Reduce, Reuse, Recycle)		**45**	**0,000**	
a. **Not yet**	**100.0%**	45		
b. Already	0.0%	0		
I_4 - Alternative energy sources				**0,115**
Alternative sources of energy besides PLN electricity		**45**	**0,000**	
a. **Only using PLN**	**100.0%**	45		
b. Having alternative sources of electricity from wind turbines/water mills/others	0.0%	0		
Efforts to enhance electricity consumption efficiency in households		**76**	**0,230**	
a. **Electricity is utilized 24 hours to support the comfort of residents, including lights, fans, TVs, and other appliances that are continuously operational throughout the day**	**44.4%**	20		
b. Using electricity according to household needs	42.2%	38		
c. Reducing the use of lights during the day, and refraining from turning on air conditioning or fans at night	13.3%	18		
d. Limiting the use of lights in certain rooms only at night and utilizing energy-efficient electronic devices.	0.0%	0		
I_5 - Adaptive sanitation				**0,000**
Availability of floating toilets		**45**	**0,000**	
a. **Not available**	**100.0%**	45		
b. Already has floating toilets	0.0%	0		
I_6 - Alternative mode of transportation				**0,472**
Ownership of alternative transportation tools during tidal flooding		**96**	**0,378**	
a. **Do not own any transportation tools other than bicycles/motorcycles/cars**	**62.2%**	28		
b. Own a boat/small boat	37.8%	68		
Alternative routes for mobility when roads are inundated by tidal flooding		**121.5**	**0,567**	
a. Still trapped inside the house until the water recedes	24.4%	11		
b. **There are roads that are not affected by tidal flooding that can be traversed**	**37.8%**	42.5		
c. There are river routes accessible by boat/small boat	**37.8%**	68		

$$\text{SCL}_1 = \frac{I_1 + I_2 + I_3 + I_4 + I_5 + I_6}{6} = \frac{0{,}263 + 0{,}101 + 0{,}000 + 0{,}115 + 0{,}000 + 0{,}472}{6} = 0{,}159$$

Source: Analysis Results, 2025

4.2. Connectivity and Communication

This dimension focuses on strengthening technology-based communication networks and community preparedness. The first variable is innovation in distance learning. The final score of this dimension is 0.293, which indicates that the community of Pantairejo is superior in terms of connectivity and communication compared to the infrastructure dimension, especially regarding the initiatives of coastal communities that possess a strong sense of mutual cooperation.

Children in the study area attending school still employ conventional learning methods, and they continue to arrive on time for classes, even though they have to traverse floodwaters in their vicinity. Online learning has not yet been implemented in the study location, unlike the widespread adoption observed since the Covid-19 pandemic. This situation is significantly influenced by the economic conditions of the community and their habits in the use of technology, which remain very minimal.

In the variable of community preparedness, there remains a lack of effectiveness in the study location, particularly regarding the early warning system for disasters that pertains to advanced technology. On the other hand, regarding the presence of active and responsive community groups in disaster management and environmental conservation, it was found that 35.6% of the population believes such groups exist. One of the active community organizations in the study area is the Forum Peduli Rob (FPR). To access weather information to anticipate tidal flooding, only 6.7% of the population is accustomed to checking weather forecasts, while 11.1% verify tidal information sourced from the Wonokerto Naval Post or independently visit the website of the Meteorology and Geophysics Agency (BMKG) provides daily weather forecasts around the Wonokerto Coastal Fisheries Port (Table 6).

For the variable of coastal community initiatives in this dimension, it is a leading variable due to its highest index. Almost the entire community is willing to contribute, ranging from suggestions/ideas, labor, to collective funding contributions (80.0%). Based on these responses, we can ascertain that the community frequently incurs personal costs for flood management contributions. Therefore, there is a need for specific financial planning for disaster preparedness, as the financial aspect of families plays a crucial role in the community's capacity to adapt and recover from disasters. However, this proves to be quite challenging for coastal communities due to financial constraints and cultural values that influence their perspectives on financial planning (Setiadi & Frederika, 2022).

For the last variable, the innovation of telemedicine services as a form of innovation in the healthcare sector is considered not yet known to the community of Pantairejo. The majority of the population (86.7%) still needs to come directly to the nearest Health Center/Hospital/Healthcare Workers when they are ill (Figure 3). In fact, this innovation would greatly assist the community in obtaining healthcare services as quickly as possible by minimizing their mobility, especially during flooding events and in areas that are difficult to access for medical personnel.

Table 6: Analysis of Variables in the Dimensions of Connectivity and Communication

Indicator	Percentage	Score	Index	Average Index
K_1 - Innovations in distance learning				**0,307**
Learning methods in children's schools		**91**	**0,341**	
a. Students choose not to go to school during tidal flooding	4.4%	2		
b. **Students still arrive on time despite the tidal flooding conditions**	**88.9%**	80		
c. Class hours adjust to the tidal flood's ebb and flow	6.7%	9		
d. Learning is altered to an online system during tidal flooding	0.0%	0		
Ownership of distance learning support devices		**82**	**0,274**	
a. **Does not own**	**53.3%**	24		
b. Borrows from neighbors/siblings if needed	11.1%	10		
c. Owns a smartphone for online learning activities	35.6%	48		
d. Owns a computer/laptop and smartphone for online learning	0.0%	0		
K_2 - Community Preparedness				**0,220**
The existence of an early warning system for tidal flood disasters		**45**	**0,000**	
a. **Not yet**	**100.0%**	45		
b. Already	0.0%	0		
The presence of community groups that are active in disaster management and environmental preservation		**129**	**0,622**	
a. None	15.6%	7		
b. There are individuals who are active and care about the environment	17.8%	16		
c. There are community groups but they are not active	31.1%	42		
d. **There are active community groups that are responsive in disaster management and environmental preservation**	**35.6%**	64		
How the community obtains information to anticipate the occurrence of tidal flooding		**80**	**0,259**	
a. **No specific actions as they are already accustomed to it**	**51.1%**	23		
b. Engaging in activities during safe hours and returning home promptly during known high-risk hours	31.1%	28		
c. Observing weather forecasts	6.7%	9		
d. Checking tidal sea water information on local port websites or the Ministry of Maritime Affairs' website	11.1%	20		
Other actions for flood preparedness		**45**	**0,000**	

Indicator	Percentage	Score	Index	Average Index
No response	**100.0%**	45		
K_3 - Coastal community initiatives				**0,600**
Community cooperation in the face of flood disasters		**126**	**0,600**	
a. None	0.0%	0		
b. Only a handful of people participate & it is done incidentally when needed	20.0%	18		
c. **The entire community is willing to contribute, ranging from suggestions/ideas, manpower, to joint financial contributions**	**80.0%**	108		
d. The entire community is active and utilizes technology in their cooperative efforts	0.00%	0		
K_4 - Innovations in Public Health Services				**0,044**
Habits of Using Telemedicine Services When unwell		**51**	**0,044**	
a. **Unaware of telemedicine and still required to visit the nearest Health Center/Hospital/Healthcare Provider in person when sick**	**86.7%**	39		
b. Aware of telemedicine but uninterested in using it, preferring to visit the nearest healthcare facility in person	13.3%	12		
c. Aware of telemedicine services but unable to utilize them in my area, and more often calling healthcare providers to my home	0.0%	0		
d. Regularly use applications on mobile phones such as Halodoc/Alodokter/KlikDokter/others to access remote health services	0.0%	0		

$$\text{SCL}_2 = \frac{K_1 + K_2 + K_3 + K_4}{4} = \frac{0{,}307 + 0{,}220 + 0{,}600 + 0{,}044}{4} = 0{,}293$$

Source: Analysis Results, 2025

4.3. Economic Diversification

Economic diversification has only one variable, which is alternative employment. The growth of the fisheries and marine sector in Wonokerto District in 2023, at 39.1%, is deemed significant, evidenced by an increase in income amounting to 4.2 billion and the economic valuation of coastal fishery natural resources reaching Rp1,442,604,000 per year (Pamungkas et al., 2024). Given this substantial income, innovation is necessary to establish resilience in income sources amidst the existing challenges of tidal flooding. The selection of alternative jobs as an additional source of income can serve as a solution for the sustainability of the community's economy. Economic diversification can utilize land in areas less affected by tidal flooding or choose other sectors that also have the potential to provide economic benefits, such as local business development or investment (Makwinja et al., 2021).

The analysis reveals that more than half of the population (64.4%) still relies on marine and coastal resources as they are only employed in the fisheries/marine sector. Only 26.7% have additional supporting jobs such as: 1) selling at Wonokerto Beach; 2) working in the office sector; 3) operating a tire repair service; 4) being an employee at the Wonokerto Beach Tourist Management; 5) duck farming; and 6) seaweed farming. The availability of these alternative jobs enhances this dimension, where the final index value for this dimension is 0.541 (Table 7).

Table 7: Analysis of Variables in the Dimension of Economic Diversification

Indicator	Percentage	Score	Index	Average Index
AE – Alternative Employment				**0,541**
Other jobs outside the fisheries sector		**118**	**0,541**	
a. Not working	0.0%	0		
b. **Only working in the fisheries/aquatic sector**	**64.4%**	58		
c. Only working in the non-fisheries/aquatic sector	8.9%	12		
d. Working in the fisheries/aquatic sector and having additional sources of income	26.7%	48		

Source: Analysis Results, 2025

4.4. Marine Ecosystem Protection

This dimension is viewed through the variable of coastal protection as the most likely action to be taken by coastal communities and is greatly needed by coastal and marine ecosystems to support the sustainability and resilience of the existing environment. The impact of these actions will become increasingly significant if carried out on a massive and organized scale. Almost half of the community is willing to participate in mangrove planting activities around the beach and river estuaries in groups (48.9%). This is also supported by the village government, the district government, and several environmental organizations active in Pekalongan Regency. The final index for this dimension is 0.437 (Table 8). There needs to be persuasive efforts from the local government to provide knowledge and raise environmental awareness among the community so that they can be more active in these activities.

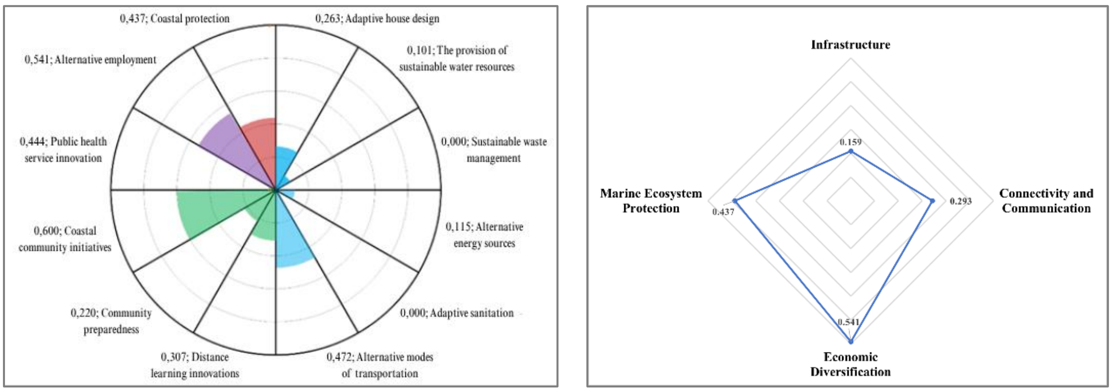
Table 8: Analysis of Variables in the Dimension of Marine Ecosystem Protection

Indicator	Percentage	Score	Index	Average Index
CP - Coastal Protection				**0,437**
Community Actions in Efforts for Coastal Protection		**104**	**0,437**	
a. No specific efforts	40.0%	18		
b. Conducting socialization and environmental awareness training	0.0%	0		
c. **Organizing group activities for the planting of mangroves around the beach and river mouths**	**48.9%**	66		
d. Forming special teams from the community to be more intensive in coastal protection	11.1%	20		

Source: Analysis Results, 2025

4.5. Dimension Assessment

Based on the analysis conducted on 12 observed variables in this study, the most dominant variable is the initiative of coastal communities (K_3) with an index value of 0.600; alternative employment (AE) with an index of 0.541; and alternative mode of transportation (I_6) with an index of 0.472 (Figure 4). This indicates that the capacity of the community is based on a strong initiative for mutual cooperation, suggesting that the community is more resilient in social aspects. Local residents are motivated to remain in their community due to strong emotional bonds with their neighbors. The spirit of togetherness and mutual assistance among residents, especially during disasters, further enhances their sense of community (Buchori et al., 2021). For the variables that are weak in their implementation in the field, namely sustainable waste management (I_3) with an index of 0.000; adaptive sanitation (I_5) with an index of 0.000; and innovation in public health services (K_4) with an index of 0.044. This is due to the absence of the 3R waste management concept and floating toilets/latrines in the study area.



(a) (b)

Figure 4. Radar Chart of SACL Context: (a) Variables and (b) Dimension
Source: Analysis Results, 2025

The low scores in the $SACL_1$ dimension are caused by the very basic provision of environmental infrastructure and there is still a lack of innovation aimed at intelligence and the efficient use of natural resources. Without better infrastructure improvements, the adaptation and resilience of the Pantairejo community to tidal flooding in the long term will remain weak. The absence of adaptive housing (I_1) indicates a high risk of property damage due to tidal flooding, which can result in higher home repair costs. Communities are required to spend significant amounts on raising their home floors every few years and must exert additional effort to secure their belongings whenever tidal flooding occurs. For some coastal communities, raising the floor is viewed as ineffective in addressing the tidal flooding phenomenon, leading them to prefer elevating household items, which they consider more effective in dealing with the incoming water, in conjunction with other adaptations (Rudiarto et al., 2020). The innovation of constructing floating homes could serve as an alternative for communities reluctant to relocate. The enhancement of the functionality and capacity of the pier, equipped with wave breaker infrastructure to protect the coastline, is also necessary to support the activities of fishermen in coastal areas (Setiadi et al., 2023).

The absence of rainwater harvesting initiatives leading to a high dependency on groundwater sources, with little significant effort towards water consumption efficiency by the community. The current tidal flooding occurring in Pekalongan Regency is a consequence of ongoing land subsidence (Griselda et al., 2021), primarily caused by uncontrolled groundwater exploitation. Therefore, it is necessary to impose restrictions on groundwater exploitation in the northern region of Pekalongan Regency by transforming the sources of water utilized, one of which is through rain harvesting. The identification of I_3 presents an opportunity to develop educational programs for sustainable community-based waste management by collecting waste from both households and tourism activities at the beach. Full dependence on PLN electricity without the utilization of renewable energy, renders the community increasingly powerless. The opportunity to utilize alternative energy sources, particularly solar panels, can serve as a solution for areas that frequently experience power outages. This area also unprepared to face flooding conditions due to the high potential risk of waste contamination to water sources during tidal flooding. I_6 is quite dominant due to the efforts made in terms of mobilization. With the increasing likelihood of tidal flooding frequency, there should be more households equipped with alternative transportation tools such as small boats or emergency rafts that can help the community remain active during tidal floods. They need the development of water-based evacuation routes, because that boats can be used to evacuate flood victims from their homes and assist them in reuniting with their families (Curtis et al., 2024).

The $SACL_2$ dimension still faces many challenges, as the high initiatives and participation of coastal communities are not supported by knowledge about tidal flooding and disaster management. There is a need for persuasive efforts to encourage the community to learn more about disaster management. It is also crucial to observe on internet and telecommunications access so that the community does not encounter difficulties in receiving emergency information, especially during disasters. Variable K_1 are not yet dominant that make a lag in the education sector for children in disaster-affected coastal areas. Local governments must develop a more flexible curriculum for emergency situations to avoid educational disparities caused by disasters. It is necessary to enhance the use of advanced communication devices as a means of accessing climate information to improve variable K_2. Otherwise, this could hinder community communication in taking preparedness actions and responding to specific natural disasters (Evariste et al., 2018).

Contrary to the community's preparedness being still reactive, K_3 is the most dominant in this dimension. Suburban residents tend to have a higher willingness to participate in social activities, such as becoming members of community organizations and cooperating among themselves to maintain/protect their residential areas (Buchori et al., 2022). They may develop stronger social/place attachments and greater awareness of disaster occurrences through such willingness. This high level of mutual cooperation indicates that the Pantairejo community possesses a commendable capacity for social adaptation. Strong social ties can build resilient communities as individuals are interconnected and support each other during disaster response and recovery through enhanced participation and the sharing of information and resources among groups and individuals (Curtis et al., 2024). The educational support from the Pekalongan Regency Government can enhance the existing social capital into a more structured community preparedness system. The government must actively involve local communities in formulating policies related to disaster management, as local knowledge is deemed effective in controlling and managing tidal flooding in coastal areas, with the hope that the planned programs and policies will be more precise (Pamungkas et al., 2024). The majority of the community still relies on direct healthcare services without the utilization of technology such as telemedicine, though telemedicine could become a solution for areas affected by tidal flooding that are difficult for medical personnel to access, as telemedicine facilitates remote clinical support and addresses challenges caused by limited mobility or patient transfer, reducing unnecessary visits to clinics, and is useful in mitigating the risk of disease transmission (Gómez Rivas et al., 2020).

$SACL_3$ dimension as the strongest one, characterized by the presence of job alternatives to avoid dependence solely on the fisheries and maritime sector. The selection of non-fishing and non-maritime livelihoods has become a solution for the Pantairejo community, as economic activities along the coastline, such as agriculture, aquaculture, fisheries, and tourism, are already vulnerable to the impacts of climate change and rising sea levels, which can exacerbate the vulnerability of coastal areas (Swornamma et al., 2024). This economic diversification requires government support, as failure to do so may lead to a decline in the spirit of the local community due to a sense of helplessness from the lack of significant income improvements. The government can develop new skills training programs so that the community can adopt alternative livelihoods such as ecotourism or home-based production, or bridge the gap in access to capital and skills, enabling the entire community to expand employment in new sectors. The community can optimize the tourism sector and the environment, which can provide dual benefits, both in terms of revenue and environmental protection.

For the last variable, which is coastal protection (CP), we can observe that there have already been efforts to plant mangroves by the community, but these efforts are still not extensive enough to provide optimal protection against abrasion and the intrusion of seawater onto land. If the mangrove rehabilitation program continues to be encouraged to be carried out independently, the coastal areas of Pekalongan Regency could be better protected from the impacts of abrasion, erosion, and tidal flooding in the future. Mangroves can be explored to reduce the risk of flooding, as they can act as a barrier against storm surges and mitigate coastal flooding in many tropical and subtropical areas (Shokatian-Beiragh et al., 2024).

4.6. Assessment of the Smart and Adaptive Coastal Living

The assessment of the SACL context aims to understand the adaptation efforts made by the community and to categorize them into levels based on the index values obtained. When viewed globally, the community's adaptation efforts in facing tidal flooding in the study area fall under the non-smart adaptive category, as the majority of variables are at this level (5 out of 12 variables), namely I_2; I_3; I_4; I_5; and K_4. In the basic smart adaptive category, there are 3 variables (I_1; K_1; and K_2), as conventional adaptation efforts have been identified, which reflect adjustment through traditional methods or old habits, such as raising building floors, the willingness to continue attending school despite having to wade through floodwaters, and the presence of an active community in disaster management (Figure 5). Furthermore, the variables I_6; K_3; AP; and PP fall into the category of moderately smart adaptive as they have developed new alternatives, such as the use of boats and the selection of other jobs outside the fisheries and marine sectors. The presence of these alternatives indicates that the community has taken the initiative to seek other solutions to address the challenges it faces.

The adaptation of the Pantairejo community has not yet reached the categories of smart adaptive or highly smart adaptive. This is due to the absence of innovations or advanced technologies that dominate the actions of the community, despite the K_3 variable approaching a threshold value of category 4, as this variable focuses on the high initiative of community cooperation to contribute to social activities in order to protect their settlement.

The increasing environmental crisis along the coastal areas demands swift adaptation to mitigate its impacts. The implementation of effective adaptation plans, including monitoring, community engagement, and capacity building, will enhance coastal sustainability and reduce the occurring climate impacts (Swornamma et al., 2024). Adaptation strategies should not be viewed as separate entities but as an integrated element of every relevant development policy in the region (Evariste et al., 2018).

Considering that the study area is dominated by marginalized groups, special attention is needed regarding this condition when formulating adaptation strategies. Muktiali & Setiadi (2022) state that in developing strategies to enhance resilience to flooding disasters, the government must provide urban infrastructure that ensures the sustainability of socio-economic activities of vulnerable communities, control land use change, and develop comprehensive and sustainable environmental conservation programs. This aligns with Rudiarto & Pamungkas (2020), who assert that better land use planning to control development is also a crucial strategy for mitigating disaster risks, as it can identify disaster-prone areas, allowing future development projects to be located in less disaster-vulnerable regions.

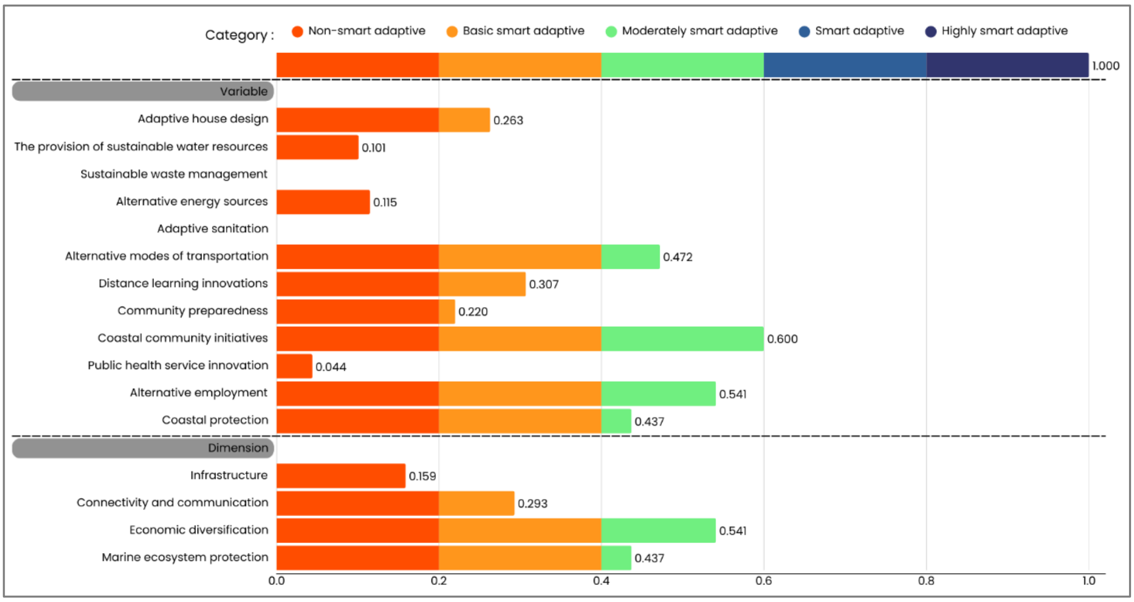


Figure 5. Achievements in the SACL Context
Source: Analysis Results, 2025

The principle of disaster resilience in the context of regional development is essential for every development initiative, where the community is seen as the subject within it (Indrasari & Rudiarto, 2020). As mentioned in this study, the community of Pantairejo has a portion that wishes to remain in place and not be relocated to other areas. A majority of the coastal residents of the Northern coast of Java share similar characteristics and mindsets. Their desire to move is not yet strong, and they are still waiting for conditions to worsen until they can no longer adapt (Buchori et al., 2021). Therefore, they must possess better resilience capabilities to withstand tidal flooding in order to maintain their quality of life. The government must be able to support the livelihoods of the community until it can provide better solutions.

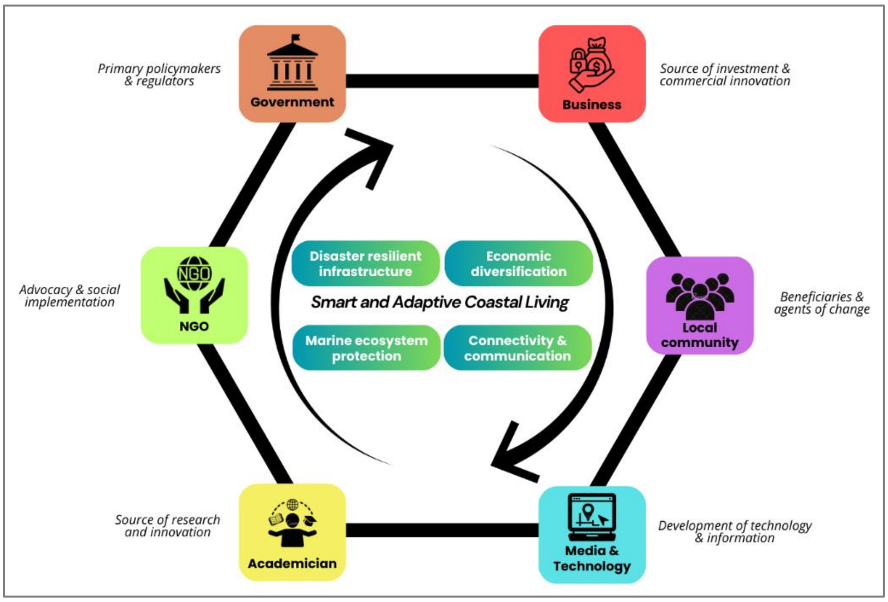


Figure 6. Hexahelix Collaboration in the Implementation of SACL Context
Source: Analysis Results, 2025

In implementing the SACL concept, local authorities need to use a multi-stakeholder approach such as the Hexahelix concept (Figure 6), which integrates the Pentahelix approach with technological elements such as IoT, Artificial Intelligence (AI), and big data. Overall, the actors involved must share the same goal of realizing a higher quality of life for coastal communities by implementing adaptive solutions to address environmental changes resulting from coastal disasters, in order to create an efficient and sustainable life. Therefore, active participation from all stakeholders is required. The six stakeholders involved in this collaboration each have their respective roles in optimizing efforts to achieve the goals of SACL (Table 9).

Table 9: The Role of Stakeholders in Hexahelix Collaboration in the Implementation of SACL

Stakeholder	Main Role	Description
Government – Pekalongan Regency Government – Central Java Provincial Government – Ministry of Public Works – Ministry of Housing & Settlements – Ministry of Marine Affairs & Fisheries – National Research and Innovation Agency (BRIN)	Key policymakers and regulators	– Formulating and integrating policies and regulations – Allocating budgets & incentives – Leading implementation of activities in the sector – Providing infrastructure & public services – Coordinating among stakeholders
Business & Private Sector – PLN (State Electricity Company) – Pertamina – Telkom Indonesia – PDAM Tirta Kajen – PDAB Tirta Utama – APINDO (Indonesian Employers Association) – Local MSMEs (Micro, Small, and Medium Enterprises)	Sources of investment and commercial innovation	– Participate in investment and development of disaster mitigation-based infrastructure – As a provider of Smart City-based solutions – Implementation of corporate social responsibility in the form of CSR
Non-Governmental Organization (NGO) – Mercy Corps Indonesia – Kemitraan – Dutch Water Authority – BINTARI – WALHI – Earthworm Foundation	Advocacy and social implementation	– Advocacy for public policy – Implementation of assistance, provision of education & raising public awareness – Support for investment financing – Implementation of social action
Academics – Diponegoro University – Gadjah Mada University – Bogor Agricultural Institute – UMPP – UNISSULA – Jenderal Soedirman University	Sources of research and innovation	– Conducting research and innovation on flood mitigation and adaptation focus – Providing evidence-based policy recommendations – Actively participating in education and training activities for coastal communities
Community – Communities affected by tidal flooding – Community groups	Beneficiaries and agents of change	– Actively participate in all city planning and disaster management activities – Strengthen communities and local adaptation – Willing to utilize technology and media for preparedness – Willing to undergo changes in mindset and behavior
Media & Technology – Batik TV – Pekalonganinfo – Radio KFM – Geographic Information System (GIS) – Artificial Intelligence (AI) – Big Data	Development of technology and information	– Optimization of technology and data for disaster mitigation as well as the implementation of Smart City – Media as a disseminator of information & communication for stakeholders and the public – Development of applications related to early warning systems – Supporting communities to utilize digital media

Source: Analysis Results, 2025

One of the improvement strategies for the integrated dimensions of SACL that can be implemented by the Pekalongan regency government is through the preparation of a blueprint concerning flood disaster adaptation in coastal areas, such as by developing a Master Plan for disaster-resilient coastal areas or a Master Plan for adaptive coastal settlements, among others. Kustiwan (2014) states that a blueprint is a product of a planning process that represents the objectives or what is intended to be achieved. The government can determine the direction of long-term coastal development by assessing the potential, issues, and characteristics of the area. As a detailed planning product, the blueprint must include zoning and spatial planning policies, infrastructure provision, as well as a roadmap and division of roles among stakeholders.

Not only focusing on the preparation of planning products, the government must also be creative in conveying them to the public. Through this blueprint, the Pekalongan Regency Government can provide an overview to the community to understand in detail how the smart and innovative flood adaptation strategies work in coastal areas. Consequently, the community, as the subjects of flood adaptation in coastal regions, can better internalize the strategies they must undertake as a form of their participation in development. The government can conduct social outreach, Focus Group Discussions (FGDs), and exhibitions or similar activities.

4.6. Research Contribution to the Sustainable Development Goals (SDGs)

This research result indicated a relevant contribution to the achievement of the Sustainable Development Goals, particularly SDG 11 Sustainable Cities and Communities, SDG 13 Climate Action, and SDG 14 Life Below Water, particularly in the context of coastal areas vulnerable to climate change. Contribution to SDG 11 is reflected through the strengthening of coastal settlement resilience based on community adaptation. This adaptation reflects the concept of urban resilience, which is increasingly positioned as a key approach to achieving sustainable development in urban areas. Studies show that urban resilience is closely related to the achievement of the SDGs, particularly in creating inclusive and resilient cities through the integration of social, environmental, and governance aspects. Furthermore, urban resilience and the SDGs emphasizes that the integration of resilience indicators into the localization of the SDGs can enhance the effectiveness of sustainable city development monitoring (Lowe et al., 2025). The findings of this study reinforce that community-based adaptation is an essential part of sustainable urban development strategies.

The contribution to SDG 13 is reflected in the research focus on adaptation to the impacts of climate change in coastal areas. Community adaptation to tidal floods represents a concrete form of locally based climate action. Integrating adaptation strategies with the SDG framework is essential to ensure that mitigation and adaptation efforts deliver cross-sectoral benefits. Kanan & Giupponi (2024) also demonstrate that coastal social-ecological systems play a key role in supporting climate change adaptation while concurrently achieving global SDGs. Therefore, this research provides empirical evidence that strengthens community-based climate adaptation approaches as part of SDG 13 implementation.

This research also contributed to SDG 14. It related to the protection of coastal and marine ecosystems as part of an integrated social-ecological system. The sustainable coastal area management must integrate environmental, social, and economic aspects to maintain the sustainability of marine ecosystems. In this context, ICZM approach based on the SDGs becomes an important framework in linking coastal area management with the goal of marine ecosystem protection (Zhang et al., 2024). This study contributes to promoting the integration of ecosystem-based approaches in coastal management. Overall, this study affirms that the adaptation of coastal communities not only plays a role in enhancing local resilience, but also has a strategic contribution to the global development agenda. The Smart Coastal Living approach serves as a bridge between local adaptation practices and an integrated sustainable development framework.

Conclusion

In the implementation of Smart and Adaptive Coastal Living in the coastal areas of Pekalongan Regency, it is known that the most influential dimension is economic diversification ($SACL_3$), while the dimension with the lowest contribution is infrastructure ($SACL_1$). The provision of infrastructure and facilities for housing still adheres to the same standards as settlements in non-endemic flood-prone areas. This requires special attention so that local governments can enhance housing services in the study area to improve the quality of life for communities, which differs from other general areas. One approach is to develop housing concepts that are more adaptive to flooding, as up until the completion of this study, housing conditions are still 100% in the form of single-family houses, which greatly affects the safety and quality of life of the community amidst daily flooding. Among the 12 observed variables used to achieve the objectives of this research, the most influential variables are the initiatives of the coastal community, alternative employment, and alternative transportation tools. The people of Pantairejo possess a strong sense of solidarity; they are willing to contribute their efforts to engage in communal work within their environment. According to them, this is the only capital they have to offer as they do not possess significant financial resources.

When viewed from the achievements of the SACL context, the adaptation of the Pantairejo community still tends to fall within the category of non-smart adaptive to moderately smart adaptive, particularly in terms of infrastructure, which remains very basic. Their adaptation has not yet reached the smart adaptive or highly smart adaptive categories because the available infrastructure is insufficient, and the community conditions in the study area do not support the existence of intelligent innovations in the implementation of SACL, which requires creativity and the willingness of the community to think innovatively. The implementation of Smart City on a global scale has also not been carried out by the Pekalongan Regency Government in its region, thereby significantly affecting the result of SACL context.

To improve, it is necessary to include assessments from the government and technology as aspects that also significantly contribute to the implementation of the Smart City concept within a city because this study only assesses the achievement of the Smart and Adaptive Coastal Living context from the perspective of the community as residents of flood-affected areas. The author focuses solely on the community's adaptation as the core subject being evaluated.

Limitations

Although this study has attempted to collaborate with various previous studies as its support, it of course still has several limitations. First, this research had limited focus on community-led initiatives while structural measures are emphasized, there is insufficient exploration of community-led adaptation strategies, such as mutual cooperation that call 'gotong royong' or localized resilience-building efforts. Second, the limitation about smart and adaptive living framework. The integration of smart city tools with community adaptation strategies remains underexplored. There is a need to align digital tools with participatory approaches to ensure inclusivity and effectiveness. Third, there has been no discussion about long-term sustainability. Existing studies focus on immediate responses but lack emphasis on long-term sustainable solutions that integrate economic, social, and environmental dimensions. Fourth, there has been no discussion about cultural and behavioral dimensions specifically. While adaptation patterns are documented, need deeper analysis of cultural and behavioral shifts in response to tidal flooding could provide insights into fostering adaptive coastal living.

While significant research has been conducted on tidal flooding in Pekalongan Regency, gaps remain in integrating smart city tools, community-led initiatives, and long-term sustainability into adaptive coastal living frameworks. Addressing these gaps requires a holistic approach that combines technological innovation, participatory governance, and cultural adaptation strategies.

Acknowledgement

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