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ADAPTATION AMIDST THE THREAT OF LAND SUBSIDENCE: THE ROLE OF LIVING COMFORT FOR THE COASTAL COMMUNITIES OF SEMARANG

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Abstract: The city of Semarang has experienced rapid growth recently, particularly in the industrial and transportation sectors. This development has led to an increased demand for land, especially in coastal areas, which has in turn triggered the conversion of ponds and swamps into industrial and residential areas. Many newcomers also choose coastal areas as their residential locations, although these are often developed without adequate spatial planning. This situation accelerates land subsidence, which directly impacts the lives of surrounding communities. In this context, the community's ability to adapt becomes crucial. One factor influencing this adaptability is the level of residential comfort. This study aims to understand the relationship between residential comfort and community adaptation strategies to land subsidence in Terboyo Kulon Village. Through a survey of 30 respondents and data collection via questionnaires, interviews, observations, and document studies, the research found that the community applies three main forms of adaptation: protective adaptation, accommodative adaptation, and retreat adaptation. These three forms of adaptation have a positive relationship with perceptions of residential comfort. These findings suggest that improving residential comfort can strengthen community resilience in the face of environmental changes such as land subsidence.

Keywords: land subsidence, community adaptation, living comfort, Semarang coastal area

INTRODUCTION

The coast is a transition zone between land and sea that has unique ecosystem characteristics and complex environmental dynamics. Complex interactions occur because coastal areas are habitats for marine and terrestrial biota as well as centers of human activity such as ports, fisheries, settlements, and industry (Prasetyo, 2016). However, the convergence of land and sea results in a high vulnerability to disasters, one of which is land subsidence. Land subsidence is the process of the ground surface sinking, which can occur gradually or suddenly over a specific period of time (Kasfari et al., 2018). Land subsidence results from multiple influences, including over-extraction of groundwater, heightened construction density, and the accumulation of weight. Furthermore, there exist natural occurrences like volcanic activity and subterranean geological processes.

Land subsidence occurs vertically and can cause various impacts (Suwarno, 2018). The northern part of Semarang City borders directly with the Laut Jawa, giving Semarang City a coastal geographical area. The coastal conditions of Semarang City have experienced rapid development in various sectors over the past few years (Aniendra et al., 2020). The sectors that have developed include industry and transportation. These two sectors will bring changes to the environment, particularly in land use. There has been a significant increase in the reclamation of ponds and swamps to create industrial zones. The development of industrial infrastructure will add to the load on buildings, leading to an increase in land subsidence (Ikhsyan et al., 2017). The rapid development of industry in Semarang City has attracted people from various regions to urbanize.

As a metropolitan city that serves as a center for economic, social, cultural, and political activities, Semarang City has experienced a significant increase in population (Wahyudi, 2024). Population growth has led to more people choosing to live in coastal areas. Relatively easy accessibility is one of the main reasons for choosing this area (Ekawati et al., 2018). However, the high density of buildings in coastal areas has led to irregularities in spatial planning. These irregularities have contributed to an increase in the intensity of land subsidence in the coastal areas of Semarang City.

Land subsidence in the coastal areas of Semarang City has caused various serious impacts, one of which is the spread of tidal flooding. Estimates suggest that Semarang City's tidal flooding will affect around 2,800 hectares by 2025 (Gultom et al., 2018). In addition to expanding the affected area, this phenomenon also puts significant pressure on infrastructure conditions. Buildings located in areas with land subsidence become vulnerable to cracks, as well as disruptions to structural stability and design (Oki et al., 2015). As a result of widespread flooding and infrastructure damage, the activities of coastal communities are also likely to undergo changes, both in terms of livelihoods and social interaction patterns. Damaged and frequently flooded houses cause residential areas to become slum-like and poorly maintained, which ultimately has a negative impact on public health (Septiani et al., 2024).

Environmental changes, whether gradual or sudden, prompt communities to make adjustments in response to conditions that no longer align with previous circumstances. These adjustments are known as adaptation, a dynamic process reflecting the ability of individuals and groups to respond to change through responsive and preventive actions (Indrayaningtias & Legowo, 2021). Adaptation is not solely an instinctive response to environmental changes but also a deliberate survival tactic designed to secure the enduring viability of communal existence (Rahman et al., 2022). Adaptation methods can differ significantly, encompassing behavioral adaptations, alterations in sources of income, fortification of infrastructure, and shifts in social interaction dynamics within a constantly evolving context. These reactions arise from the inherent ability of communities to manage environmental challenges like land subsidence, tidal inundation, and various climatic disruptions (Andriyani, 2020; Janah et al., 2024).

This perspective aligns with (Lindenberg, 1995) notion that adaptation has an anticipatory foundation, i.e., the ability to anticipate potential changes and adjust early on. The sense of comfort that exists between individuals and their environment drives communities in the adaptation process. The desire to maintain a decent quality of life, such as length of residence, land ownership, and housing conditions, drives various adaptation efforts to be carried out independently (Alfiani & Purnomo, 2016). In other words, adaptation is not only aimed at survival but also at preserving, as much as possible, the sense of comfort and belonging to their place of residence amid increasingly complex environmental pressures.

LITERATURE REVIEW

Prior investigations have thoroughly examined adaptation from multiple viewpoints, including social ties among individuals and human engagement with the environment. For example, a study (Sanjoto et al., 2021) on fishermen shows that communities continue to make adaptation efforts, albeit limited and simple. They continue to try to maintain their livelihoods despite the severe challenges posed by climate change. Research by (Nurhasanah et al., 2019) also shows that communities tend to begin adapting when their living comfort is disrupted, for example, due to floods that damage their homes or reduce the quality of the surrounding environment. This means that factors related to living comfort, including home safety, environmental health, and ease of activity, are important drivers in the community adaptation process.

Communities in the coastal regions of Semarang City exhibited several strategies for adapting to environmental alterations. (Mintiea et al., 2018) investigated how settlement characteristics correlate with the forms of adaptation adopted by communities in response to tidal flooding. Meanwhile, (Oki et al., 2015) highlighted the impact of land subsidence on the economic tactics employed by coastal towns as an adaptive response. Nonetheless, even with the thorough analysis of different adaption strategies, most studies are confined to the descriptive characteristics of community behaviors. A significant number of studies have failed to rigorously analyze the connection between elements of living comfort and the adaption strategies adopted by communities.

RESEARCH METHODS

This study uses a quantitative descriptive approach with a focus on the role of residential comfort as a factor driving the community to adapt to land subsidence. The research location is in the coastal area of Semarang City, specifically in Terboyo Kulon Village, Genuk District. The population in this study is the entire community living in Genuk District, which is affected by land subsidence. The sample consists of 30 respondents selected using purposive random sampling from Terboyo Kulon Village based on criteria determined by the researcher.

Data collection was conducted through documentation studies, field observations, and questionnaire distribution. Factors shaping adaptation and community adaptation patterns were measured using a scoring technique with a 4-point Likert scale approach. To analyze the relationship between variables, Spearman's correlation analysis technique based on a ranking system was used. In this study, the perception of living comfort was used as variable X, and adaptation efforts as variable Y. The relationship between variables X and Y was analyzed to determine the influence and role of the perception of comfort on the adaptation efforts made by the community. The Spearman correlation formula was used

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$$

Explanation:
r_s = Spearman correlation coefficient
d = Difference between 2 sets of variables
n = Number of samples

RESULTS AND DISCUSSION

1.1. Overview of Research Location

There are five subdistricts in Semarang City that have coastal areas, including Semarang Utara Subdistrict, Tugu Subdistrict, Semarang Barat Subdistrict, Gayamsari Subdistrict, and Genuk Subdistrict. Genuk Subdistrict is one of the coastal areas that has experienced development in the industrial sector. The most severely affected community in Genuk Subdistrict by land subsidence is Terboyo Kulon Village, which is the subject of this research. The geographical distribution of the samples is shown in Figure 1.

Pigure 1. Research Location Map

Terboyo Kulon Village is one of the administrative areas under Genuk Subdistrict, Semarang City. This village has the smallest number of households (HH) compared to other villages in Genuk Subdistrict, with a total of 195 HH. Administratively, Terboyo Kulon consists of only two Neighborhood Units (RW), making it the village with the smallest territorial coverage in the subdistrict. However, Terboyo Kulon Village faces the highest disaster risk due to its direct border with Laut Jawa.

The RW 2 area in Terboyo Kulon Village has suffered significant infrastructure damage, particularly to road access, caused by land subsidence and tidal flooding that occur almost daily. This situation is exacerbated by the construction of a dam for a toll road in the northern part of the village, which also affects water flow and soil pressure in the surrounding area. Additionally, landfilling activities for industrial development further worsen the vulnerability of this area to environmental disasters. The combination of these factors makes Terboyo Kulon Village one of the most vulnerable areas to the impacts of coastal environmental changes in the city of Semarang.

1.2. The Phenomenon of Land Subsidence in Semarang City

Land subsidence is the process in which the land surface slowly or suddenly sinks due to the compaction of sedimentary layers caused by an increase in effective stress and the displacement of subsurface soil materials (Gavokosh et al., 2021). Since World War II, cases of land subsidence have increased with the intensive extraction of water, oil, and gas. Poland and Davis (1969) in (Miranda et al., 2018) were pioneers in linking subsidence to groundwater extraction. The guidebook by Poland (1984) in (Miranda et al., 2018) summarized various global studies on this phenomenon and became an important reference in subsidence research.

Semarang City also highlights the issue of land subsidence. Based on monitoring results, land subsidence in Semarang City is slow but continuous, with an average rate ranging from 1 to 2 centimeters per year (Syafitri & Rochani, 2021). People living in the affected areas often do not immediately feel the effects of land subsidence, which occurs periodically. The symptoms are often latent and are only felt after a few years, generally in the range of two to five years after the subsidence begins to occur. The impacts are quite complex, ranging from the emergence of wider tidal inundation, cracking of buildings and infrastructure, and road damage to disruption of daily activities. In the long run, this condition can also affect the quality of life of the community, such as decreased comfort of living, increased health risks due to an unhygienic environment, and economic losses due to damage to productive assets.

The highest rates of land subsidence have been seen in Semarang City, especially in the Pedurungan, Genuk, and North Semarang districts. These three areas are generally located in low-lying areas, close to the coastline, and have high population densities and economic activity, including industrial and warehousing areas. Further data on the rate of subsidence in each subdistrict can be found in Table 1 and Table 2, which include measurement results from geospatial studies and periodic monitoring.

This phenomenon highlights the importance of awareness and adaptive actions from various parties, including the government, the community, and industry players, to anticipate and reduce the risks posed by land subsidence. Steps such as controlling groundwater use, strengthening infrastructure, and replanning coastal area spatial planning are highly relevant measures to be implemented moving forward.

Table 1. Land Subsidence Rate in Semarang City from 2015 to 2022

No	Measurement Method	Year	Decrease
1	GNSS Survey	2015-2016	0.02-0.03 cm
2	GNSS Survey	2016-2017	0.05-1.31 cm
3	GNSS Survey	2018-2019	0.00-0.07 cm
4	InSAR Analysis	2015-2022	110-120 mm/year

Source:(Aditiya & Ito, 2023; Wirawan et al., 2019)

Table 2. Highest Rate of Land Subsidence by Subdistrict in Semarang City in 2020

No	Subdistrict	Rate of land subsidence (mm/year)
1	Pedurungan	100-120
2	Genuk	100-120
2	Semarang Utara	70 -100
3	Gayamsari	50-70
4	Semarang Timur	50-70
5	Semarang Barat	30-50
6	Tugu	20-40

Source: Badan Pusat Statistika 2020

The Terboyo Kulon sub-district has experienced a higher rate of land subsidence than

other sub-districts along the coast of Genuk District. Field observations have revealed that starting at 3:00 p.m. local time, the Terboyo Kulon sub-district experiences tidal flooding with a duration of 5–12 hours. Additionally, damage such as cracks in roads and house walls is visible, as shown in Figure 2. The community feels these effects because ponds and swamps near their area have been filled in to make room for industry.

Picture2. Damage to Roads and Houses in Terboyo Kulon Village

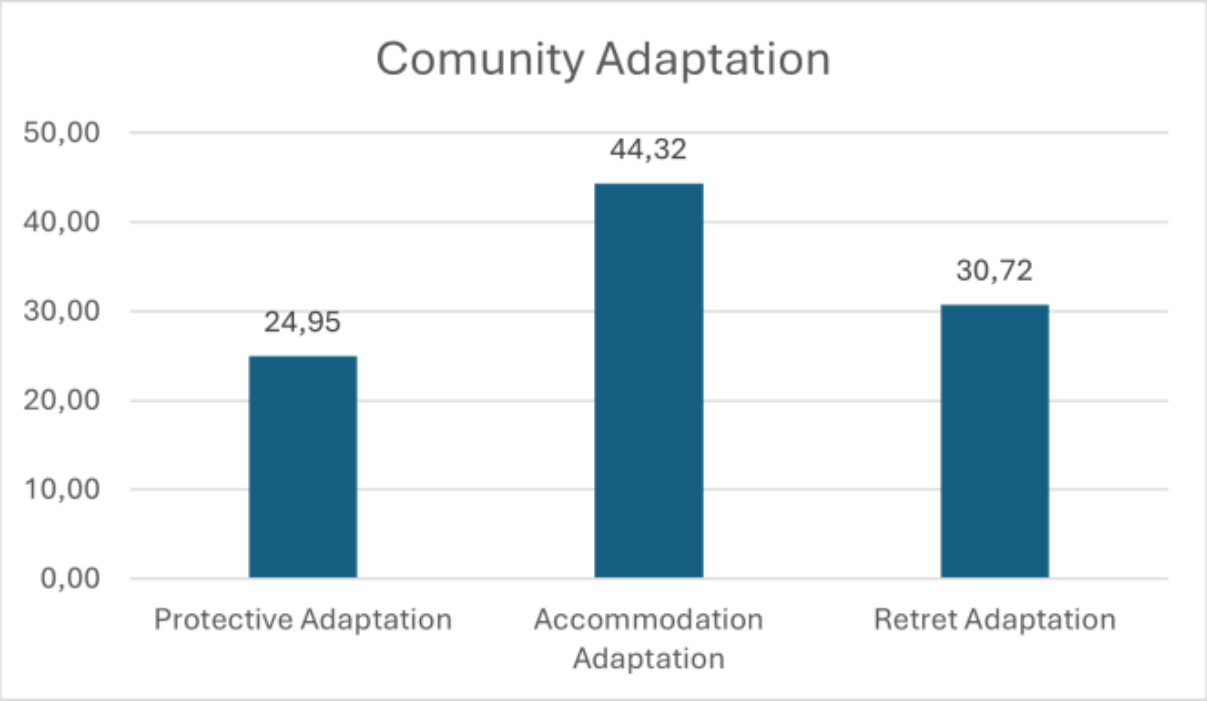
1.3. Community Adaptation in Facing Land Subsidence

According to Jhon W. Benner (1976) in (Harahap, 2020), adaptation is a concept that emphasizes the behavioral dimension of humans, particularly in responding to environmental changes through anticipatory responses. Cultural characteristics, norms, and group identity also influence adaptation. This view is reinforced by (Lindenberg, 1995), who states that anticipation is an important foundation in the adaptation process. In line with this, (Indrayaningtias & Legowo, 2021) explain that coastal communities facing environmental changes, particularly due to land subsidence, can engage in various forms of adaptation classified into three types: protective adaptation (protect), retreat adaptation (retreat), and accommodative adaptation (accommodate).

The adaptation efforts undertaken by the community of Terboyo Kulon tend toward accommodation adaptation. This adaptation allows the community to survive and adjust to changes in their environment. The community makes adjustments so that they can continue to live their lives as normally as possible. Accommodation adaptation is the adaptation most commonly utilized by the community, with a prevalence of 44.32%. This adaptation is implemented in various ways, such as raising the height of residential buildings over a period of 5 to 10 years, with each elevation increasing the foundation height by an average of 50 to 100 meters. Road elevation is also conducted over a period of 2 to 5 years. These efforts are a response to the gradual yet inevitable subsidence of the land surface, which is now being felt more acutely by coastal residents.

The next adaptation effort is retreat adaptation. According to the assessment results, retreat adaptation ranked second with a score of 30.77%. Retreat adaptation is a backward adaptation or avoidance of risks that occur in a changing environment. With the significant intensity of land subsidence and daily tidal flooding, most of the community hopes to

relocate to a safer place. However, this desire is hindered by costs and the community's perception that they have lived there for a long time and are reluctant to move from their environment. Many residents are willing to relocate to safer areas if given the opportunity. The community rarely practices protective adaptation. With the lowest value of 24.95%, this adaptation relates to the community's efforts to protect themselves from worse things in the future. The lack of awareness among the community in protecting their surroundings has contributed to the low value of protective adaptation. Protective adaptation has only been implemented through simple measures such as small-scale plant care.



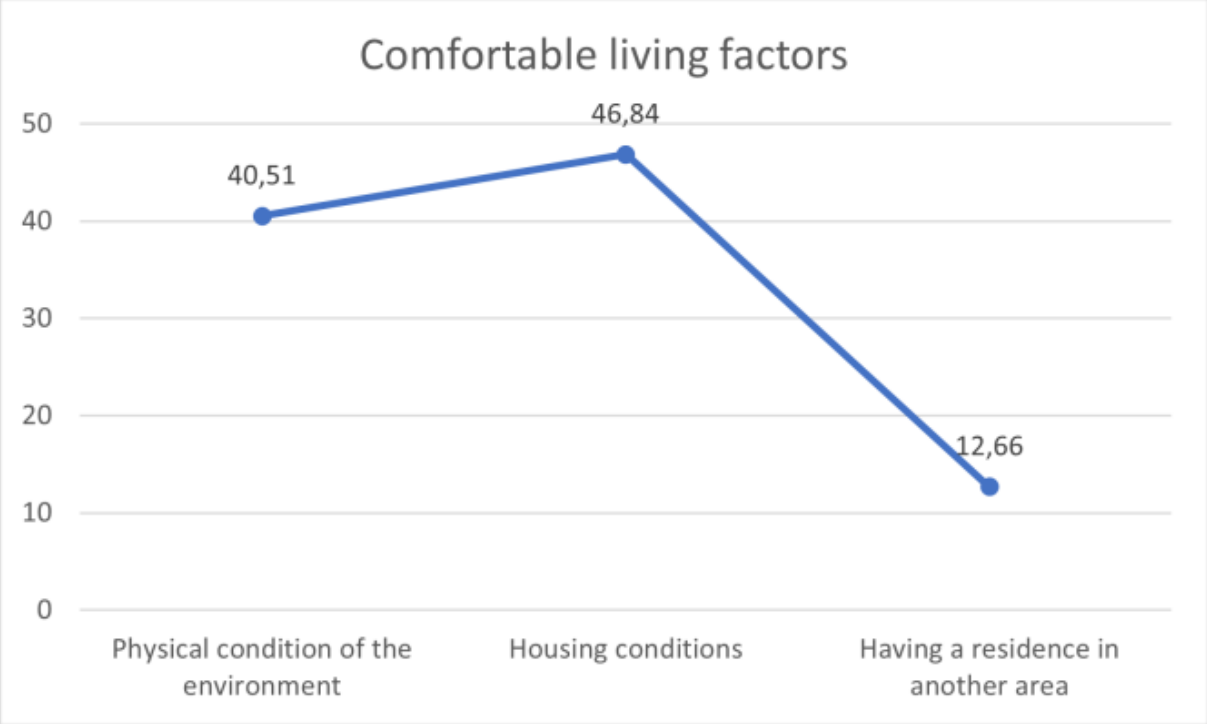
Picture3. Level of adaptation in Terboyo Kulon Village

1.4. Perception of Living Comfort

The impact of severe land subsidence in Terboyo Kulon Village should reduce the level of comfort residents have for remaining in their environment. However, the community in Terboyo Kulon Village has become accustomed to their living conditions, which will trigger adaptation. Perceptions of comfort are related to how people view a particular condition or environment. (Sari & Webliana, 2019). Most people still choose to remain in their living environment due to the comfort factor. Comfort influences an individual's behavior in responding to and addressing a particular condition (Alfiani & Purnomo, 2016). Comfort is related to an individual's psychological condition (Suwendar, 2019). This study indicates residential comfort through three factors: housing conditions, comfort with environmental conditions, and duration of residence. Despite daily disasters, the community chooses to stay and finds comfort in their environment due to these three factors. The community feels settled and more at ease in their own homes.

In this study, the highest comfort indicator was in the condition of the house, with a percentage of 40.51%. Houses that are already permanent with brick walls are the main reason people are reluctant to move and leave their homes. In addition, regular repairs carried out every 2 - 10 years make people feel that their house is their savings and the only asset they have. Furthermore, the fact that the homes are privately owned reinforces their decision to stay. This is related to the lowest-scoring factor, which is asset ownership in other areas, with only a 12.66% percentage. Almost the entire community does not own assets in other areas. Besides not owning assets, the community tends to avoid considering moving to other areas. The next strongest factor contributing to the community's reluctance to move is the length of residence. Most of the community are natives who have lived there for over a decade. They feel their spirits have merged with the area and have come to understand their living environment's characteristics due to their long residence.

These three reasons significantly reinforce the community's comfort in staying in that environment, even though they must continue to adapt to high disaster conditions. They have also developed an instinct for survival in high-disaster conditions due to the necessity of adapting as a result of the interaction between humans and their environment. Each value of the residential comfort indicators can be seen in figure 4.



Picture4. Graph of Comfort Points by Indicator for Terboyo Kulon Subdistrict

1.5. The Relationship Between Comfort Factors and Community Adaptation Efforts

Communities adapt in response to changes in their environment. The level of adaptation is influenced by several factors, one of which is comfort. Comfort is the factor most often cited by communities as the reason for remaining in their environment. In this study, Spearman's correlation analysis will be used to determine the relationship between adaptation efforts and the level of residential comfort among the community in Terboyo Kulon Village. Tables 3 and 4 present the basis for decision-making in the calculations generated by the SPSS software, as well as the strength of the relationships produced.

Table 3. Basis for Decision Making

Significance Value	Description
<0.05	Correlated
>0.05	Not Correlated

Source: (Mustamu et al., 2015)

Table 4. Criteria for the Level of Correlation Strength

Correlation Coefficient Value	Description
0.00 – 0.25	Very weak relationship
0.26 – 0.50	Moderate relationship
0.51 – 0.75	Strong relationship
0.76 – 0.99	Very strong relationship
1.00	Perfect relationship

Note: Negative data has the same criteria *Source: (Mustamu et al., 2015)*

Table 5. Results of Spearman's Correlation Calculation between Perceptions of Comfort and Adaptation Efforts Made by the Community of Terboyo Kulon Village

		Perception of Comfort
Protective Adaptation	Pearson Correlation	.218*
	Sig (2-tailed)	.039
	N	90
Accommodation Adaptation	Pearson Correlation	-.251*
	Sig (2-tailed)	.017
	N	90
Retreat Adaptation	Pearson Correlation	-.046
	Sig (2-tailed)	.669
	N	90

**.Correlation is significant at the 0,01 level (2-tailed)
*.Correlation is significant at the 0,05 level (2-tailed)

The results of the Spearman correlation analysis above show that the perception of comfort plays a role and is related to accommodation and protection adaptations. The relationship between living comfort and accommodation adaptation is significant, with a negative correlation indicating the impact of land subsidence, such as daily tidal flooding, which weakens the community's comfort level toward their environment. Therefore, the community makes adjustments to maintain their comfort through adaptation.

During disasters, the community chooses to remain in their environment to sustain their livelihood. Based on field observations during moderate tidal floods, communities tend to stay in their homes because they feel more comfortable there than evacuating to public facilities. To create this sense of comfort, communities undertake adaptation efforts such as raising the height of their homes and constructing two-story houses to enable them to remain in their homes during tidal floods.

A weak relationship was found between residential comfort and protective adaptation. The relationship between residential comfort factors and protective adaptation is directly proportional, as this relationship is generated because communities undertake various protective adaptations such as planting trees and creating simple gardens to improve residential comfort. The protective strategies adopted by the community are still simplistic, and they have not yet understood that their initiatives are part of the efforts to avert and diminish land subsidence, resulting in a weak association.

CONCLUSION

Communities adapt as a response to environmental changes, either consciously or unconsciously. In Terboyo Kulon Subdistrict, adaptation is carried out as a survival strategy amid disaster-prone conditions, particularly land subsidence and tidal flooding (rob). The perception of residential comfort serves as a key factor motivating residents to remain in the area despite the ongoing environmental pressures. Considering Terboyo Kulon's geographical position next to the Java Sea and its exposure to daily tidal flooding, rigorous controls from the authorities are needed for the allocation of coastal buffer zones for population expansion. In addition, controlling building density is essential to prevent further expansion of residential areas into disaster-prone coastal zones in Semarang City. Given the poor public understanding of land subsidence, it is recommended that extensive community outreach and education initiatives be conducted to improve awareness and preparedness for the environmental threats confronted by local communities.

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