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Sink cities and land subsidences: How it affects the development of coastal city in Malaysia?

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Abstract

Land subsidence is the process through which the surface of the Earth gradually sinks or suddenly sinks due to the movement of earth components occurring below the surface. Subsidence can occur suddenly or gradually. The impacts of permanent inundation, which might make the environment of the settlement area worse, will raise the risks and challenges that the population will face in the future. These risks and challenges may include things like natural disasters and economic instability. This is true especially because cities that are inundated will enhance the dangers and difficulties that the population would have to face. The objective of this article is to provide a comprehensive overview and systematic literature on sink cities and land subsidence and how it affects the development of coastal cities in Malaysia. It examines how development contributes to land subsidence and sink cities in coastal area. According to the findings, cities in various countries, including Malaysia, have been affected by land subsidence. Based on the research, cities, and land in countries like Indonesia, Bangladesh, and Vietnam are sinking due to land subsidence. As a result of land subsidence, changes in land use have occurred, the most noticeable of which are those associated with the erection of structures and residential areas in the coastal zone. The findings indicate that Malaysia is one of a select number of nations where sinking cities and land subsidence occur. Seawalls, breakwaters, gabions, groynes, and sluices are some of the potential solutions to the problems created by subsiding land and sinking cities. The purpose of these regulations is to forestall the development of "sink cities".

Keywords: Coastal city, coastal communities, land subsidence, shoreline, sink city

Introduction

Malaysia is in Southeast Asia. It is made up of two parts: Peninsular Malaysia and the States of Sabah and Sarawak, which are located on the northern section of Borneo Island and are together referred to as East Malaysia, make up the entirety of the country. Peninsular Malaysia is the name given to the southern portion of the country. These two sections are split apart by a distance of 640 kilometers (400 miles) over the South China Sea. In addition, there are around a thousand different islands and coral reefs that make up this country. There is no official definition for the coastal zone yet because it hasn't been decided how it should be categorized geographically. On the other hand,

in a more generic sense, this phrase refers to areas where terrestrial and aquatic habitats and processes interact with one another. This category includes not just the coastal plains but also the coastal wetlands, estuaries, and lagoons as well (Abdullah, 2013). The coastline region of Malaysia is of critical importance, not only to the country's economy but also to the ecology. It is the core of economic activity that includes urbanization, agriculture, fisheries, aquaculture, oil and gas extraction, transportation and communication, and recreation, and it provides for a significant portion of the total population. If the massive expansion of economic activity in coastal areas of Malaysia is not adequately planned for and managed to ensure sustainable development, it will cause problems like the loss of marine resources and a worsening of the social environment (Wu et al., 2022). This is because sustainable development requires adequate planning and management (Bin Nordin, 2006). Other than that Malaysia will face other difficulties in handling coastal areas such as cost, management of the coastal area, and how to handle the coastal area that has been affected by climate change.

The risk of having "too much" water to deal with is looming over a significant number of the world's largest coastal and delta towns. These dangers are made significantly worse by the consequences of climate change, which raise both the severity and the incidence of water-related catastrophes (Ashley et al., 2021; FMT, 2022). In many coastal megacities across the world, land subsidence has led to an increase in the frequency of floods, the depth of the water that they inundate, as well as the length of time that they last. In addition to human casualties, floods are responsible for a large amount of property destruction and economic loss. As a consequence of the weight of the structure pressing down on the earth, which eventually causes it to sink, enormous economic losses happen in the form of structural damage and increased maintenance costs (Waltham, 2015). There is currently, and will continue to be, a greater amount of economic development in places that are at risk of being submerged as a result of urbanisation and population growth that are both occurring in delta regions, notably in coastal mega cities. The gradual urbanization of coastal areas will inevitably lead to the sinking of cities, which will be a serious and unavoidable consequence. The land subsidence that results from human growth will create an increase in the level of the sea, which in turn will force cities that are located along the coast to sink.

The rates at which the climate on Earth is undergoing a transition are unparalleled in the recent history of humanity. One of the most worrisome and expensive aspects of climate change is the rise in sea level, which has four primary repercussions for coastal areas: coastal flooding, coastal inundation, coastal erosion, and salt-water intrusion. These are significant obstacles to the long-term growth of coastal communities because of the direct impact they have on real estate, essential coastal infrastructure such as the infrastructure for transportation networks and utility services, the manufacturing process, and natural and cultural resources. In addition, they affect the ecosystem, economic activity, income, wealth, public health and safety, and the community's general social well-being. Coastal communities are particularly vulnerable to the effects of these factors (Ehsan et al., 2019). The term "coastal zone" refers to a more general term that encompasses all of the regions of Malaysia's coastline that are subject to the interaction of terrestrial and marine processes. This includes the country's coastal areas, shallow marine areas, coastal ecosystems, estuaries, and lagoons. Peninsular Malaysia has a total coastline land area of around 1.2 million hectares, whereas Sabah and Sarawak each have a total coastal land area of approximately 1 million hectares and 2.2 million hectares, respectively. The overall land area of Malaysia is 330,803 km^2 and the total shoreline in Malaysia is 8,840 kilometres (km). Within a radius of 5 kilometers from the coast, the coastal regions of Malaysia cover a total land area of 4.4 million

hectares, which is equivalent to 13% of the entire land area of the country. Coastal areas are home to approximately 70% of the world's population. There are a total of 12,400 rural settlements, 22 urban communities, 28 industrial complexes, and 54 ports located along the coast of Peninsular Malaysia. Furthermore, there are a total of 28 industrial estates (Ehsan et al., 2019). The lengthy shorelines in Malaysia indicate the presence of several coastal cities that may face the challenges of sinking cities and land subsidence occurrences. This raises the question of how these people would adapt to such circumstances.

The coastline of Malaysia is vulnerable to the results of coastal erosion combined with the consequences of rising sea levels, which are caused by changes in the climate. According to the findings of the National Coastal Erosion Study, conducted in 2015, 15% of the total shoreline of 1,348 km of shoreline has been actively eroded, with one-third of that total falling into categories deemed crucial and substantial and requiring structural protection. The findings of a study that was carried out in 2017 on the topic of sea level rise in Malaysia reveal that the estimated annual rise in sea level is somewhere between the range of 0.67 millimeters and 0.74 millimeters. The research was carried out in Malaysia. The goal of this study was to assess the efficiency of selected coastal protection structures along the coast of Malaysia in terms of avoiding erosion and adapting to rising sea levels. Coastal management methods were also taken into consideration (Rashidi et al., 2021). The phenomenon of climate change-induced sea level rise is a significant concern, particularly when coupled with land subsidence, resulting in the submergence of coastal cities. Sea level rise serves as persuasive proof for the occurrence of land subsidence and the sinking city phenomenon in coastal areas. The use of artificial intelligence in remote sensing is the most effective approach for evaluating sea level changes, which contribute to the phenomenon of coastal region subsidence. Therefore, this article presents a thorough analysis of sink cities and land subsidence and how they affect the development of coastal cities in Malaysia. The analysis is regarded as a sign of land subsidence in conjunction with the sinking cities, especially in Malaysia. Land subsidence is a global problem and can affect development in coastal areas more quickly if not curbed by the government or the parties involved. The biggest factor that can affect the coastal area is cost. Due to soil build-up and damage to buildings, the cost of submerged cities will continue to rise.

The development of coastal city in Malaysia

The term "coastal zone" refers to an area along the shore that is characterized by the interaction of terrestrial and marine activities. The coastal plains, deltaic zones, and coastal wetlands are all included in this category including estuaries and lagoons. Because river and coast processes work together and depend on each other, it is impossible to set a permanent geographical limit for the coastal zone. This makes it difficult to plan for and manage coastal development. Since the beginning of development, coastal communities have always been at risk of experiencing severe weather conditions. The problem of controlling threats to coastal cities is being made more difficult by climate change, in particular by the rise in sea level. This challenge was compounded by rapid urban development. In addition, fragile coastal areas are put under additional stress as a result of pollution and the loss of habitat as cities grow and land use patterns alter and become more intensive. Because of the high population density, as well as the concentration of infrastructure, economic activity, and ecological systems within the coastal zone, specific consideration must be given to the risks posed by climate change.

In major coastal cities, the shoreline or the 100-year flood zone is generally home to long-lasting structures including port facilities, transportation and utility infrastructure, schools, hospitals, and other similar buildings. The area that is at risk of flooding once per hundred years is included in this calculation. These assets may be in danger of both temporary flooding and permanent inundation if the water level continues to rise. Cities along the coast should be very aware of increasing sea levels at their current and predicted rates, as well as any new scientific information that suggests faster or slower rates of sea level rise (Dawson et al., 2018). The city is at risk due to a global rise in water levels that could cause it to sink. One of the most significant issues that coastal towns must face is figuring out how to plan for and react to the devastation caused by natural disasters such as flooding, storm surges, and rising sea levels. Many coastal communities are especially susceptible to the potentially devastating effects that climate change brought on by human activity may have over the long term, as has been highlighted by several recent scientific studies (Lee & Gamez, 2017).

Malaysia is the only country that uses the Federal system to run Coastal Zone Management. Malaysia is driving Coastal Zone Management to make sure that the plan for the environment and natural resources focuses on keeping clean and healthy living resources to fulfil the requirements of economic development (Abdullah et al., 2020). Because the coast is such an important place for shipping, people want to live and work there. The operation of reclamation land in coastal areas, especially in the states of Johor and Penang, is also influenced by the past (coast in the western side of Malaysia). There are about 22 towns and cities along Malaysia's coast. These towns, which serve as State Administrative or District Centers, include some significant cities like Georgetown, Malacca, Johor Bahru, and Kuantan, amongst others. The population of coastal areas is growing at a rapid rate, in addition to the rapid development that is taking place in coastal areas (Bin Nordin, 2006).

In the early days of human settlement, people gravitated toward the coastal regions of Malaysia, particularly the river mouths, because these sites provided convenient access to the rich fisheries that were made possible by the coastal wetland. Melaka is an example of how a number of these pioneering communities developed into commercial cities that served both domestic and international markets. As the population grew, they started forming the hinterland to establish agricultural and mining industries for tin. This development coincided with the expansion of trade. When the British came, they turned a lot of land that used to be uninhabited forests into rubber plantations. A significant number of the coastal communities in the coastal zone, especially those near estuaries, like Kota Bharu, Kuala Terengganu, Kuantan, Johor Bahru, Melaka, and George Town, grew to become the capitals of their respective states and major urban centers. In recent years, other towns that used to be small fishing villages have also become more important, for example, Dungun, Chukai, Pekan, Mersing, Batu Pahat, Muar, Port Dickson, Kelang, Lumut, Perai, and Kuala Perlis. These towns include Dungun, Chukai, Pekan, Mersing, Batu Pahat, and Port Dickson (Abdullah, 2013). Malaysia's coastal economic activities are growing quickly, which could hurt marine resources and the social environment if they aren't planned and managed well. The term for this type of growth is "sustainable development." It is significant since fishing and farming account for around 13.6% of Malaysia's total gross domestic product (Bin Nordin, 2006).

The coastal areas of Malaysia are susceptible to the impacts of rising sea levels. According to a computer simulation conducted by the Centre for Governance and Political Studies (Cent-GPS), it is projected that by the year 2050, nine significant states will experience the phenomenon of having their territory situated below sea level. The phenomenon of global climate warming is anticipated to result in significant climatic changes in Malaysia, which are projected to be

unparalleled in their magnitude during the next three decades. The Centre for Governance and Political Studies (Cent-GPS), a research business located in Malaysia, conducted a computer simulation to assess the potential impact of this circumstance on the nation. The findings give cause for concern. According to the Cent-GPS analysis, it is projected that by the year 2050, nine significant states will experience the impact of land subsidence, resulting in some areas being situated below sea level. The aforementioned locations include Perlis, Kedah, Penang, Perak, Negeri Sembilan, Terengganu, Pahang, Kelantan, and Sarawak. According to the Cent-GPS data, five locations in Malaysia are experiencing gradual submergence and rapid sinking. These locations include Kelantan, Klang, Penang, Kedah, and Kuala Lumpur (Dorall, 2019). The phenomenon of gradual submergence in some locations may be attributed to the rapid sinking of the fundamental surface area caused by underlying factors. The issue that has gotten the most attention in recent times is related to the recurring occurrence of flash floods and groundwater-related concerns.

Based on (Aliza & Iylia, 2022) a specialist in land surveying stated that the act of drilling for subsurface water, formerly seen as a potential solution to the state's water challenges, may result in subsidence of the soil. The phenomenon of ground settling resulting from groundwater extraction has the potential to exacerbate flooding events. Despite the acknowledgement by Dr Zheng of the challenge of identifying the exact underlying cause due to limited data, a strong association was seen between subsidence, which refers to the downward movement of land or structures, and the extraction of groundwater. Kelantan is widely recognised as a city that is extremely well known for being one of the cities that utilises the maximum amount of groundwater. The lack of foresight about future occurrences, particularly concerning groundwater use, has been identified as a significant factor contributing to land subsidence and the sinking of urban areas, and it will be more prevalent around coastal areas. The Member of Parliament, Santiago, referred to the Cent-GPS 2019 study, wherein it was stated that many coastal cities in the nation, including Klang, are projected to be submerged over three decades. According to a recent study report published by Nature.com, it has been projected that Klang, a region, would experience submergence as a consequence of the escalating sea levels and the impacts of climate change. Klang has had five instances of flooding over five months, with the most severe occurrence occurring on December 17th and 18th of the previous year.

The city in consideration is defined by its status as a port and its high population density. To address the challenges posed by this situation, the city needs more financial resources to enhance the capacity of its drainage systems (Dineskumar Ragu, 2022). According to Ili Nadiah Dzulfakar, the chairperson of Klima Action Malaysia, the impacts of climate change extend beyond the loss of coastal lands due to increasing sea levels and may also lead to significant disruptions. This phenomenon has the potential to exacerbate socio-economic disparities between those with resources and those without. Some of the challenges included in this category are the lack of a secure water supply and concerns related to food production (The Vibbes, 2022).

Kedah is well recognized as the state that exhibits the highest susceptibility to the impacts of sea level rise. The granary regions included by the Muda Agricultural Development Authority (MADA), which includes Yusof's rice fields, exhibit a heightened susceptibility to flooding caused by rising sea levels, particularly during the south west monsoon season. This vulnerability is mostly attributed to the low-lying nature of the coastal plains in these areas. During the flood event in June 2016, the occurrence of high tide hindered the discharge of interior floods into the sea, leading to prolonged flooding of the granary region for two days. The inundation caused by the flood event led to significant agricultural losses for paddy farmers residing in the Kuala Kedah

region, with a recorded reduction of over 75% in their crop yield. This decline may be attributed to the intrusion of saltwater into their rice fields (MESTECC, 2018). Penang and Kuala Lumpur are confronted with a common issue, specifically the occurrence of regular flash floods. This situation has led researchers from Cent-GPS to project that by the year 2050, some areas in Penang and Kuala Lumpur will be situated below sea level. Figure 1 shows the provided map illustrating the spatial distribution of coastal cities throughout the country of Malaysia. Among the cities shown, it is essential to include those that possess the ability to confront the issue of sinking cities by the year 2050.

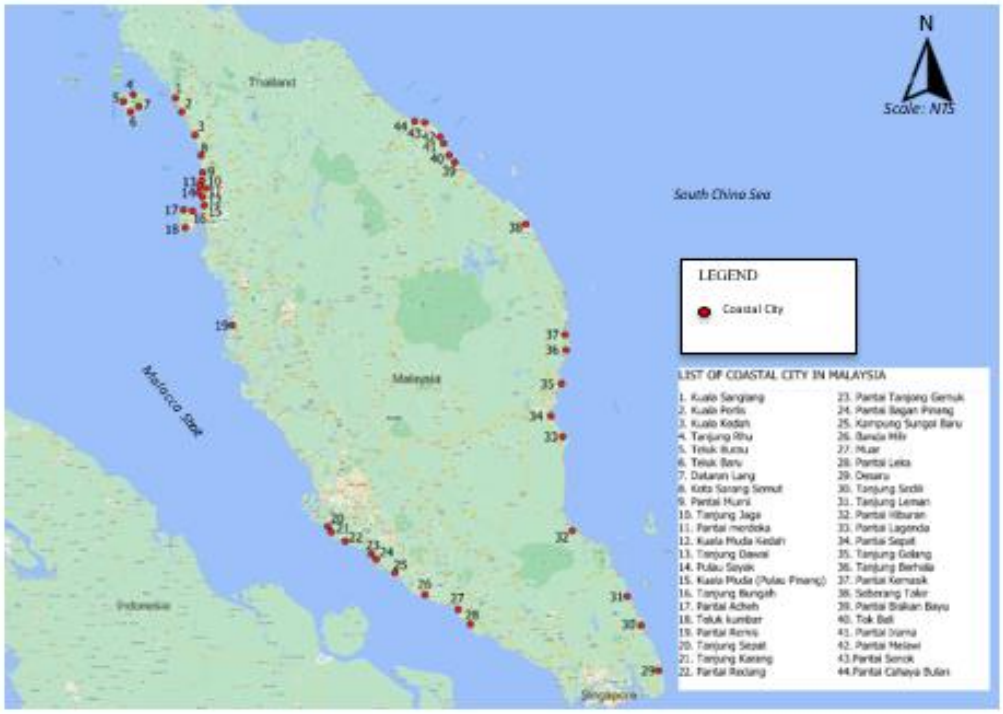

Figure 1. The overall distribution of coastal cities in Malaysia (Peninsular Malaysia)

Theoretical of land subsidence

The phenomena of land subsidence can increase the risk of a natural disaster, particularly in coastal areas, but it is frequently difficult to identify and, as a result, receives less attention than it should (Solihuddin et al., 2021). Subsidence is a geological hazard phenomenon that typically happens when there is a significant depletion of aquifer bodies. This can cause the land to sink. Subsidence of land may be caused by natural processes, such as the migration of tectonic plates, or by human activity, such as the extraction of minerals or the construction of tunnels. In most cases, the economic condition of any particular community might be significantly worsened as a direct result of land subsidence (Pradhan et al., 2014). As the elevation of the land falls below that of the surrounding water, it contributes to the permanent flooding of coastal areas. This happens because the land sinks below the level of the sea. Subsidence also causes other dangers, such as the loss of land and water resources and the destruction of cultural infrastructure. Subsidence also makes river flooding worse, changes the way the land slopes, and breaks up the land surface (Galloway & Hydrology, 2008; Moharrami et al., 2021). The overexploitation of groundwater has led to land

subsidence in several nations throughout the world, including the United States of America, Mexico, Canada, and Italy, which is a significant environmental geological concern. Land subsidence results in large financial losses and causes damage to municipal infrastructures, such as the cracking of subterranean pipelines and buildings, as well as a loss of elevation and a rise in the risk of flooding in coastal communities (Li et al., 2022).

Asian countries that have been experiencing a phenomenon known as land subsidence include China, Indonesia, and Malaysia. The process of land sinking is a complicated one that is influenced both by human activity and the natural geological environment. The process of taking water out of the ground from within an aquifer by human activity is the primary fundamental reason for the sinking of the land's surface. This is due to the drastic fall in the level of the groundwater that causes the aquitard to get compacted, which in turn causes the land surface to sink (Li et al., 2021). Even though the quantity of groundwater that has been extracted has remained constant since 1980, the rate of sinking land in Shanghai's central business district has sped up, and the level of groundwater has already continued to drop. This is even though the amount of groundwater that has been extracted has not changed. The level of groundwater has been going down since 1980, according to data from monitoring stations. This is one of the things that has caused the land to sink since 1980 (Xu et al., 2016). For Indonesia, the city of Semarang, which serves as the capital of the Central Java Province and has a high population that is currently somewhere about 1.5 million, has experienced land subsidence before. The city has previously experienced this kind of occurrence. In comparison to other areas, the part of Semarang that is located to the north and east, close to the coast, has continued to have a rate of subsidence that is considerably greater while also seeing an acceleration in sinking rates. This is especially true in comparison to other regions along the coast. In the city of Semarang, the phenomenon known as land subsidence is said to have been caused by the extraction of groundwater (Andreas et al., 2019).

The occurrence of land subsidence throughout Malaysia has been alarmingly growing over the past few years. This is because of the rapid growth of urban infrastructure, as well as the overexploitation of groundwater and other resources, changes in soil composition, and mineral extraction. The term "ground subsidence" refers to the process in which the surface of the earth sinks at a different rate than the topography that is immediately next to and around the land surface. It is because of factors like the removal of underground resources and the existence of space in the subsurface, both of which can be caused by natural processes or by the acts of humans. Since resources have been taken from below the ground, the amount of space in the subsurface has grown (Abubakar et al., 2020). Natural processes such as subsidence and landslides are two examples of those that have the potential to alter the structure and contours of the Earth's surface. Both subsidence and landslide activity might result in potentially dangerous situations. In a similar vein, the incidence of land subsidence has a detrimental effect on human life and safety throughout the world. As a result of continual sinking over lengthy periods, many urban facilities, including railways, buildings, and highways, as well as electrical instruments buried in the earth, sustain damage. The most significant shift in land use and land cover throughout human history is attributable to the spread of urbanization. The most important preconditions for urbanization are a growth in the human population as well as the usage of available land. One of the potential causes of changes in the climate, as well as the physical environment, is the failure to effectively manage changes in land use and land coverage that are connected to the expansion of urban areas. The considerable temperature disparity between suburban and urban areas has a significant influence on the process of urbanization. This is because urban areas have far higher levels of radiation and thermal conductivity than rural areas do (Abubakar et al., 2020).

The factor of land subsidence

The subsidence of land, whether it is produced by natural processes or by human activity, is a global phenomenon that may be attributed to a wide range of different sources, the vast majority of which are linked to hydrogeologic processes. Subsidence can be caused by several natural things, such as the weight of sediment, geological processes, volcanic eruptions, and the dissolution of minerals that are only moderately soluble, like carbonate and evaporate. Several of the natural processes that cause subsidence are directly affected by human actions, such as the use of land and water, as well as by the climatic fluctuations that occur. The extraction of water resources from groundwater sources to supply clean water to human habitation and cultivation for agricultural purposes often leads to the consumption and diversion of existing surface water supplies and relies on groundwater supplies. This is because groundwater supplies are more stable than surface water supplies (Galloway & Erkens, 2016). When thinking about how sea level rise will affect coastal communities, it's important to think about the relative sea level rise, or how high the sea will get compared to the land around it.

In addition, a significant number of the coastal regions that are undergoing the highest rates of ground sinking in the surrounding area are home to big cities that were developed on level deltas of rivers with low elevations. Because of this, places with lots of people and a lot of economic value are vulnerable to the effects of local relative sea level rise (RSLR). As a consequence of this, it is very necessary to take into account the local land subsidence when evaluating the potential threats that RSLR poses in the future to the environmentally responsible development of coastal areas. The removal of groundwater resources, oil, and gas, along with the natural, self-weight-driven compacting of sediments, are the root causes of local land subsidence (Tay et al., 2020). Land subsidence has escalated in the region as a result of increases in population and urban growth, which have led to excessive depletion of groundwater resources and an increased load from buildings and other structures (Abidin et al., 2013, 2015). The rate at which land subsidence activities are occurring in Malaysia is currently accelerating. The primary factors contributing to land sinking are the overuse of groundwater and the use of groundwater resources, as well as the fast growth of infrastructure in towns and metropolitan areas. Land subsidence is now one of the most important problems the country is facing right now (Abubakar et al., 2020).

Impact of sinking city and land subsidence of coastal city

Due to gaps in both space and time data, it is hard to know what the current state of coastal subsidence is on a global scale. Herrera-Garcia et al. did a systematic review of the literature and found that land has sunk because of the loss of groundwater in 200 places in 34 countries over the past 100 years. They have 200 total locations, and some of them are on the coast. Many coastal communities are experiencing land subsidence at a quicker rate than sea level rise. Assuming current rates of subsidence persist, these cities will face the risk of catastrophic flooding far earlier than predicted by sea level rise models (Wu et al., 2022). One of the most major and expensive repercussions of global warming is that it has caused sea levels to increase, which has led to cities sinking beneath the water. Land subsidence, faster coastal erosion, coastal flooding, and salt-water intrusion are some of the potential negative effects that sea level rise could have. The rising sea levels around the world are also discovered to be ultimately accountable for the difficulties of long-

term coastal erosion. Coastal erosion and rising sea levels can cause people to die, cause problems in some economic sectors, and hurt natural ecosystems and biodiversity (Rashidi et al., 2021)

The phenomenon of rising sea levels is one of the potentially disastrous consequences that climate change has had on the ecosystem. This phenomenon, in turn, has had negative repercussions on the communities that are located along the coast. The coastal sea is negatively impacted by rising sea levels, including greater erosion of the shoreline and the possible submersion of small islands. To add to their precarious position, coastal communities are especially susceptible to hazards like flooding and ground subsidence. Furthermore, areas along the coast are especially vulnerable to natural disasters. If it is not managed appropriately, the calamity will have a more profound effect (Prasetyo et al., 2019). Land subsidence makes coastal areas more susceptible to flooding, both in terms of frequency and duration, which has major repercussions for the economy in the form of damaged infrastructure and increased upkeep expenses for transportation networks, hydraulic infrastructures, sewage systems, building foundations, and building structures (Solihuddin et al., 2021). The land along the coast is a significant resource that has considerable value not only economically, but also socially, culturally, and ecologically. However, coastal towns in Malaysia are already experiencing substantial impacts from sea level rise. Most of these effects are caused by coastal erosion and flooding, which puts the lives of millions of people in danger while also endangering property and infrastructure worth billions of dollars (Ehsan et al., 2019).

Over 30% of the people living along the coast of Malaysia were constantly affected by environmental problems, which got worse because of climate change and human activity. Over twenty per cent of the regions around Malaysia's coastlines are currently being developed, mostly for urbanization and tourism. This is because the coastal regions of Malaysia are the heart of the country's economic operations, which include aquaculture, agriculture, industrial production, and the extraction of oil and gas. Because of the loss of land and the increased risk of floods, these dangers have a significant impact on coastal areas. This is especially true when it comes to how old coastal structures are because they are constantly and unexpectedly exposed to the weather. This makes infrastructure break down faster and is expected to drive more people to cities along the coast (Rashidi et al., 2021).

The United Nations has categorised Malaysia as a nation that is at moderate risk from the effects of natural disasters or climate change. Pahang, Johor, Kelantan, Kedah, and Terengganu have all experienced severe natural disasters as an immediate consequence of the effects of climate change. These catastrophes include flooding, storms, and droughts. This indicates that Malaysia will almost certainly suffer negative consequences and face dangers in the future. The National Hydraulic Research Institute of Malaysia (NAHRIM) has carried out a few significant research projects with urgent climate change challenges. These projects include the compilation of inundation maps, as well as assessments of coastal vulnerability for high-risk regions. Changes in sea level will affect marine habitats and ecosystems, as well as the natural processes that occur along coastal areas. These changes will likely affect infrastructure and the economy. This makes it more difficult to develop coastal cities while also protecting them (Bagheri et al., 2021).

The term "land subsidence" refers to a lowering of land levels in comparison to a certain reference field that is generally regarded to be stable. In this particular instance, alterations take place in the vertical direction within a region. Depending on the symptoms that are present in a region, land subsidence can happen gradually or it might happen suddenly in that region. Flooding is one of the many negative effects that can be caused by land subsidence. Subsidence can have a wide range of unfavourable consequences, including but not limited to the occurrence of flooding.

The sinking of subsurface water, the hardening of clay in aquifers, the mining of sediments and their subsequent compaction, the alluvial deposits' natural compaction over time, landfilling, and the development of buildings are some of the factors that can cause subsidence of the land. Other factors that can cause subsidence in the land include the loading of buildings. There are several examples of land sinking at a pace of a few centimetres every year, and this phenomenon is quite common. Alterations in the ground surface that take place all of a sudden are often followed by real physical changes that are easily observed and recorded, including the degree of the change and its rate of decrease (Prasetyo et al., 2019).

Table 1. The multi-perspective literature on sinking cities and land subsidence and how it affects the development of coastal areas around the world

Authors	Years	Title	Country	How it affects the coastal area
Prasetyo et al., 2019	2019	Impact of land subsidence and sea level rise influence shoreline change in the coastal area of Demak.	Demak, Indonesia	The average change in the coastline in the Demak region is -119.08 m. Demak experienced a land subsidence of +2,078 to -8,376 cm/year. The biggest abrasion occurred in Sayung Subdistrict of -691 m. The largest accretion occurred in the District of Wedung + 512.48 m.
Bagheri et al., 2021	2021	Impacts of future sea-level rise under global warming assessed from tide gauge records: A case study of the East Coast Economic Region of Peninsular Malaysia	Peninsular Malaysia	Peninsular Malaysia's East Coast is vulnerable to sea-level rise, particularly at Kula Terengganu, Terengganu state, with a rate of 1.38 ± 7.59 mm/year, and Tanjung Gelang, Pahang state, with a rate of 1.87 ± 7.33 mm/year.
Rahman et al., 2018	2018	Influence the condition of land subsidence and groundwater impact of Jakarta coastal area	Jakarta, Indonesia	Many groundwater extractions for drinking water have caused intensive scouring of land rock and further triggered land subsidence developed widely in the coastal area of Jakarta. Measurement of land subsidence has been performed by various experts and institutes. Between 1974 to 2010 subsidence happened between 3 to 4.1 meters, especially in Jakarta coastal area.
Gao et al., 2021	2021	Flood inundation analysis in Penang Island (Malaysia) based on InSAR maps of land subsidence and local sea level scenarios	Penang, Malaysia	uplift in the Butterworth of an average mean of about 4mm/year. And also suggest the subsidence at Pari, Bukit Mertajam and Juru of about -5mm/year, -2mm/year and -7mm/year respectively.
Abidin et al., 2015	2015	Environmental impacts of land subsidence in urban areas of Indonesia	Indonesia	In urban areas of Indonesia, the subsidence impacts can be seen already in the field in the forms of cracking and damage of housing, buildings and infrastructure; wider expansion of (riverine and coastal) flooding areas, malfunction of the drainage system, changes in river canal and drain flow systems and increased inland seawater intrusion.
Chaussard et al., 2012	2012	Sinking cities in Indonesia: Space-Geodetic Evidence of the rates and spatial	Indonesia	the Indonesian islands of Sumatra and Java identified 6 major cities undergoing

		distribution of land subsidence		ground subsidence at vertical rates varying from 2 cm/yr to up to 24 cm/yr.
Sarwar, 2005	2005	Impacts of sea level rise on the coastal zone of Bangladesh	Bangladesh	coastal communities and the natural environment of the coastal zone will be affected by the anticipated sea level rise. It will also affect the national and food security of the country. The Sundarbans, the most important ecosystem of the country will be lost with the one-meter rise in sea level.
Takagi et al., 2016	2016	Sea-level rise and land subsidence: Impacts on flood projections for the Mekong Delta's largest city	Vietnam	daily maximum inundation depth, which is generally shallower than 10 cm on the road, seems to be still manageable; however, our analysis indicates that this will start drastically increasing in the coming decades and reach an average depth of 70 cm by 2050.
Hanh & Furukawa, 2007	2007	Impact of sea level rise on the coastal zone of Vietnam	Vietnam	The sea level in Vietnam has increased by 5 cm within the past 30 years. Sea level is expected to rise to 9 cm in 2010; 33 cm in 2050; 45 cm in 2070; and 1 meter in 2100.

Adaptation measures to reduce the impacts of Sink City and land subsidence

Increases in sea levels in Malaysia and elsewhere will intensify these effects and create new threats to coastal populations and infrastructure. The same is true regardless of where sea levels rise around the world, including in Malaysia. As a result, given the lack of adaptation measures employed, the economic impact of an increase in the level of the seas along the Malaysian coastline might be extremely substantial, as has been shown by previous studies to be the case in other coastal regions across the world (Ehsan et al., 2019). The term "adaptation practices" refers to actions that, in the long run, improve resilience or make people less vulnerable to observed changes or changes in decision environments. For example, building protection infrastructure to make people less vulnerable to storm surges or expected changes in climate is an example of actual adaptation practice. Adaptation practices are actions that, in the end, make people more resilient or less vulnerable to changes or adjustments in decision environments (Stone, 1976).

There were primarily two different ways that the indicated adaptation alternatives may be used to safeguard the coastline. The first strategy involves the erection of physical obstacles, whereas the second strategy is less focused on construction-related activities. The installation of physical barriers is one possible kind of adaptation that can be used for cities that are sinking (e.g., seawalls, breakwaters, gabions, groins, and sluices). Adaptation measures such as seawall, rock revetment, Breakwater, and Perpendicular Groyne have been implemented in Malaysia. Based on (Rashidi et al., 2021) seawalls and rock revetment are often regarded as the prevailing, highly efficient, and expeditious measures for mitigating shoreline erosion. However, it is important to note that these methods are also associated with substantial costs and have the potential to have detrimental consequences for the adjacent coastal environment (Susilo et al., 2023; Wu et al., 2022). At Port Dickson, Negeri Sembilan, an innovative porous seawall construction has been constructed, and its length, which is around one hundred meters, has been erected. The construction was composed of reinforced concrete, measured 1.2 meters on all three dimensions, had a 45-degree face angle, and weighed 2500 kilogrammes per unit (Ahmad et al., 2018).

Abdullah et al. (2020) assessed how the local population felt about the efficiency of the rock revetment in place to prevent erosion at Pantai Jeram and Pantai Remis in the state of Selangor in Malaysia. After eight years of implementation, it was seen that the breadth of the beaches had increased. Besides that, The implementation of breakwater structures necessitates a substantial financial investment, therefore necessitating the completion of comprehensive feasibility studies. These studies include a range of essential components, such as an intricate hydrographic survey, meticulous engineering design, a thorough seabed geotechnical study, a meticulous evaluation of wave height, and comprehensive evaluations of material requirements. The selection of an optimal cross-sectional design for breakwaters is a critical consideration to mitigate severe issues such as beach erosion and sediment scour, which often result in substantial destabilization of the foundation (Young & Testik, 2009). The implementation of a combined breakwater and perpendicular groin structure has resulted in the augmentation of stabilization mechanisms, leading to sediment accumulation and subsequent beach expansion in Pantai Cahaya Bulan in Kelantan and Pantai Paka in Terengganu. Furthermore, it is worth noting that a groin protection structure has already been erected by the local population in the vicinity of Cherating Beach.

The most efficient solution to the problem of how to deal with the consequences of climate change on cities that are sinking is to build physical barriers. The physical barriers have the potential to reduce the rise in sea level up to the highest point in the coastal area. This method can also be detrimental to the intertidal habitat, leading to a loss of marine habitat and a compromise of the inherent resistance of the natural environment to change. The second adaptation that can be used to stop or slow down land sinking along the coast is less about building and more about better environmental management. These methods will include: (a) beach nourishment, which focuses on keeping shoreline at a predisposition level; and (b) protecting current ecosystems and reforesting regions near coasts can help prevent floods caused by storm surges and distribute the energy of waves, which in turn lowers the intensity of wave run-ups.

Discussion

Based on finding the impact of sink cities and land subsidence that occur in a few cities, including those in the Asian region. Malaysia, Indonesia, and Vietnam are the countries that are affected by the changes brought on by climate change of sink cities and land subsidence. The potential of sea level rise shows that changes in sea levels in Malaysia and other countries around the world will exacerbate these existing impacts and threaten coastal populations and development. Based on the findings, land subsidence occurs because of groundwater extraction for water supply in urban and coastal areas and causes the area to sink. Coastal areas are natural resources that open job opportunities in the marine industry and tend to influence many people to migrate. Rapid urbanization along the coastal area will increase water demand, which will also highly increase the extraction of water to supply clean water. The degradation of groundwater supplies is the cause of land subsidence, which is responsible for the sinking of cities near the coastline. This is due to the rapid urbanisation and uncontrolled development to adequately accommodate the population. Vietnam is a good example of a developing country since it is extremely reliant on its natural resources along with climate change, and any alteration in the way the environment is managed will have major repercussions if it is not properly cared for. The acceleration of global warming and, in particular, the rise in sea level will make all of these ongoing problems significantly worse. The north-east monsoon, increased river flows, locally heavy rains, and human activities,

particularly considerable increases in development, are some of the factors that contribute to the rising sea level rise in Vietnam. These causes will pose a threat to the coastline in the future. Coastal marshes and wetlands are especially susceptible to damage caused by rising sea levels. The edges of these wetland regions will begin to wear away as the sea level continues to rise, and new wetland areas will form in areas that were dry before the sea level rose. This will occur as the sea level continues to rise.

The fast expansion of development along the coastal region, in the absence of proactive engagement and regulation by stakeholders and local authorities, may necessitate extensive groundwater extraction. This extraction, if not properly managed, has the potential to induce land subsidence, posing a significant risk of areas sinking. Stakeholders have the authority to safeguard coastal cities through the development of protective structures, therefore mitigating the occurrence of city sinking and land subsidence. The use of adaptation measures, such as seawalls, rock revetments, breakwaters, and perpendicular groynes, offers a distinct advantage in mitigating and minimising the adverse effects of Sink City and land subsidence on the coastal regions next to the shoreline. Although the implementation of adaptation measures incurs significant costs, it poses a disadvantage to stakeholders if these measures prove inadequate in mitigating the impacts of natural events.

Conclusion

Understanding the existence of geological, ecological, and physical features of coastal towns is essential for gaining an understanding of the effects that climate change will have on coastal metropolitan regions. Planners need to ensure that the planning for coastal development is more strategic and that the methods used are also better to study and analyze the geographical context of coastal cities around the world so that they can produce better guidelines to deal with global climate change. Sunken cities and land subsidence are phenomena that may not be seen by the community, but this phenomenon will be affected more severely if no action is taken. The issue of underground clean water sources for big cities is a link between urban water management and urban planning. This will lead to increased development in the surrounding coastal cities. The use and distribution of clean underground water resources are affected, either directly or indirectly, in coastal cities and the surrounding areas. Under the supervision of the government, the facility between these two aspects not only helps the city in dealing with water risks such as the city sinking and land subsidence, which can be handled well and can ensure quality access, but it also helps the city become more systematic and, in addition to that, can improve human health, well-being, and quality of life. In working toward the goal of achieving both peace and prosperity throughout the nation, It is the responsibility of both the government and the citizens of the area to guarantee that the lives of those living along the coast are not negatively impacted in any way. According to scholarly studies authored by many scholars, numerous Asian nations are now grappling with the challenges of land subsidence and the phenomenon of sinking cities. Vietnam and Indonesia, together with Malaysia, are the nations that provide the most distinct perspectives on the subject. Malaysia is now addressing the implementation of adaptation measures to mitigate the effects of the issue. While the country has already established protective structures in some areas, there have been noticeable improvements in pursuing the same strategies. To mitigate the adverse impacts of climate change, the government must implement measures that promote comprehensive coastal development while minimising its detrimental consequences on the climate.

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