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Resilient Urban Design Approach for Coastal Settlement (Case Study: Kampung Bahari Tambak Lorok, Semarang)

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Abstract: Kampung Bahari Tambak Lorok is a coastal settlement in Semarang that has a vulnerability to disaster. The main problem of the vulnerability is the tidal and annual flooding every rainy season. The flooding is caused by the location of Kampung Bahari, the land subsidence issue, and the effect of climate change that causes extreme weather and sea-level rise (SLR). Kampung Bahari is located in North Semarang and is formed by the young alluvial deposits that trigger subsidence, while the subsidence itself is not only caused by geology reason but also geotechnical reasons, such as excessive water consumption, consolidation, and excessive land loads. This paper aims to examine the design approach that is most probable to be implied due to the vulnerability of Kampung Bahari towards the tidal and annual flood caused by the reasons mentioned above. The research will be carried out by data collection about Kampung Bahari, finding the actual settlement condition, and describing the problems deeper. The result will focus on the physical intervention consisting of implementing water-sensitive design principles, especially in the spatial planning of the settlements, urban system efficiency, building prototype guidelines, and infrastructure.

Keywords: Coastal Settlement, Flood, Land Subsidence, Resilient Urban Design, Waterfront

INTRODUCTION

Coastal settlement is an area with a unique typology from the location, environment, and cultural aspect resulting from the resident's daily habit. However, by the location aspect that is directly adjacent to the sea, the coastal area has its vulnerability to various disasters, especially floods. Moreover, with the issue of climate change that has hit the whole world and has resulted in rising sea levels, the position of coastal settlements is increasingly vulnerable to these disasters. Kampung Bahari Tambak Lorok Semarang is one of the coastal settlements that are vulnerable to so many probabilities of disaster. The dominant problems of this settlement are flood that

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had happened in these past decades and the issue of land subsidence. The land subsidence in Semarang, especially at Kampung Bahari Tambak Lorok has been a serious concern for the government that has to be solved because of the big impact on the environment, the settlements, and the people itself. Land subsidence that occurred in North Semarang is quite significant, namely 8.23 – 15.8 cm/year. Besides, extreme weather and rising sea levels make the coastal areas of Semarang City more vulnerable. In December 2020, extreme weather resulted in relatively high waves in the Java Sea and caused the coastal belt of Semarang City to collapse, hitting 13 houses of fishermen from Kampung Bahari. February 2021, the intensity of heavy-extreme rain with a rainfall level of 171 mm makes Semarang City have the potential to be affected by flooding/flash .

Unfortunately, in 2019 the residents of Tambak Lorok village have been evicted because of Banjir Kanal Timur river (BKT) normalization project. As a result of the eviction, 97 families seemed to have lost their lives and livelihoods. Previously, the residents of Tambak Lorok would be moved by the Semarang Government to Rusunawa Kudu, which is located far from the sea, but the residents refused because most of the residents are fishermen and fish farmers who depend on marine products. In addition, the government didn't compensate them for their personal belongings and chose them to stay in Tambak Lorok.

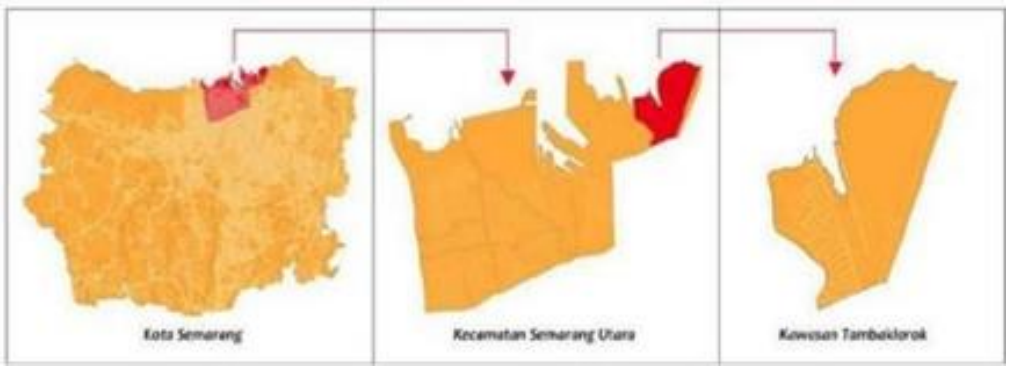
This paper examines the design approach that should be applied at Kampung Bahari Tambak Lorok.The consideration of the design approach is being adaptive to the existing conditions of settlements, demography, environment, and disaster vulnerability. The design approaches are water-sensitive design based that is concerned with land use proposals in the area, prototypes of building masses that respond to this situation, and regional infrastructure that responds and becomes a solution of disaster mitigation for the people of Kampung Bahari Tambak Lorok. In the paper of United Nations Climate Change (UNFCC Secretariat, 2017), adaptation to disasters and climate change is described in SDGs No. 13 about the urgency of action to combat climate change and its impacts to be able to regulate emissions and encourage progress in the development of renewable energy. In this case, the government's step is to integrate the SDGs indicators into national policies, strategies and planning. The emission reduction step is a sustainable step and has been listed in the 2015-2019 RPJMN, for implementation commitments until 2030 it still needs to be mainstreamed into the 2020-2025 RPJMN and the RPJPN upcoming 2026-2045 (Alisjahbana, 2018), in achieving the target of improving environmental quality, disaster mitigation nature, and climate change management. The policy plan has been integrated into various cross-sectoral programs with the aim of increasing resilience to climate change and reducing greenhouse gas emissions by 26% of emissions resulting from business as usual activities

Study Area

Kampung Bahari Tambak Lorok is a fisherman settlement located in North Semarang, Central Java. The north is bordered by the Java sea, while the south is bordered by Jalan Arteri Primer, the east is bordered by Kali Banger, and the west is bordered by PLTUG. The coastal area in Semarang City has its perception for the surrounding community and people who have visited. Kampung Bahari Tambak Lorok is coastal settlement that located in Kelurahan Tanjungmas, Kecamatan Semarang Utara, Kota Semarang. The total area of the settlements is 46,8 Ha and the average height is 0,5 above sea level. This settlement is different from the urban settlements in general, both visually, location, and community activities that take place in it as a reflection of its traditions and culture. In 2014, the population of the Kampung Bahari Tambak Lorok was 9,503 people

(5130 women and 4573 men) and most of them worked as fishermen, traders, small industries, and home industries related to fishing (Setioko, 2013).

From the existing land use map below, Tambak Lorok mostly consists of housing, and the attraction points are placed in the centre, which is the TPI (*Tempat Pelelangan Ikan*), mosque, school, and traditional market (Anita, 2020). Based on the geographical aspect, the location of the fishermen's settlement area in Tambak Lorok is ideal for residents with fishermen's livelihoods because of the location between two river mouths, where fish nest. During the west monsoon season, fishermen can moor their boats on the banks of the two rivers to protect themselves from the dangerous waves. While waiting for the ideal time to go fishing, they carry out ship repair and maintenance of nets which are carried out on the riverbanks (Setioko, 2013).



Source: Courtesy of RTPLP Tambaklorok 2016

Figure 1. The Location Aspect of Tambak Lorok

Meanwhile, from existing spatial condition Kampung Bahari Tambak Lorok map has divided into five neighbourhoods, RW 12, RW 13, RW 14, RW 15, and RW 16. Tambak Lorok has the main road but the road is only 4,5 m – 5m, and own a harbour for ships to dock.

Source: Courtesy of Analysis Result, 2021

Figure 2. left to right: Existing Spatial Map of Tambak Lorok Consists of Residential Building, Road Network and Land Use Map

There are two climates in Semarang, rainy and dry climate. In rainy season, the precipitation is high, especially in the coastal area. The highest precipitation in Semarang occurs in February, which increase the possibility of raining and casuing flood in

Semarang, especially in North Semarang, where Kampung Bahari Tambak Lorok is located (BPS, 2021).

As an area with a populated density settlement category, the building conditions in Kampung Bahari Tambak Lorok are mostly or 60% of permanent houses, with various pattern conditions. More than 65% of the buildings are irregular, and the building density is >150 units/ha. From the aspect of building density, all residential buildings in Kampung Bahari Tambak Lorok have BCR >70%. This indicates that Kampung Bahari Tambak Lorok is a dense settlement and there is no green open space in the area. The large number of people who use land and water areas for living, in the form of residential buildings, makes Kampung Bahari Tambak Lorok very dense and vulnerable to disease outbreaks because of the lack of awareness of protecting the environment.

Source: Nashrullah, 2016

Figure 3. a-Left: Water Trapped in Settlements b-middle: Semi-Permanent House c-right: Permanent House and Flood

METHOD

The methodology used in this paper is qualitative research with a triangulation method. Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena (Patton, 1999). Triangulation has also been seen as a qualitative research strategy to test validity through the convergence of information from various sources with data collection, literature study, and findings that are described in a descriptive design approach and translated into spatial planning concepts.

Tambak Lorok Disaster Threat

The main problem of this vulnerability is the tidal wave and annual flooding at least once a year every rainy season. The flood threat was caused by several reasons, there are the location aspect Kampung Bahari, the land subsidance problem, and the effects of climate change which triggers the extreme weather and sea-level rise (SLR). Kampung Bahari is located in North Semarang and it is formed by young alluvial deposits that allow for compaction which can cause land subsidence, while the subsidence itself is not only caused by geological reasons but also geotechnical reasons, such as excessive water consumption, consolidation, and excessive soil loads.

Source: Akbar, 2019

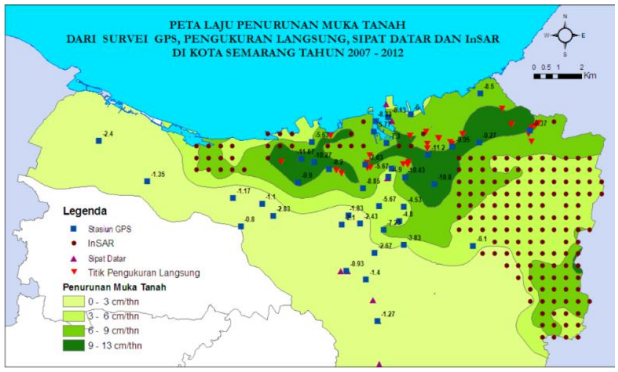
Figure 4. Coastal Erosion on Study Area Tambak Lorok

Land Subsidence

The movement of the earth's substance beneath the surface causes land subsidence, which is described as a slow or sudden sinking of the earth's surface (Galloway, 1999). Furthermore, subsidence is frequently coupled with horizontal deformation and the occurrence of substantial damage-causing soil failure. Land subsidence is thought to have started during World War II as a result of the increased extraction of water, oil, and gas from the subsurface. Groundwater depletion is currently the leading cause of land subsidence around the world. Poland and Davis were the first to introduce it (1969). The handbook for investigating subsidence owing to groundwater depletion (Poland, 1984), includes a number of case studies from around the world, providing a significant source of information on the subject.

Subsidence frequently affects huge regions; for example, one of the most notable occurrences occurred in the San Joaquin Valley, when the subsidence exceeded 9 meters and the impacted area was 13,500 km^2 (Galloway, 1999). More than 150 communities with ground subsidence concerns (Barends F. B., 1995), incurred annual economic losses of more than US$ 125 million in the 1990s (Nuhfer, 1993).

Beijing (Zhu, 2015), Shanghai (Shi, 2008), Murcia (Tomás, 2009), Bologna (Modoni G, 2013), Tokyo (Sato, Abe, & Ootaki, 2003), Las Vegas (Galloway, 1999), and Semarang are now the cities most affected by land subsidence owing to groundwater loss. Based on GPS surveys, direct measurement, flat and inSAR in Semarang, a map of soil degradation was created. In the period 2007-2012 (Abidin, 2013), the rate of land subsidence in Semarang City, particularly in the northern section, was 9-13 cm/year, which is the highest rate in the city and is also a big problem in the city's coast.



Source: Yuwono and Abidin, 2013

Figure 5. Map of Land Subsidence Rate, Based on GPS Survey, Direct Measurement, Flat and Insar in the City of Semarang in 2007-2012

Sea-Level Rise and its Coastal Impact

In recent years, the scientific community, as well as the media and the general public, have become increasingly interested in sea-level rise caused by global warming and its effects on coastal zones. The accumulation of greenhouse gases (GHGs) inside the atmosphere, caused by anthropogenic fossil fuel consumption and changes in land use (mainly deforestation), is now well recognized as the primary cause of global warming (S. Solomon, 2007) (T.F. Stocker, 2013). Warming of the earth's mean surface temperature (Morice, 2012) and ocean heat content (Levitus, 2005), melting of sea ice and glaciers (Cogley, 2009), and loss of ice mass from the Greenland and Antarctica ice sheets (Shepherd, 2012) are just a few of the visible consequences of global.

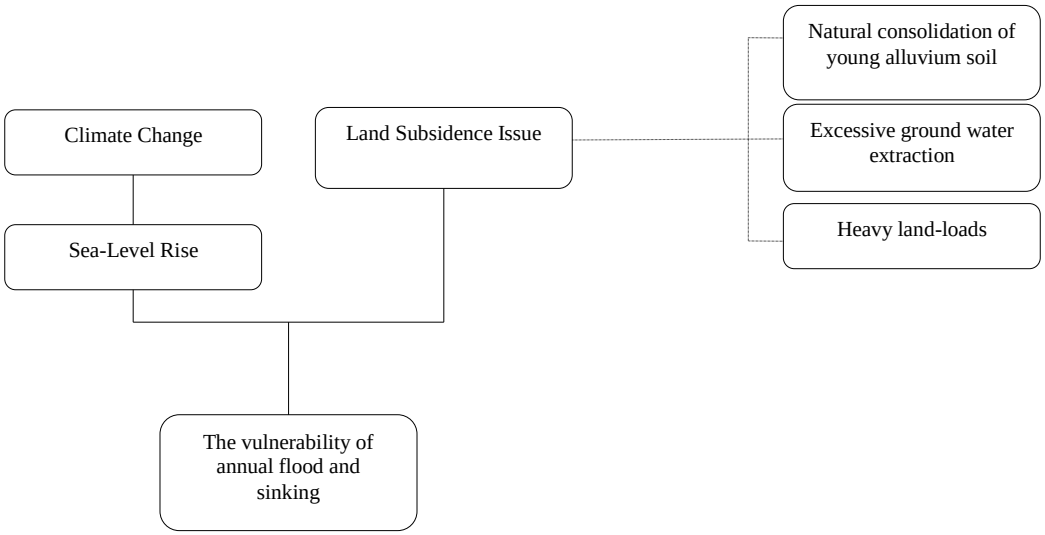
Sea-level rise is caused by ocean warming, which produces thermal expansion of seawater. Similarly, water from land glaciers melt eventually makes its way to the oceans, causing sea-level rise. Direct sea level monitoring from in situ tidal gauges and high-precision altimeter satellites have shown that sea level is rising since the mid-to-late eighteenth century (Jevrejeva, 2006).

Regional variations in the rate of rising have also been observed (Lombard, 2005). Modelling of future climate change under various radiative forcing scenarios shows that sea levels will continue to rise for decades, if not centuries (Levermann, 2013). If we consider that 10% of the world's population lives in coastal areas less than 10 meters above sea level (McGranahan, 2007), adverse effects of sea-level rise in coastal areas are usually regarded a major hazard of climate change. Shoreline erosion has been observed in many parts of the world's coastlines in the twentieth century (Bird, 1987), but it is unclear whether this is due to climate-related sea-level rise (Vellinga, 1989) or to more local non-climatic factors such as ground subsidence (causing relative sea-level rise), coastal management, land use and land use changes, waves and currents, sediment supply deficits, and so on, or a combination of all factors (Bird, 1996).

Environment Issue at Tambak Lorok

From the problems that have been studied in several literatures, mapping diagrams of problems that occur due to the issue of climate change, land subsidence issues that cause housing conditions Impact on community buildings Tambak Lorok has to renovate houses every 5 years using their own money and relying on bank loans, sea-level rise that

endangers the coast of the city of Semarang, causing the city's annual flooding. The environmental issues in the case study at Tambak Lorok are as follows:



Source: Analysis Result, 2021

Figure 6. Environment Issue at Tambak Lorok

Resilient Measures

Planning for urban system in coastal area has different approach compared to other regions. Based on the analysis of the problems and risks in Kampung Bahari Tambak Lorok, it is necessary to have a certain strategy in responding to these conditions. Reduction of risk by mitigation and adaptation measures is the first step of realization of the challenge and charge of resilient design to address global warming and climate change issue, followed by restoration of ecosystem services and revitalization and reinvestment toward community and regional sustainability. Adaptation step means adjustment. Adapting to the climate change and the impact is about taking action to prepare for and adjust to both the current effects of climate change the predicted impacts in the future. Meanwhile, mitigation is a series of efforts to reduce disaster risk, both through physical development and awareness building, and increasing capacity to deal with disaster threats (*Peraturan Pemerintah*, 2008). The comprehensive approach to disaster management comprises four phases: prevention, preparedness, response and recovery (PPRR) to ensure a balance between the reduction of risk and the enhancement of community resilience, while ensuring effective response and recovery capabilities. In managing a settlement, several scopes of design responses are needed in dealing with environmental issues and natural hazard threats, such as regional planning policy and floodplain management, infrastructure scale civil engineering/stormwater design and water engineering, landscape architecture and design, and building project scale, architecture and construction (Watson, 2011). Several aspects that have a direct influence on mitigation efforts are regional, infrastructure and landscape, while the building project scale scope have an indirect influence on climate change mitigation efforts.

Table 1. Environmental and Natural Hazard Threat and Professional Design Response

	1 Regional	2 Infrastructure	3 Landscape	4 Building
Sea-level rise/increased storm surge	●	●	●	○
Land subsidence/loss	●	●	●	○
Saline water intrusion	●	●	●	
Ocean acidification		○	○	

● Direct Influence
○ Indirect Influence
1. Regional planning policy and watershed/floodplain management
2. Infrastructure scale, civil engineering/stormwater design and water engineering
3. Landscape architecture and design
4. Building project scale, architecture, and construction

Source: Watson and Adams, 2011

The basic principles of adaptation to the impact of land subsidence and SLR, such as permanent inundation, are adjustments to physical and non-physical aspects. Physical aspect focuses more on urban geometry, while non-physical focuses on activity, community awareness and education (Jha, 2011). This paper focuses on the physical aspects of structuring Kampung Bahari Tambak Lorok by a design criteria and spatial planning proposal. Based on the elaboration of several literature studies, it was found that five main aspects should be applied in structuring the Tambak Lorok Bahari Village that will be focus on adaptive and mitigation measures. The aspects are coastal settlement spatial planning, urban system efficiency, building mass intensity and prototypes, infrastructure for the area, coastal areas with SLR and land subsidence risk, and the application of water sensitive urban design principles. What must be considered in carrying out spatial planning in coastal settlement areas is the linkage system, conservation of resources, the ability to build and integration. Meanwhile, things that must be considered in order to create an efficient urban system are connectivity and the existence of green lines. From these two aspects, we have something in common named linkage system and connectivity, which can be seen in the aspect of accessibility. Accessibility in coastal areas is important because the narrow form of parcels and circulation paths perpendicular to the shoreline can reduce structural damage by providing water ingress (Watson, 2011). In addition, the existence of a good accessibility system can also facilitate the community in making preparations in the event of a sudden flash flood when the rainfall is high.

The intensity and building mass are also important measures. The usage of elevated house design is an adaptive step that can be applied, thus, the people of Tambak Lorok can adapt better to the risk of a flood disaster and minimize the damage to buildings. This design will make the people can evacuate quicker and not passing the period of shock for too long. In addition to adaptive measures, mitigation measures should also be taken to reduce the risk of sustainability of climate change and land subsidence, so it is necessary to apply green infrastructure to provide a sustainable water supply in the aims to reduce the groundwater use that can lead to subsidence, surface water runoff reduction and treatment to accelerate the absorption of rainwater in the area and reduce carbon-footprint which can increase the risk of climate change. The regulation of land use area is also important to maximize the decreasing of land-loads and regulate the density of buildings in the area, for example, to encourage the existence of a mixed-use function, so the landed buildings in the weak areas can be reduced and lightened up the land-load.

In addition to literature review, we should also put an attention to applicable regulations, such as regulations regarding coastal boundary lines and intensity and building regulations, especially regulations about coastal boundary lines that have been calculated based on the disaster index and vulnerability index. The disaster index itself includes a

practical approach and numerical approach, while the vulnerability index includes topography, biophysics, economy and culture needs, and other considerations (*Menteri Kelautan dan Perikanan Republik Indonesia*, 2018).

Table 2. Urban Design Approach for Kampung Bahari Based on Literature Studies

Issue and Problems	Aspect	Principals	Source
Issue • Sea-level rise • Rob Flood • Land Subsidence Problems • Inefficient circulation path. • Dense settlement that caused a heavy land-loads. • Lack of green area. • Lack of natural conservation area. • Lack of coastal infrastructure to reduce the risk of flood. • The buildings are often damaged because of the flood and need annual renovation. People of Tambak Lorok are burdened because they depend on bank loans.	WSUD Intervention	• Sustainable water supply • Wastewater reduction andtreatment • Surface water runoff reduction and treatment +flood water integration	Water Sensitive Urban Design in the UK - Ideas Book, CIRIA. 2013. London (CSIRO). (2005). *WSUD Engineering Procedures*.
	Settlements Spatial Planning	• Linkage System • Socio-Cultural relevance andrequirements • Conservation of resources • Capability building • Integration	Guidebook on SustainableCoastal Land Use Planningand Management Volume II,IEMSD 1997,p. 13-20
	Efficiency of Urban System	• Connectivity • Green path • Urban Farming	Urban Planning and UrbanDesign. In *Climate Changeand Cities,* 2018
	Building Mass	Buildings must be elevated on an open foundation (e.g.,piling, piers)	Watson and Adams, 2011
		General protection of building from flood damage (Buildings may be constructed on raised groundwith apron around or Stilts orcolumns with wall free space at ground level)	Building Materials & Technology Promotion Council, 2010.
	Infrastructure for the coastal area with SLR and land subsidence risk	• Green infrastructure to reduce the carbon-foot print and increase rainfall absorption.	Watson and Adams, 2011
		• Additional infrastructure toreduce the water ground consumption for daily basis.	Pranantya, 2019
		• Seawall or coastal-belt for theheavy wave or rob flooding barrier.	Pranantya, 2019

Design Criteria and Approach

The principles above will be detailed in several approaches as a step to achieve a resilient coastal settlement. The detailed explanation regarding the approaches and the classification (adaptive or mitigation) every aspect and principle that have been chosen, will be written in Table 3.

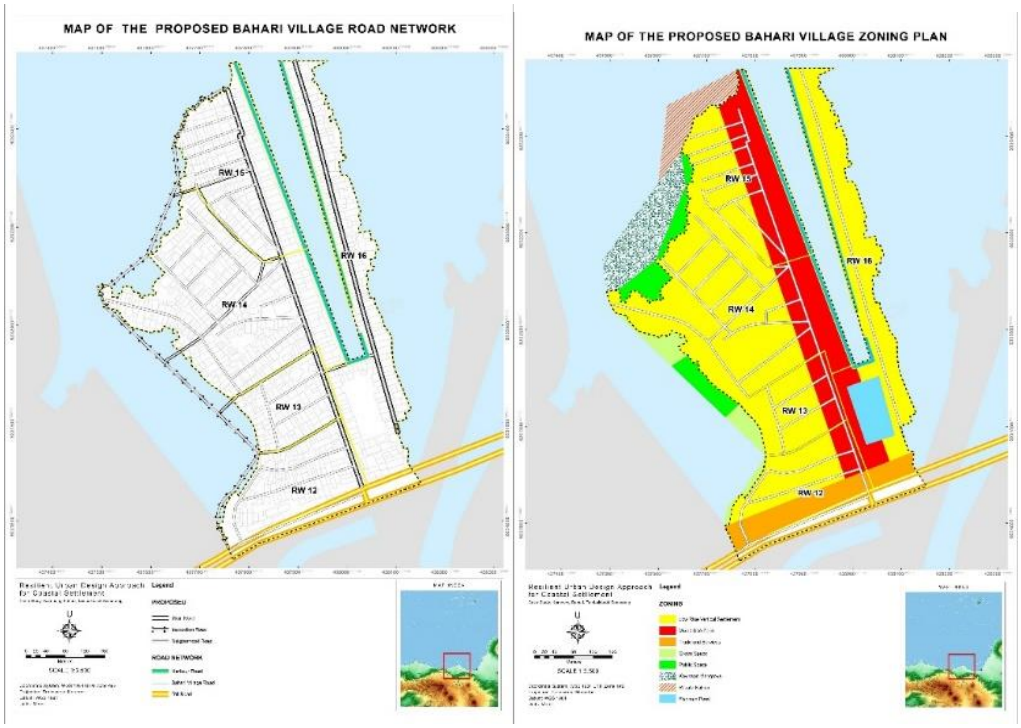
Table 3. Result or Design Approach Tambak Lorok

Aspect	Principles	Approach	Classification
Coastal Settlement Spatial Planning	• Linkage system • Conservation of resources • Capability building	Circular and integrated circulation in the settlements.	Adaptive
		Adding conservation area in the coastal line to reduce the risk of abrasion. *Rhizopora mucronata* and *Avicennia* marina are highly recommended to be in conservation area.	Adaptive
Efficiency of Urban System	• Connectivity • Green path • Urban farming	Adding more green space area as a multifunction space for evacuation and for natural water absorption.	Mitigation
		More mixed-use zoning.	Mitigation
Intensity and Mass Building Prototype	• Elevated foundation • Protection of building from flood damage	Implementing vertical housing concept.	Adaptive
		Differentiate the vertical housing and regular housing to maximize the building capability in the settlement.	Mitigation
		Implementing floating building for several functions.	Adaptive
		Columns with wall-free space at ground level (piling, wood) so it can be used as a storage, open space, or green space.	Adaptive
		Foundation (using burned brick or stone, cement – sand mortar, wood, or even pile).	Adaptive
		Implementing wall construction such as solid brick walls (230 mm), solid concrete block (200 mm).	Adaptive
		Implementing the coastal boundary line based on the calculation of disaster risk level.	Adaptive
Infrastructure for The Coastal Area with SLR and Land Subsidence Risk	• Green infrastructure to reduce the carbon-footprint and increase rainfall absorption • Additional infrastructure to reduce the water ground consumption for daily activity • Seawall or coastal-belt for the heavy wave or rob flooding barrier	Calculate the daily water consumption of Tambak Lorok people to recognize the needs and amount of rain-water harvesting tank.	Mitigation
Water Sensitive Urban Design Intervention	• Sustainable water supply • Wastewater reduction and treatment • Surface waste runoff reduction, treatment and flood water integration	Implicating the bioretention infrastructure in the green belt.	Mitigation
		Applicating the coastal belt in the coastal line of Kampung Tambak Lorok integrated to the circulation of the settlement.	Adaptive

Source: Courtesy of Analysis Result, 2021

From the design criterias and approaches above, we can transform those into a spatial planning that regulates the zoning and circulation in Kampung Bahari Tambak Lorok. The spatial planning focuses on the circulation in the area, single building settlement, low rise vertical settlement, mixed use zone, trade and services, green space, public space, mangrove area, floating market (culinary tourism), and fish pond.

The circulation is made continuous and uninterrupted, adding inspection roads as a form of integration of circulation and seawater retaining infrastructure. The mixed-use area is proposed to make the settlement more compact to reduce the land-loads, hopefully it can decrease the land subsidence risk in the area. The mixed-use development is vertical and middle-rise buildings, located in the middle because the land strength in the middle area is still possible to withstand the compressive forces of the building. Meanwhile, trade and service areas are close to arterial road access for a better visibility and accessibility to the public. The low-rise house area tends to be near the sea because the land strength is still possible. A green open space area as a public space node and natural absorption area, and also a conservation area with mangrove forest is necessary for natural preservation and mitigation reasons to reduce the land subsidence risk.



Source: Courtesy of Analysis Result, 2021

Figure 7. Left to right: Proposed map of the road network and Zoning Plan Tambak Lorok

From the explanation above, it can be seen that in order to reach the Resilient Urban Design point, there are several aspects that are transformed into principles and approaches. As previously written that the first step in realizing a resilient design to encounter the issue is the mitigation and adaptation step, the first point for achieving a resilient urban design has been achieved by transforming the approach into two classifications of approaches, which are adaptation and mitigation as already written in Table 3. The adaptation and mitigation approaches are elaborated, so Kampung Bahari

Tambak Lorok does not only take the preventive measures to handle the problems and disaster threat, but also adjustment through adaptation steps.

The second step towards achieving resilient urban design is the recovery and revitalization of ecosystem services, which seeks to be achieved by adding conservation areas on the coastline to reduce the risk of abrasion, spatial planning arrangement by increasing the number of green open spaces as natural catchment areas, reducing the usage of aquifer water by rainwater harvesting, and the application of green infrastructure for rainwater management. Meanwhile, reinvestment steps towards community and area sustainability can be achieved with a non-physical approach which can be achieved by community empowerment.

CONCLUSION

From the explanation above, it can be concluded that land subsidence, sea level rise and climate change are global phenomena that can occur as a result of natural activities and human actions. This phenomenon is a challenge for the coastal environment, including Kampung Bahari Tambak Lorok, Semarang. The area already has environmental problems such as flooding and land subsidence which have a huge impact on the people in it. This is worsened by the issue of sea level rise, so it is not impossible that in the future, the land area of Kampung Bahari Tambak Lorok will continue to decrease. Therefore, adaptive and mitigation measures are needed to make this area more resilient to these threats. The adaptive steps are needed so the area and society can adapt to things that can happen due to these threats. Meanwhile, mitigation measures are needed to reduce disaster risks for the area. These adaptive and mitigation steps then become the main foundation for Kampung Bahari Tambak Lorok to become a resilient area. The spatial arrangement of the area is also required by taking into account various aspects according to urban design criteria and approaches that have been formulated, such as zoning arrangements, circulation aspects which can be elaborated by making seawater retaining infrastructure, encouraging mixed-use development, structuring open space, and establishing mangrove forests. For future research, it is necessary to consider the non-physical aspect in the form of community participation, so that regional problems are not only highlighted from an environmental perspective, but also from a social perspective.

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