JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 9, Number 1 (October 2021):3093-3105, doi:10.15243/jdmlm.2021.091.3093
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

The impact of mangrove damage on tidal flooding in the subdistrict of Tugu, Semarang, Central Java

Westi Utami*, Yuli Ardianto Wibowo, Ahmad Haris Hadi, Fajar Buyung Permadi

Sekolah Tinggi Pertanahan Nasional, Jl. Tata Bumi No.5, Area Sawah, Yogyakarta 55293, Indonesia

*corresponding author: westiutami@stpn.ac.id

Article history:
Received 9 July 2021
Accepted 31 July 2021
Published 1 October 2021

Keywords:
land use change
mangrove
tidal flooding
tidal impact

Abstract

Expansion of industrial areas, aquaculture, settlements, and limited knowledge of the community about the function of mangroves allegedly led to the conversion of mangrove functions in the early 1990s. This study aimed to map the condition of mangroves from 1988, 1990, 1995, 2008, to 2021 and their effect on the widespread of tidal flooding in three villages (Mangkang Kulon, Mangunharjo, Mangkang Wetan) in Tugu subdistrict, Semarang City. The research method was carried out by using spatiotemporal analysis of Landsat 5 and Landsat 8 imagery through the supervised approach (Maximum Likelihood algorithm). In order to map the correlation of mangrove damage with the widespread impact of tidal flooding, an overlay analysis of land use maps was carried out in 1988, 1990, 1995, 2008 and 2021. The results of the study showed that mangrove damage is correlated with the widespread of tidal flooding that drowns settlements, ponds, and agricultural land. Data analysis showed that the mangrove area in three villages has decreased from 1988 to 2021, covering an area of 242.66 ha. This condition is one of the triggers for the increase in tidal flooding area from 1988 to 2021, covering an area of 253.135 ha. As a natural barrier to prevent abrasion and tidal flooding, mangrove conservation is very necessary, considering the impact of tidal flooding on the coast of Semarang City is increasingly widespread.

To cite this article: Utami, W., Wibowo, Y.A.**,** Hadi, A.H. and Permadi, F.B. 2021.The impact of mangrove damage on tidal flooding in the subdistrict of Tugu, Semarang, Central Java. Journal of Degraded and Mining Lands Management 9(1):3079-3091, doi:10.15243/jdmlm.2021.091.3079.

Introduction

In recent decades, several countries have faced the issue of mangrove damage as a major threat to the sustainability of coastal ecosystems (Gedan et al., 2011; Osland et al., 2012; Nortey et al., 2016; Meng et al., 2017). The degradation of coastal ecosystems, which has an impact on the failure of sustainable coastal management, also occurs in Indonesia, especially on the coast of Semarang City (Suhelmi, 2012; Pujiastuti et al., 2015). Environmental degradation, the emergence of slum settlements, sea water intrusion that interferes with the availability of clean water, water and air pollution are the bad faces of the central government in Central Java (Pratikno et al., 2014). The demand for development and development of economic centres has caused the carrying capacity of the environment in the city of Semarang to decrease. Coastal reclamation for various development purposes as well as the expansion of several industrial areas also has implications for the destruction of coastal ecosystems and the spread of disasters (Nadzir et al., 2014; Wu et al., 2018), especially tidal flooding that inundated residents' settlements.

The mainland on the coast of Semarang is geomorphologically formed by the sedimentation process of rivers/reservoirs so that the type of soil in this area is alluvial soil (Suhelmi, 2012) with younger conditions compared to the geological structure in Jakarta (Wardhana et al., 2014; Widodo et al., 2018). The formation of soil which is still relatively new and continuing to be under pressure due to the very heavy load of development is correlated with the compression of the soil. On the other hand, excessive groundwater extraction (Ikhsyan et al., 2017) also triggers land subsidence (Yuwono et al., 2013; Maarif et al., 2015). Several studies showed that the decline that occurs on the north coast is very high, reaches 5.16 cm-5.58 cm/year causing the land to decline further so that tidal flooding is increasingly spreading to ponds and residential areas (Wirasatriya et al., 2005; Pujiastuti et al., 2015; Islam et al., 2017; Ondara et al., 2020).

Morphologically, the waters on the coast of Semarang City are sloping with waves that are not as high as the South Coast (Nugraha et al., 2015). However, climate change and environmental degradation have implications for sea-level rise, which causes tidal flooding, the biggest threat to the north coast of Java (Wirasatriya et al., 2005). In addition to land subsidence and sea-level rise, mangrove damage is also suspected to be the initial trigger for tidal flooding in Semarang City. This mangrove damage certainly has implications for the negative impact on the environment because various studies have shown that mangroves are a natural barrier/green belt of tropical and subtropical beaches, have an important role in maintaining the balance of the ecosystem (Kusmana, 2011; Sheng and Zou, 2017; Matatula et al., 2019). The strong root and stem structures make mangroves able to reduce waves, withstand abrasion, storms, mud, and sediment traps, function as biofilters of water pollution (Kariada et al., 2014; Rahman et al., 2019), and prevent seawater intrusion from entering the land (Lasibani and Kamal, 2010; Senoaji and Hidayat, 2016; Miswadi et al., 2017). Mangroves also play an important role in nutrient turnover and become a habitat for various marine biota, contributing to the productivity of fish/shrimp/crab catches for fishermen (Mclvor et al., 2012; Wahyudi et al., 2014; Pramudji, 2015), so that it can be said that coastal communities, especially fishermen, are very dependent on the sustainability of mangroves (Gemilang and Kusumah, 2017). In general, the types of mangroves in these three villages are dominated by *Rhizophora mucronata* and *Avicennia marina,* with trunk diameters ranging from 4-16 cm and tree heights ranging from 1- 5 m. *Avicenia marina* has a better quality to maintain the balance of the ecosystem and neutralize water pollution, especially Cu/copper (Gemilang and Kusumah, 2017).

The conversion of mangrove functions for economic development (Setiyowati et al., 2016) has left part of the north coast in a bare condition with no natural barrier to prevent disaster (Wahyudi et al., 2014; Martuti et al., 2018). Damage to mangroves on the north coast is generally caused by anthropogenic and natural factors. Some of the triggers for anthropogenic factors include the conversion of functions to ponds/agriculture/settlements and industry, lack of public awareness of the function of mangroves, negative perceptions that mangroves are nests of aquaculture pests, high environmental pollution, and pollution due to industrial waste (Indawan et al., 2017; Sejati et al., 2020). In addition, coastal reclamation for industrial development and development without regard to environmental morphological conditions has an impact on the spread of tidal flooding, especially in the lowland area. Meanwhile, the second factor is influenced by nature, including tsunamis, tidal waves, and tropical cyclones. Mangrove logging on the north coast in the 1980s to 1990s had a significant impact on the damage to the coastal ecosystem and correlated with tidal disasters on the coast of Semarang City. The phenomenon of mangrove damage in coastal areas does not only occur in Semarang but also in the coastal areas of Jakarta Bay (Aini et al., 2015), waters in Batam (Rizki et al., 2017) as well as on the coast of Kalimantan (Sukarna and Syahid, 2015). Likewise, in several other countries, mangrove degradation also occurs in New Zealand (Faridah-Hanum et al., 2014), Thailand, India, and several other Asian countries (Mitra, 2013; Nortey et al., 2016).

Various studies related to tidal flooding were carried out by testing the parameters that caused flooding (Kasfari et al., 2017; Islam et al., 2017), tidal flood modeling (Sanjaka et al., 2013; Dewi et al., 2018), socio-economic impact analysis (Pratiwi, 2012; Pratikno et al., 2014; Wicaksono et al., 2018), as well as mitigation efforts to prevent the spread of tidal flooding (Ikhsyan et al., 2017). In addition to the studies mentioned above, studies related to the causal factor correlation approach, the magnitude of the risk, and monitoring of the level of tidal flood inundation need to be carried out in order to formulate appropriate policies and mitigation (Lin et al., 2014). This study aimed to map the distribution and the areas of mangroves in Mangunharjo, Mangkang Wetan and Mangkang Kulon Villages from 1988, 1990, 1995, 2008, to 2021 and their impact on tidal flooding in three villages. Although mangrove damage is not the main cause, mangrove restoration is a possible way to reduce disaster risk in the study area (Gedan et al., 2011; Duarte et al., 2013; Temmerman et al., 2013; Spalding et al., 2014). Meanwhile, other variables, namely land subsidence and sea-level rise, are variables causing tidal flooding that are quite difficult to control, considering that these two are the accumulation of a series of massive development activities.

Materials and Methods

Study area

The selected locations in this study are three villages in Tugu Subdistrict, Semarang City, namely Mangunharjo, Mangkang Wetan and Mangkang Kulon (Figure 1). The three areas were chosen because they have a very high level of vulnerability, experience a very wide impact of tidal flooding (Sanjaka et al., 2013; Wahyudi et al., 2014), as well as massive mangrove damage.

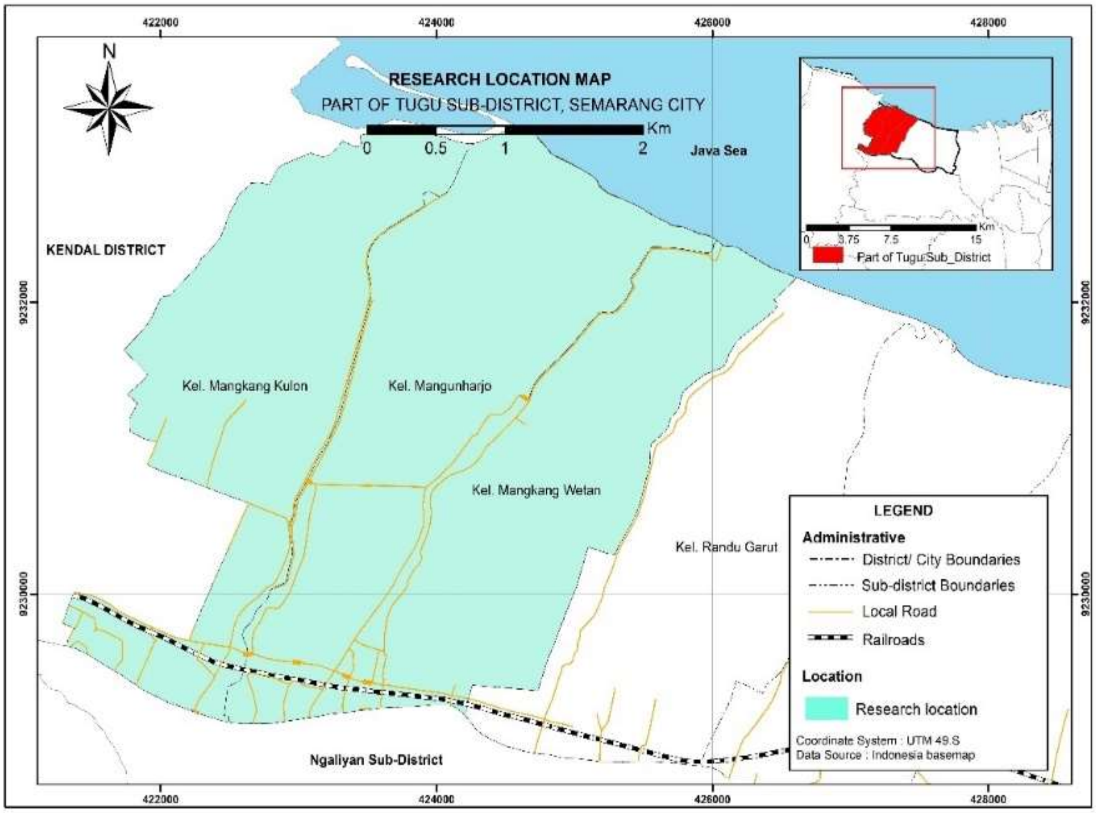


Figure 1. Research location.

At the research location, there is also the development of industrial areas and pond expansion which have implications for the imbalance of coastal ecosystems (Prihatanto et al., 2013).

Image and data processing

The absence of data and maps of land use in the past to determine the condition of mangroves were fulfilled through the use of satellite imagery. In this study, researchers used Landsat 5 imagery to map land use in 1988, 1990, 1995, 2008 and Landsat 8 imagery to map land use in 2021. Landsat 5 imagery has 7 bands, including visible, near-infrared, thermal and mid-infrared wavelengths with a spatial resolution of 30 m. Meanwhile, the Landsat 8 imagery that has been in orbit since 2013 is divided into two sensors, namely the Operation Land Imager (OLI) sensor with 9 bands and the Thermal Infrared Sensors (TIRS) with 2 bands. Image selection was based on literature reviews and interviews with villages/community officials regarding significant changes in mangrove conditions from the 1980s to 2021. Based on these considerations, the determination of image selection was carried out based on several criteria, as presented in Table 1.

The initial stages of image processing were carried out through atmospheric correction with the aim that the reflectance value of the object can be derived from the influence of radiation and remove the influence of the atmosphere. To obtain an image according to the study area, an Area of Interest (AOI) was selected. Furthermore, the data classification analysis process for Landsat 5 and Landsat 8 images was carried out through the maximum likelihood algorithm. This algorithm was chosen because it has a fairly good level of stability and is most commonly used in remote sensing data classification (Jia et al., 2011).

Table 1. Landsat satellite image selection criteria.

Year	Information
1988	Mangrove condition was still natural. After 1988, pond development expanded massively; thus there was mangrove degradation.
1990	Pond expansion was increasingly displacing the mangrove forest. After 1990, there was an awareness of the importance of mangroves that led to mangrove restoration.
1995	Mangrove area increased.
2008	Mangrove restoration continued. After 2008, industrial expansion occurred, thus mangrove land conversion occurred again.
2021	The existing condition when the study was conducted was used to compare the mangrove area and its impact on tidal flooding.

Some of the advantages of maximum likelihood include having statistical values that are more stable and more logical in classifying each pixel value of digital images (Hamdir and Herumurti, 2014: Parsa et al., 2019). In conducting this analysis, a training area is needed for each land use, which includes (mangroves, tidal flooding, built-up land, ponds and non-mangrove vegetation).

The training area taken for each land use class is 100 pixels; for the next training area, a "Compute ROI Separability" test is carried out to calculate the separation of each class to obtain an ROI value above 1.9. The Maximum Likelihood Classification (MLC), uses the assumption that statistical data from each class in each channel is normally distributed and calculates the probability of a pixel falling into a certain class. The pixel value probability threshold is determined in the classification process. If the highest probability value of a pixel is lower than the specified threshold value, then the pixel is included in the unclassified pixel class.

Data accuracy and analysis

The accuracy of the image data classification was tested by conducting a sample test in the field. Results of the accuracy test using the following equation showed that the accuracy level of the samples tested in the field was 95.12%. The results of Landsat image classification through the maximum likelihood algorithm which has been tested for accuracy produced land use maps. Furthermore, to analyze the correlation of mangrove degradation with the extent of tidal flooding, an overlay analysis of land use maps was carried out from 1988 to the year 2021. The results of the overlay map of land use also produce a map of land use changes from year to year that occur in the study area. The data, methods, and analysis in this study are presented in Figure 2.

$$\text{Level of Accuracy } = \frac{\text{Number of validation samples matched (39)}}{\text{Total number of validation samples (41)}} \text{ x } 100\%$$

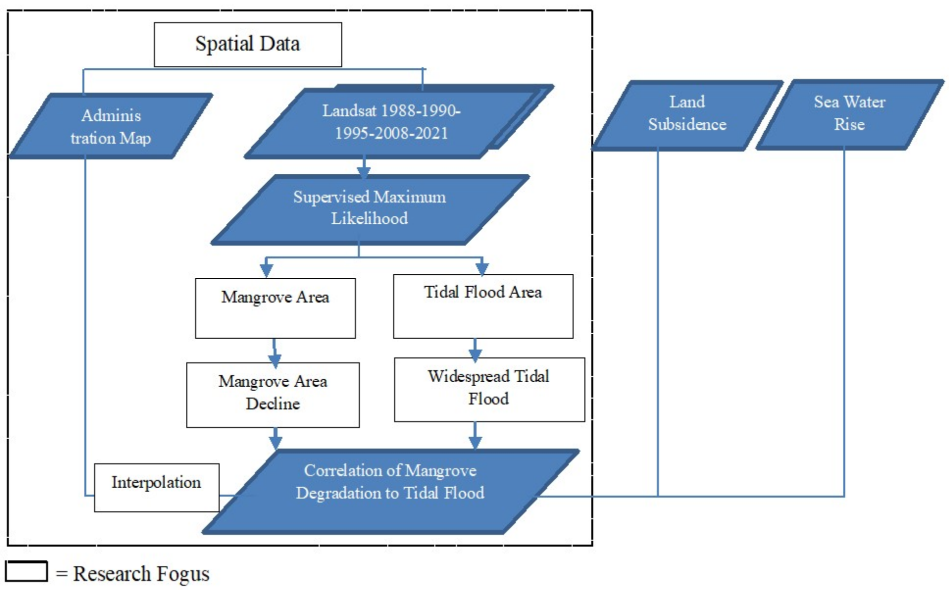


Figure 2. The flow of framework.

Results and Discussion

The impact of mangrove degradation on tidal flooding

The results of the study on Landsat imagery analysis in 1988 showed that the condition of the mangroves in three villages was still in good condition, whereas the distribution of mangroves area is presented in Figure 3. Figure 3 shows that the mangrove conditions are very dense, with an area of 292.44 ha, reaching 22.29% of the total area. This condition was able to maintain the ecosystem and natural balance and to protect land areas from the brunt of the waves. In this period, the phenomenon of tidal flood disaster had not yet emerged because land use was carried out according to what it should be, where the coastal area had the main function as a natural barrier. Likewise, the settlements were quite far from the coastline so that they were safe from the threat of disasters. In 1988, the water inundation only occurred on mangrove land so that it did not cause losses or damage to settlements. Sandilyan and Kathiresan (2012) stated that mangroves are endemic plants, especially in the tropics, so they can thrive with diverse characteristics and types. The strong root system and mangrove trees in coastal areas make mangroves a natural barrier to protect the coast from the threat of disasters (Meng et al., 2017).

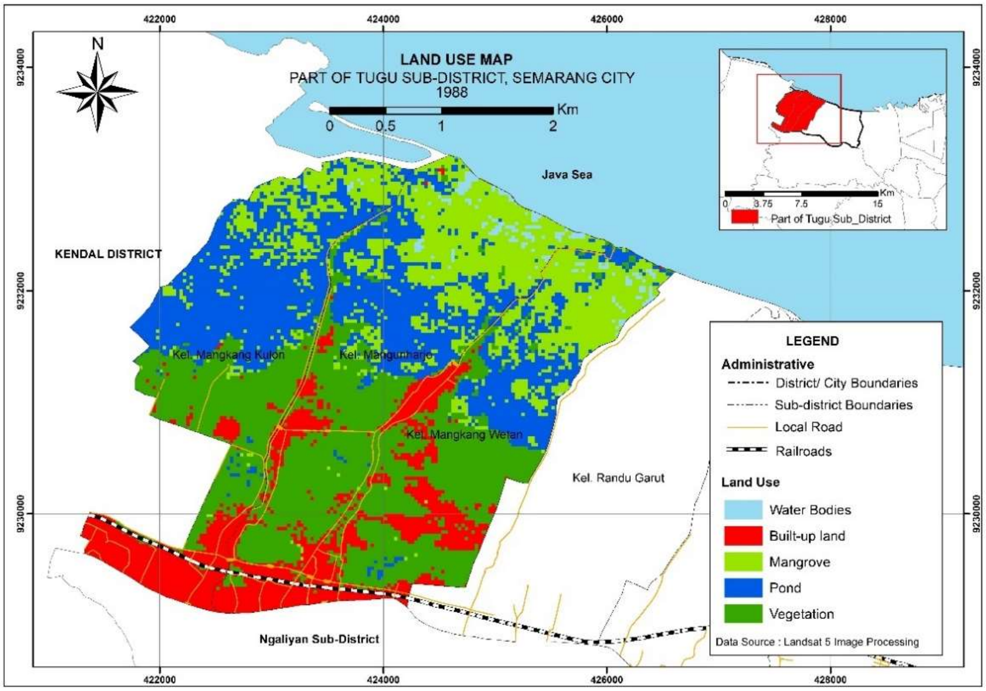


Figure 3. Mangrove condition map in 1988.

One of the major threats to coastal disasters, namely tidal flooding, storms and cyclones that have occurred on Orissa Beach can be suppressed by mangrove forests, but on the contrary, deforestation of mangrove forests that occurred in the Mahanandi Delta resulted in similar disasters that resulted in fatal losses and damage to the community (Mitra, 2013). Data and studies (FAO, 2007) also state that before 1980 the density of mangroves in several areas such as Asia, Africa and Mexico was still very good, as well as in Thailand, the condition of mangroves in 1960 was still very natural (Naito and Traesupap, 2013). However, in the 2000s, namely for two decades, millions of hectares of mangroves in various parts of the world were reduced by 35%, and this condition also occurred in the study area (FAO, 2007; Naito and Traesupap, 2013). Anthropogenic factors such as shrimp pond expansion, tourism area development, pollution, mining operations are major factors in the destruction of mangroves in various countries (Sandilyan and Kathiresan, 2012; Mitra, 2013). The natural balance that was maintained before the 1988s did not last long because the conversion of mangrove functions in two years, namely after 1988 to 1990, was very massive. The expansion of aquaculture and the development of industrial and residential areas in the three villages in those two years had changed and eliminated the mangrove forest covering an area of 123.4 ha or almost 42% of the total mangrove area. Mangrove logging that removed the very thick, dense plants with strong root structures during this period had a significant impact on environmental degradation. For some fishermen, the impact of the damage was directly felt by decreasing fish/shrimp catches (interviews with the community). Meanwhile, for some fishermen who lived in coastal areas, the damage had caused waves to reach the settlement areas. The condition of land use with the narrowing of mangroves is presented in Figure 4 and Table 2. Figures 4 and 5 show the massive conversion of mangroves that occurred in 1990 in the Mangunharjo Subdistrict, namely in the vital part, the front area that was the centre of the main barrier to tidal flooding. The conditions that occurred in the 1990s, when analyzed using the imagery, had a direct impact on the emergence of the tidal flood phenomenon, where for two years, the area of the tidal flood increased to 45.55 ha (22.77 ha/year). This condition became the beginning of a disaster in the three villages where the community started to experience the impact as the ponds and community settlements began to be flooded. Public unrest and concern about the threat of flooding had caused the emergence of public awareness of the importance of mangroves. Environmentalists and academics began to think about the threats that could occur if the damage to mangroves increased. As a mitigation effort, mangrove restoration was initiated by the community, academics, NGOs, and the local government. Although it was not done massively, mangrove replanting was able to increase the mangrove area, as shown in Figure 6. The results of the analysis showed that the mangrove area for five years from 1990 to 1995 increased by 10.72 ha. Although the mangrove area had increased, the mangrove conditions were not as thick and strong as before. The incomplete recovery of the mangrove as the main barrier caused a wider impact of tidal flooding. The data analysis showed that the inundated area in 1995 increased by 24.66 ha.

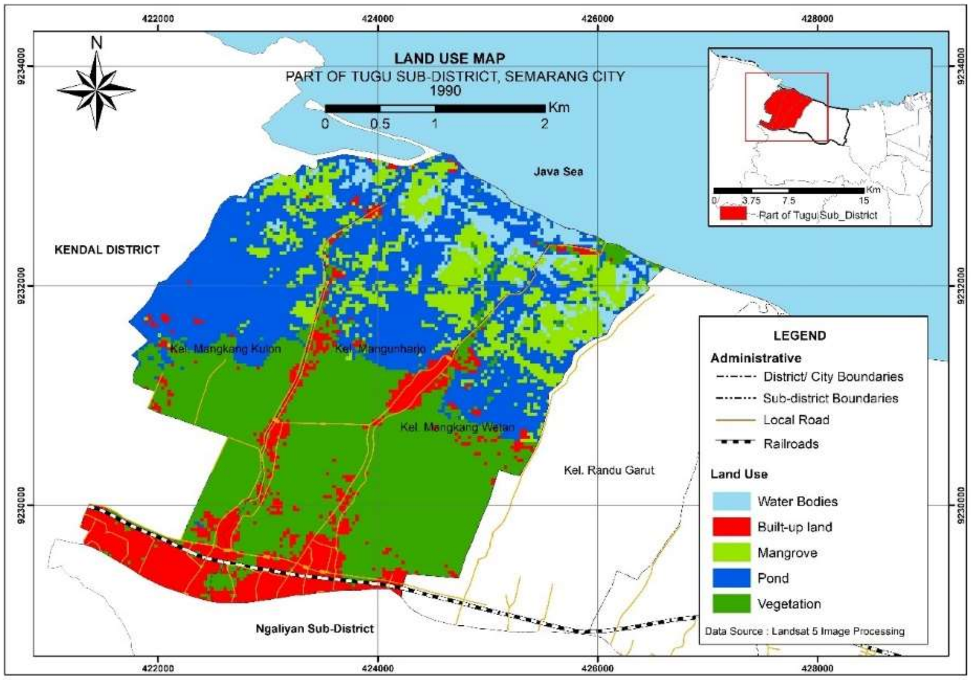
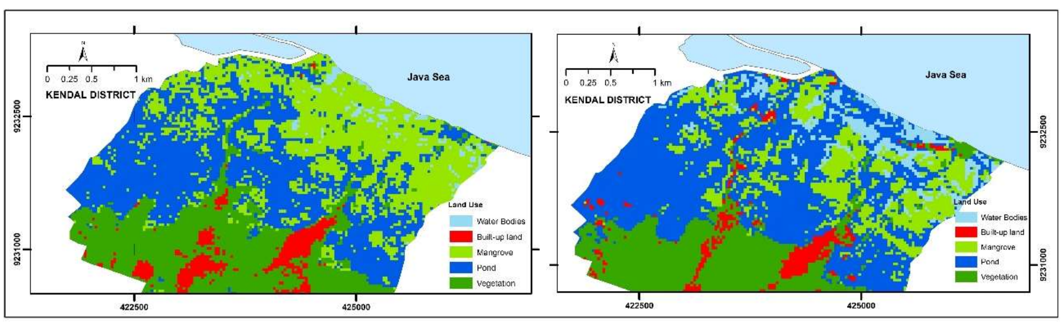


Figure 4. The decline in mangrove areas impacted the widespread of tidal flood in 1990 (Source: Landsat 5 Imagery Analysis).



Mangrove Spatial Distribution in 1988 Mangrove Spatial Distribution in 1990

Figure5. Mangrove degradation in 1990 (Source: Landsat 5 Imagery Analysis).

The restoration carried out did not directly restore the environmental balance because the mangrove vegetation converted in 1999 and 1990 was decades old so that its function was irreplaceable. The imbalance that occurred on the coast has caused weakness of the wave barrier so that the tidal flooding led to a massive impact, namely the inundation of several community settlements covering an area of 66.7 ha and the loss of community ponds covering an area of 45.32 ha.

Restoration efforts that had been continuously carried out by the community and stakeholders in the three villages until 2008 were able to increase the mangrove area to 12.13 ha, but these efforts did not directly correlate to the decrease in tidal floods inundation. The lack of dense mangroves and the presence of other factors, namely sea level rise and land subsidence, had implications for increasing tidal flood inundation covering an area of 110 ha. Although not yet successful, the community's efforts to restore mangroves in the 2000s in the study of Rosenzweigh et al. (2011) become one of the important things and become a form of community adaptation pattern to reduce coastal vulnerability, protect the coast from the threat of disaster for long-term projects in the future (Hale et al., 2009). Restoration of mangrove forests to achieve dense and dense trees, strong root and stem conditions, as studied by Anwar (2007) and Mclvor (2012) takes approximately 10 years. Mclvor (2012) states that when a mangrove forest has dense trees, strong roots and extends widely, it can reduce waves from 5 to 50 cm and can reduce wind speeds up to 75%. Therefore, several countries have implemented mangrove restoration as the most effective form of adaptation in reducing the level of coastal vulnerability (Zhang et al., 2012; Lundquist, 2014). The condition of mangroves and the widespread of tidal flooding in 2008 are presented in Figure 7.

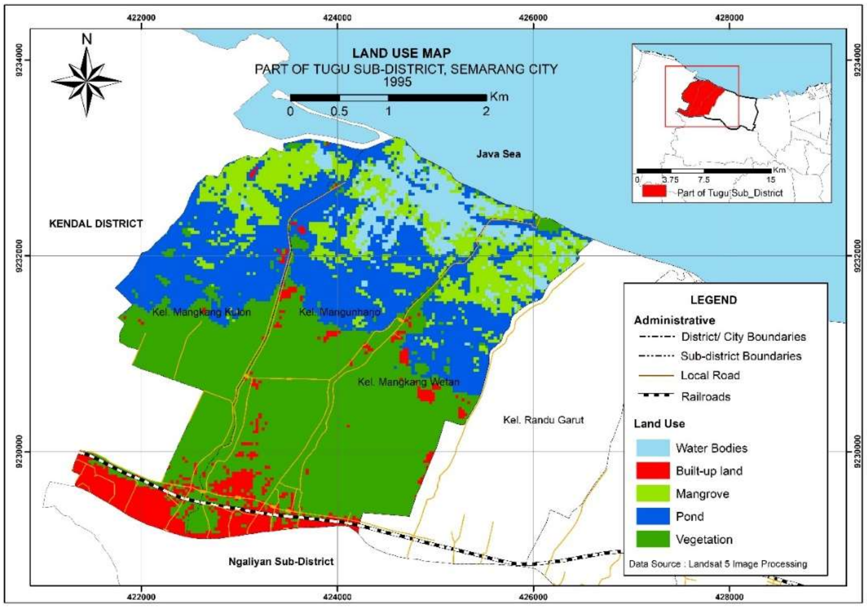


Figure 6. The decline in mangrove areas impacted the widespread of tidal flooding in 1995 (Source: Landsat 5 Imagery Analysis).

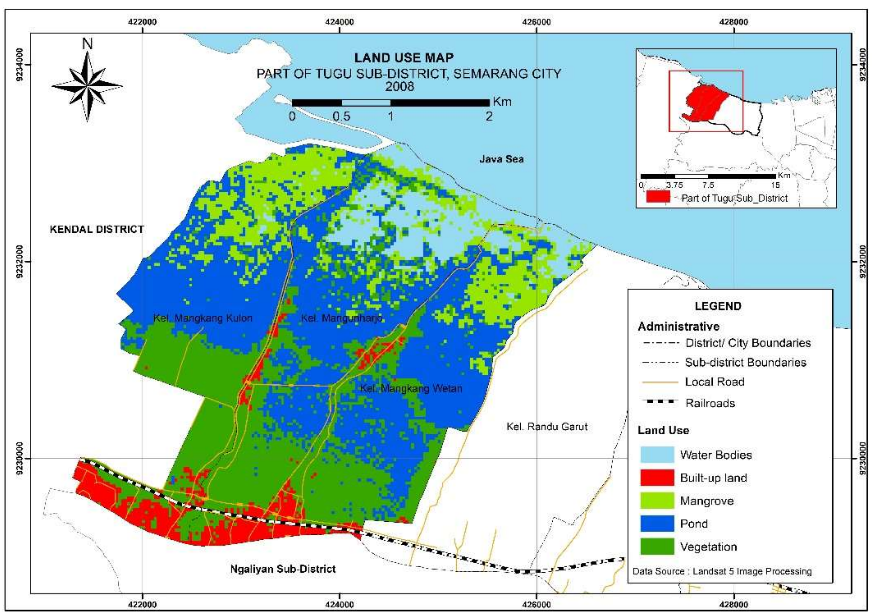


Figure 7. Mangrove distribution and the impact of tidal flooding.

Economic growth that continued to increase and the existence of the three villages that are quite close to the government centre, ports, airports, and the north coast route had resulted in an increase in land use. The expansion of ponds and the emergence of several industrial areas in the study area were also increasingly pressing the mangroves. Likewise, natural factors in the form of tidal waves that hit the mangroves with weak root structures and low density caused some of the mangroves to drift and die. The results of the study showed that until 2021, the condition of mangroves is increasingly degraded where the remaining area is only 49.78 ha, meaning that there was a decrease in the area to 242.66 ha in 23 years. The complexity of the problems faced on the north coast, especially mangrove degradation, has caused tidal flooding to be increasingly widespread in the three villages up to 271.5 ha. The description and distribution of the existing conditions of mangroves are presented in Figure 8. Figure 9 describes mangrove degradation and its impact on the widespread of tidal flooding from year to year.

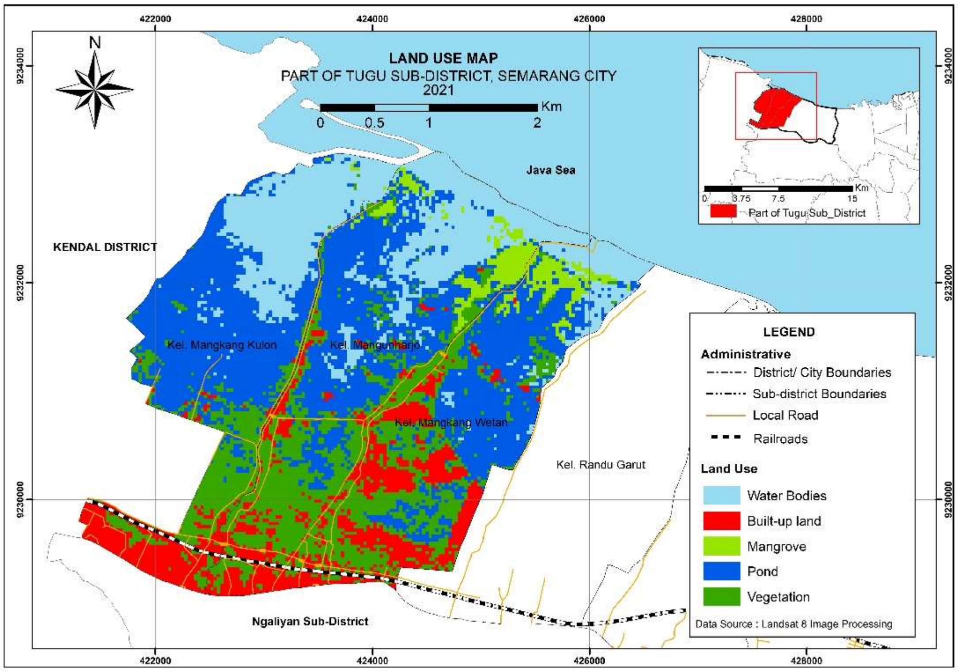
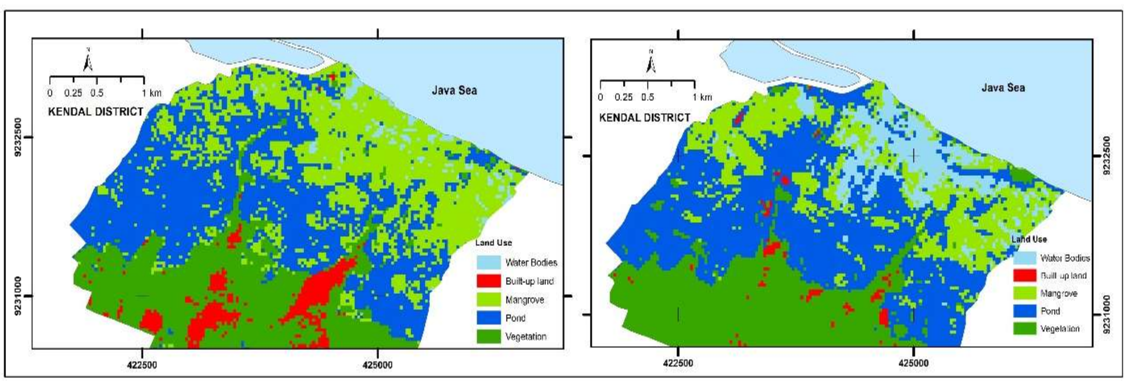
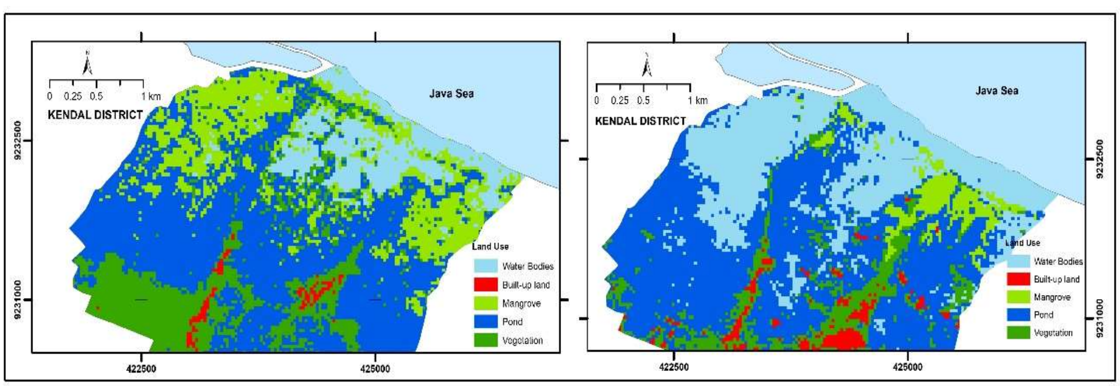


Figure 8. Mangrove degradation causing the widespread of tidal flooding.



Mangrove Conditions in 1988, Tidal Flooding Have Not Occured

Mangrove Degradation in 1995, Tidal Flooding Began to Occur



Mangrove Degradation in 2008, Tidal Flooding is Expanding

Mangrove Degradation in 2021, Tidal Flooding is massive and widespread

Figure 9. Mangrove degradation and its impact on the widespread of tidal flooding.

Figure 9 shows that the disappearance of mangroves as a natural barrier in the three villages has caused the tidal waves to enter and break through the ponds and community settlements. One area that has experienced very significant changes from 2008 to 2021 is in Mangkang Kulon Subdistrict, where the conversion of mangrove functions for ponds has caused tidal flooding to reach far inland.

Loss of community settlements, ponds, and agricultural land

The disappearance of the natural barrier/mangroves, land subsidence phenomenon, and sea-level rise that took place after 1988 have drowned ponds, settlements, agricultural land/rice fields, and infrastructure. Data on the condition of land use changes due to mangrove degradation through the analysis of Landsat imagery are temporally able to provide information on the widespread of tidal flooding. The availability of Landsat imagery that has existed since 1972, with a fairly wide recording coverage, can provide spatial information, especially land cover data periodically. From the results of temporal analysis of Landsat imagery through the supervised maximum likelihood analysis, data on periodic land use changes are presented in Table 2.

The impact of mangrove degradation on tidal flooding has caused losses and inundation of settlements, infrastructure, agricultural land, and aquaculture. The results of interviews with the community also indicated that the continued intrusion of sea water has resulted in the rice being unable to be used for farming so that the community converted it into ponds. The graph of land use changes that occurred in the three villages is presented in Figure 10. Meanwhile, the graph of mangrove degradation against the widespread of tidal flooding is presented in Figure 11. Figures 10 and 11 show that the rate of tidal flooding from year to year is increasing on the north coast. On average, for 33 years, the area of tidal flooding increases by 7.67 ha/year, in which the highest rate of tidal flood inundation occurred from 1989 to 1990 with an average inundation rate of 22.78 ha/year. The logging of mangroves, which at that time was already very dense, was allegedly the beginning of the problem of environmental damage. This condition was even more complex with the reclamation project that occurred in the 2008s, one of which was through the stipulation of the Decree of the Mayor of Semarang City Number 590/04310 concerning the reclamation of an area of 200 ha for the development of industrial estates (Maskur, 2010).

Table 2. Changes in land use from 1988 to 2021.

No.	**Classification**	**Area (ha)**					**Changes in 1988-2021**
		1988	**1990**	**1995**	**2008**	**2021**	
1	Water body	18.37	63.92	88.59	110.05	271.51	253.13
2	Built-up Land	213.667	169.82	103.09	85.09	179.51	-34.16
3	Mangroves	292.45	169.04	179.77	191.90	49.79	-242.66
4	Ponds	354.46	417.64	372.31	522.39	496.41	141.95
5	Nonmangrove Vegetation	433.24	491.76	568.42	402.75	314.98	-118.27

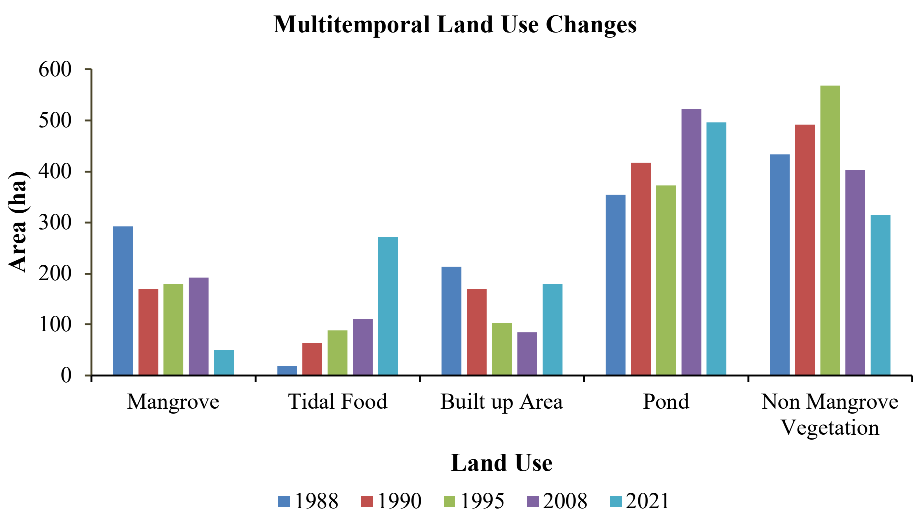


Figure 10. Land use changes.

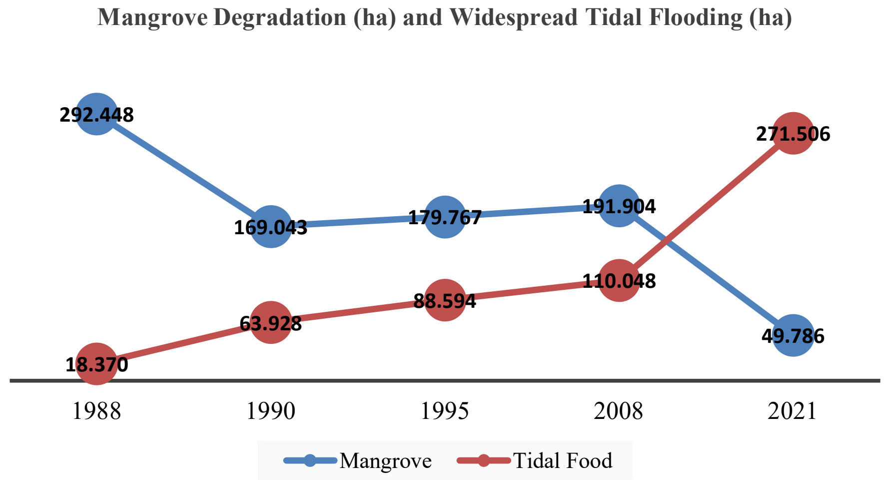


Figure 11. Correlation of mangrove degradation to the widespread of tidal flooding.

The reclamation project by hoarding water areas to be higher than residential areas was one of the triggers for the widespread of tidal flooding. This condition made most people lose their ponds and agricultural land as the main support for their lives. The declining, even the loss of ponds has caused declining incomes, leading to more poverty in the coastal areas of Semarang City (Warsilah, 2017; interviews with the community). The agricultural sector is also a vital aspect that is affected by the tidal wave as seawater intrusion causes waterways that function as irrigation channels to become the entry point of seawater to rice fields. Lundquist (2014) explains that massive mangrove logging if calculated from an economic perspective, is not commensurate with the losses or environmental damage that must be suffered. Furthermore, Mclvor (2012) stated that the cost and recovery time required a very high value to restore the function of mangroves to protect the coast

Environmental degradation and the threat of disasters due to global climate change that occur on the north coast (Pratiwi, 2012) are unavoidable. The complexity of environmental problems faced by the north coast and the widespread of tidal flooding certainly require proper management. Massive mangrove restoration is one of the strategies that are currently possible, given that the variables of sea level rise and land subsidence are also increasing rapidly on the north coast. Mangrove restoration as a strategy to withstand waves and reduce inundation rates towards the mainland are also being carried out in various countries, considering the impact of global climate change is getting more and more inevitable (Mclvor et al., 2012; Sheng and Zou, 2017). Various studies and strategies for mangrove restoration involving academics, environmentalists, and the community by applying technology are carried out to restore the function of mangroves as a balancer for the ecosystem (Osland et al., 2012). The existence of mangroves in mitigating disasters due to global climate change has been proven to be able to reduce losses and damage caused by waves and other coastal disasters (Gedan et al., 2011; Bhattacharya and Guleria, 2012). Mangrove restoration, apart from being able to reduce the level of risk of tidal flooding, is also one of the main sources for community sustainability (Komiyama et al., 2017) which depends on the fishery sector for their livelihood. The reciprocal relationship of the existence of mangroves that is beneficial for the prevention of disasters due to climate change and the source of sustainable community livelihood should become one of the considerations to be concerned about for policy makers in determining the direction of sustainable use of space on the north coast.

Conclusion

The degradation of mangrove forests on the north coast of Semarang City due to the expansion of ponds, development of industrial areas, trade, and settlements has caused an increase in vulnerability and disaster risk. Mangrove forest as a natural barrier to protect the community from disasters and as a spawning ground for marine biota has been degraded and decreased up to an area of 242.66 ha (82.97%). The remaining of only 17% (49.78 ha) of mangroves has resulted in widespread of tidal flooding, reaching 271.5 ha in a period of 33 years. The increasing environmental degradation and weak land use regulation as well as spatial control has resulted in increased losses and even poverty in the study area. Efforts to restore the function of the coast as an area for protecting the land through mangrove restoration and development policies by taking into account environmental sustainability are very necessary considering the impact of tidal flooding is increasingly widespread. This effort is recommended so that coastal communities are safe from the threat of disasters due to climate change and obtain a decent and sustainable life.

Acknowledgement

This study was carried out with funding from Sekolah Tinggi Pertanahan Nasional. The authors would like to thank the community, environmentalists, and local government willing to be interviewed.

References

Aini, H.N., Rusdiana, O. and Mulatsih, S. 2015. Identifications of the vulnerability degradation of mangrove forest in Muara Village, Tangerang, Banten. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan* 5(1):79-86 (*in Indonesian*).

Anwar, C. 2007. The growth of mangrove seedlings planted at various spacing and tidal inundation treatments in Pemalang, Central Java. *Jurnal Penelitian Hutan dan Konservasi Alam* IV (4):353-364 (*in Indonesian*).

Bhattacharya, T. and Guleria, S. 2012. Coastal flood management in rural planning unit through land-use planning: Kaikhali, West Bengal, India. *Journal of Coastal Conservation* 16(1):77-87, doi:10.1007/s11852-011-0176-x.

Dewi, R.C., Hakim, O.S. and Siadari, E.J. 2018. Mike 21's modeling in the rob flooding event ahead of the lunar eclipse on the Semarang Coast. *Jurnal Meteorologi Klimatologi dan Geofisika* 5(3):1-7 (*in Indonesian*).

Duarte, C.M., Losada, I.J., Hendrks, I.E., Mazarrasa, I. and Marba, N. 2016. The role of coastal communities for climate change mitigation and adaptation. *Nature Climate Change* 3:961-968.

FAO. 2007. The World's Mangroves 1980-2005. FAO Forestry Paper No. 153. Rome.

Faridah-Hanum, I., Latiff, A., Hakeem, K.R. and Ozturk, M. 2014. Mangrove ecosystems of Asia: status, challenges and management strategies. *Mangrove Ecosystems of Asia: Status, Challenges and Management Strategies* 1-471, doi:10.1007/978-1-4614-8582-7.

Gedan, K.B., Kirwan, M. L., Wolanski, E., Barbier, E.B. and Silliman, B.R. 2011. The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. *Climatic Change* 106(1):7-29, doi:10.1007/s10584-010-0003-7.

Gemilang, W.A. and Kusumah, G. 2017. Status of mangrove water contamination index based on physical-chemical assessment in Coastal Brebes District, Central Java. *EnviroScienteae* 13(2):171-180 (*in Indonesian*).

Hale, L.Z., Meliane, I., Davidson, S., Sandwith, T., Beck, M., Hoekstra, J., Spalding, M., Murawski, S., Cyr, N., Osgood, K., Hatziolos, M., Eijk, P.V., Davidson, N., Eichbaum, W., Dreus, C., Obura, D., Tamelander, J., Herr, D., McClennen, C. and Marshall, P. 2009. Ecosystem-based adaptation in marine and coastal ecosystems. *Renewable Resources Journal* 25(4):21-28.

Hamdir, A.N.R.W. and Herumurti, S. 2014. Comparisonal study of multispectral classification maximum likelihood and support vector machine for land cover mapping. *Jurnal Bumi Indonesia* 3(4):1-7 (*in Indonesian*).

Ikhsyan, N., Muryani, C. and Rintayati, P. 2017. Analysis of distribution, impacts and adaptation societies flood rob in the Eastern District of Semarang and Semarang Gayamsari District. *Jurnal GeoEco* 3(2):145-156 (*in Indonesian*).

Indawan, E., Hapsari, R.I., Ahmadi, K. and Khaerudin, D.N. 2017. Quality assessment of mangrove growing environment in Pasuruan of East Java. *Journal of Degraded and Mining Lands Management* 4(3):815-819, doi:10.15243/jdmlm.2017.043.815.

Islam, L.J.F., Prasetyo, Y. and Sudarsono, B. 2017. Analysis of land subsidence in Semarang City using Sentinel-1 image based on DinSar method in SNAP software. *Jurnal Geodesi Undip* 6(2):29-36 (*in Indonesian*).

Jia, K., Li, Q., Tian, Y. and Wu, B. 2011. A review of classification methods of remote sensing imagery. *Guang Pu Xue Yu Guang Pu Fen Xi* 31(10):2618-2623.

Kariada, N. and Irsadi, A. 2014. Role of mangrove as water pollution biofilter in Milkfish Pond, Tapak, Semarang. *Jurnal Manusia dan Lingkungan* 21(2):188-194 (*in Indonesian*).

Kasfari, R., Yuwono, B.D. and Awaluddin, M. 2018. Observations of Semarang City land subsidence year 2017. *Jurnal Geodesi Undip* 7(1):120-130 (*in Indonesian*).

Komiyama, A., Kato, S., Poungparn, S., Sangtiean, T., Maknual, C., Piriyayotha, S., Jintana, V., Prawiroatmodjo, S., Sastrosuwondo, P. and Ogino, K. 2017. Comprehensive dataset of mangrove tree weights in Southeast Asia. *Ecological Research* 32(1), doi:10.1007/s11284-016-1417-0

Kusmana, C. 2011. Management of mangrove ecosystem in Indonesia. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan* 1(2):152-157(*in Indonesian*).

Lasibani, S.M. and Kamal, E. 2010. Distribution pattern of propagule growth of mangrove rhizophoraceae in coastal areas of West Sumatra. *Jurnal Mangrove dan Pesisir* X (1):33-38 (*in Indonesian*).

Lin, B.B., Khoo, Y.B., Inman, M., Wang, C., Tapsuwun, S. and Wang, X. 2014. Assessing inundation damage and timing of adaptation: sea-level rise and the complexities of land use in coastal communities. *Mitigation Adaptation Strategy Global Change* (19):551-568, doi:10.1007/s11027-013-9448-0.

Lundquist, C.J., Morrisey, D.J., Gallagher, R.V.G. and Swales, A. 2014. Managing mangrove habitat expansion in New Zealand. *Mangrove Ecosystems of Asia* 416- 434, doi:10.1007/978-1-4614-8582-7_19.

Maarif, S., Pramono, R. and Sunarti, E. 2015. Social capital in settlement relocation after the merapi eruption lessons learned from a case study in Cangkringan Sleman, Yogyakarta. *Jurnal Riset Kebencanaan Indonesia* 1(1):58-66 (*in Indonesian*).

Martuti, N.K.T., Susilowati, S.M.E., Sidiq, W.A.B.N. and Mutiatari, D.P. 2018. The role of community groups in the rehabilitation of mangrove ecosystems in the coastal city of Semarang.. *Jurnal Wilayah dan Lingkungan* 6(2): 100-114, doi: 10.14710/jwl.6.2.100-114 (*in Indonesian*).

Maskur, A. 2010. Reconstruction of legal arrangements beach reclamation in Semarang City. *Law Reform* 5(2):67-82 (*in Indonesian*).

Matatula, J., Poedjiraharjoe, E., Pudyatmoko, S. and Sadono, R. 2019. The spatial spread of the mangrove forest environmental condition at Kupang Seashore. *Journal of Natural Resources and Environmental Management* 9(2):467-482, doi:10.29244/jpsl.9.2.467-482 (*in Indonesian*).

Mclvor, A., Spencer, T. and Möller, I. 2012. Storm surge reduction by mangroves. *Natural Coastal Protection Series*: Report 2.

Meng, X., Xia, P. and Li, Z. 2017. Mangrove development and its response to Asian monsoon in the Yingluo Bay (SW China) over the last 2000 years. *Estuaries and Coast* 40:540-552, doi:10.1007/s12237-016-0156-3.

Miswadi, Firdaus, R. and Jhonnerie, R. 2017. Utilization of mangrove wood by the indigenous people of the Liong

River, Bengkalis Island. *Dinamika Maritim* 6(1):35-39 (*in Indonesian*).

Mitra, A. 2013. Climate change and its impact on brackish water fish and fishery. In: *Sensitivity of Mangrove Ecosystem to Changing Climate*, pp 291-217, doi:10.1007/978-81-322-1509-7_6.

Nadzir, N.M., Ibrahim, M. and Mansor, M. 2014. Impacts of coastal reclamation to the quality of life: Tanjung Tokong community, Penang. *Procedia-Social and Behavioral Sciences* 156:159-168, doi:10.1016/j.sbspro.2014.10.050.

Naito, T. and Traesupap, S. 2013. The Relationship Between Mangrove Deforestation and Economic Development in Thailand. In : Faridah-Hanum, I., Latiff, A., Hakeem, K.R. and Ozturk, M. (eds), *Mangrove Ecosystems in Asia*, pp 273-294, Springer.

Nortey, D.D.N., Aheto, D.W., Blay, J., Jonah, F.E. and Asare, N.K. 2016. Comparative assessment of mangrove biomass and fish assemblages in an urban and rural mangrove wetlands in Ghana. *Wetlands* 36(4):717-730, doi:10.1007/s13157-016-0783-2.

Nugraha, W., Rochaddi, B. and Rifai, A. 2015. Study of bathymetry and land loss in the coastal area of Tugu Semarang. *Jurnal Oseanografi* 4(2);442-450 (*in Indonesian*).

Ondara, K., Dhiauddin, R., Wisha, U.J. and Rahmawan, G.A. 2020. Hydrodynamics features and coastal vulnerability of Sayung Sub-District, Demak, Central Java, Indonesia. *Journal of Geoscience, Engineering, Environment, and Technology* 5(1):32-39, doi:10.25299/jgeet.2020.5.1.3996

Osland, M.J., Spivak, A.C., Nestlerode, J.A., Lessmann, J.M., Almario, A.E., Heitmuller, P.T., Russell, M.J., Krauss, K.W., Alvarez, F., Dantin, D.D., Harvey, J.E., From, A.S., Cormier, N. and Stagg, C.L. 2012. Ecosystem development after mangrove wetland creation: Plant-soil change across a 20-year chronosequence. *Ecosystems* 15(5):848-866, doi:10.1007/s10021-012-9551-1.

Parsa, M., Dirgahayu, D. and Harini, S. 2019. Development of paddy field classification method based on multi-temporal indeces of Landsat images. *Jurnal Penginderaan Jauh dan Pengolahan Data Citra Digital* 1(1):35-44 (*in Indonesian*).

Pramudji, 2015. Mangrove status in the North Coastal Area of West Java (Karawang and Indramayu) and Management Efforts, *Oseana* 2:43-52 (*in Indonesian*).

Pratikno, N.S. and Handayani, W. 2014. The effect of tidal flooding inundation on the socio-economic dynamics of the people of Bandarharjo Village, Semarang. *Jurnal Teknik PWK* 3(2):312-318 (*in Indonesian*).

Pratiwi, M.R.I. 2012. Impact of the tidal floods dynamics to social ecological system of Semarang City (Case study in Tanjung Mas District) Thesis, Institut Pertanian Bogor (*in Indonesian*).

Prihatanto, A., Giyarsih, S.R. and Suharyadi. 2013. Identification of disaster conditions in the coastal area of Tugu District, Semarang City. *National Seminar on The Utilization of Geospatial Information* (*in Indonesian*).

Pujiastuti, R., Suripin, and Syafrudin. 2015.The effect of land subsidence on floods and robs in East Semarang. *Media Komunikasi Teknik Sipil* 21(1):1-12, doi:10.14710/mkts.v21i1.11225 (*in Indonesian*).

Rahman, Yulianda, F., Rusmana, I. and Wardiatno, Y. 2019. Production ratio of seedlings and density status of mangrove ecosystem in coastal area of Indonesia. *Advances in Environmental Biology* 13(6):13-20, doi:10.22587/aeb.2019.13.6.3.

Rizki, F., Situmorang, A.D.L., Wau, N., Lubis, M. Z. and Anurogo, W. 2017. Mapping of vegetation and mangrove distribution level in Batam Island using SPOT-5 satellite imagery. Journal *of Geoscience, Engineering, Environment, and Technology* 2(4):264-267, doi:10.24273/jgeet.2017.2.4.1002.

Rosenzweig, C., Solecki, W., Blake, R., Bowman, M., Faris, C., Gornitz, V., Horton, R., Jacob, K., LeBlanc, A., Leichenko, R., Linkin, M., Major, D., O'Grady, M., Patrick, L., Sussman, E., Yohe, G. and Zimmerman, R., 2011. Developing coastal adaptation to climate change in the New York City infrastructure-shed: process, approach, tools, and strategies. *Climate Change* 106(1):93-127, doi:10.1007/s10584-010-0002-8.

Sandliyan, S. and Kathiresan, K. 2012. Mangrove conservation: a global perspective. *Biodiversity and Conservation* 21(14):3523-3542, doi:10.1007/s10531-012-0388-x.

Sanjaka, P.A., Widada, S. and Prasetyawan, I.B. 2013. Inundation modeling (flood rob) in Coastal Semarang City using hydrodynamic model. *Jurnal Oseanografi* 2(3):353-360 (*in Indonesian*).

Sejati, A.W., Buchori, I., Kurniawati, S., Brana, Y.C. and Fahira, T.I. 2020. Quantifying the impact of industrialization on blue carbon storage in the coastal area of Metropolitan Semarang, Indonesia. *Applied Geography* 124: 102319, doi:10.1016/j.apgeog.2020.102319.

Senoaji, G. and Hidayat, M.F. 2016. The role of mangrove ecosystem in the coastal of city of Bengkulu in mitigating global warming through carbon sequestration. *Jurnal Manusia dan Lingkungan* 23(3):327-333 (*in Indonesian*).

Setiyowati, D., Sipriharyono, and Triarso, I. 2016. Economic valuation of mangrove resources in Mangunharjo Village, Tugu District, Semarang City. *Saintek Perikanan Indonesian Journal of Fisheries Science and Technology* 12(1):67-74, doi:10.14710/ijfst.12.1.67-74 (*in Indonesian*).

Sheng, Y.P. and Zou, R. 2017. Assessing the role of mangrove forests in reducing coastal inundation during major hurricanes. *Hydrobiologia* 803(1):87-103, doi:10.1007/s10750-017-3201-8.

Spalding, M.D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L.Z., Shepard, C.C. and Beck, W.M. 2014. The role of ecosystems in coastal protection. *Adapting to Climate Change and Coastal Hazards* 90: 50-57, doi:10.1016/j.ocecoaman.2013.09.007.

Suhelmi. 2012. Study on the impact of land subsidence on increasing inundation area in Semarang City. *Jurnal Ilmiah Geomatika* 18(1):9-16 (*in Indonesian*).

Sukarna, R.M. and Syahid, Y. 2015. FCD application of landsat for monitoring mangrove in central Kalimantan. *Indonesian Journal of Geography* 47(2): 60-170, doi:10.22146/ijg.9259 (*in Indonesian*).

Temmerman, S., Meire, P., Bouma, T.J., Herman, P.M.J., Ysebaert, T. and de Vriend, H.J. 2013. Ecosystem- based coastal defence in the face of global change. *Nature* 504:79-83, doi:10.1038/nature12859.

Wahyudi, A., Hendrarto, B. and Hartoko, A. 2014. Assessment of mangrove habitat vulnerability in Mangunharjo Village, Tugu District, Semarang City against oceanographic variables based on the Cvi method (Coastal Vulnerability Index). *Diponegoro Journal of Maquares* 3(1):89-98 (*in Indonesian*).

Wardhana, D.D., Harjono, H. and Sudaryanto, H. 2014. Subsurface structure of Semarang City based on gravity data. *Riset Geologi dan Pertambangan* 24(1):53-64 *(in Indonesian*).

Warsilah, H. 2017. Living and surviving in Semarang which continues to sink, The Conversation, https://theconversation.com/hidup-dan-bertahan-di-semarang-yang-terus-ambles-78356 (*in Indonesian*).

Wicaksono, A., Wicaksono, P., Khakhim, N., Farda, N.M. and Marfai, M.A. 2018. Tidal correction effects analysis on shoreline mapping in Jepara Regency. *Journal of Applied Geospatial Information* 2(2):145-151.

Widodo, D.R., Nugroho, S.P. and Asteria, D. 2018. Analysis of the causes of people staying in the disaster-prone area of Mount Merapi (study on the slope of Mount Merapi, Cangkringan District, Sleman Regency, Special Region of Yogyakarta) *Jurnal Ilmu Lingkungan* 15(2):135, doi:10.14710/jil.15.2.135-142 (*in Indonesian*).

Wirasatriya, A., Hartoko, A., Suripin. 2006. Study of sea level rise as a base for rob problem solving in coastal region of Semarang City. *Jurnal Pasir Laut* 1(2):31-42 *(in Indonesian*).

Wu, W., Yang, Z., Tian, B., Huang, Y., Zhou, Y., Zhang, T. 2018. Impacts of coastal reclamation on wetlands: loss, resilience, and sustainable management. *Estuarine, Coastal and Shelf Science* 210:153-161, doi:10.1016/j.ecss.2018.06.013.

Yuwono, B.D., Abidin, H.Z. and Hilmi, M. 2013. Geospatial analysis of the causes of land subsidence in Semarang City. *Proceedings of the 4th SNST in* 2013, January 2013: -12 (*in Indonesian*).

Zhang, K.Q., Liu, H., Li, Y., Hongzhou, X., Jian, S., Rhome, J. and Smith III, T.J. 2012. The role of mangroves in attenuating storm surges. *Estuarine, Coastal and Shelf Science* 102:11-23.