Assessing the Impact of Flood Induced by Sea Level Rise and Land Subsidence in Semarang City

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SUMMARY

Semarang city faces problematic problems, one of which is land subsidence. Land subsidence is a phenomenon that still occurs in the city of Semarang. Land subsidence has a significant impact. These impacts can be categorized as direct or indirect. Direct impacts can be identified from building cracks, sloping buildings, abandoned buildings, and damage to infrastructure. Meanwhile, the indirect impact is in the form of expanding flood inundation, decreasing quality of life, slum areas, health problems, and decreasing inc.

The impact assessment is very important for the purposes of flood management and decision making for mitigation steps. The studies include the mapping of the spatial distribution of the damage locations caused by land subsidence and the losses suffered by the economic, social, and environmental sectors, respectively.

This paper aims to present a literature review on assessment of the impact of flood in Semarang city, detailing on its applications and limitations. This paper also identifies and examines the types of data and methods used to obtain the value of losses due to flood caused by land subsidence in Semarang city. The paper also discusses assessment of loss damage of flood induce by sea level rise and land subsidence.

SUMMARY

Kota Semarang menghadapi permasalahan problematis, salah satunya adalah penurunan muka tanah. Penurunan muka tanah merupakan fenomena yang masih terjadi di Kota Semarang. Penurunan muka tanah memberikan dampak yang cukup signifikan. Dampak tersebut dapat dikategorikan sebagai langsung maupun tidak langsung. Dampak langsung dapat diidentifikasi dari adanya retakan bangunan, bangunan miring, bangunan terlantar, dan kerusakan infrastruktur. Sedangkan dampak tidak langsung berupa perluasan genangan banjir, penurunan kualitas hidup, daerah kumuh, gangguan kesehatan, maupun turunnya pendapatan.

Penilaian dampak sangat penting untuk tujuan pengelolaan banjir dan pengambilan keputusan untuk langkah-langkah mitigasi. Kajian tersebut meliputi pemetaan sebaran spasial lokasi kerusakan yang diidentifikasi sebagai kerusakan akibat penurunan permukaan tanah, serta penilaian kerugian yang diderita masing-masing sektor ekonomi, sosial dan lingkungan.

Makalah ini bertujuan untuk menyajikan tinjauan pustaka tentang penilaian dampak banjir di Kota Semarang, merinci aplikasi dan batasannya. Makalah ini juga mengidentifikasi dan mengkaji jenis data dan metode yang digunakan untuk memperoleh nilai kerugian akibat banjir akibat penurunan muka tanah di Kota Semarang. Makalah ini juga membahas penilaian terhadap kerugian akibat banjir yang dipicu oleh kenaikan muka air laut dan penurunan muka tanah.

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1. INTRODUCTION

Semarang is the capital of Central Java province, Indonesia. It is a city that is vulnerable to environmental influences because of its geographic location on the north coast of Java island so that it comes under pressure in the form of sea level rise in the form of tidal flooding. This condition was made worse by the phenomenon of land subsidence that occurred in the northern region of Semarang, which had an impact on the widespread inundation that occurred. Floods can cause major disruption in cities, and have significant human, economic, social and environmental impacts. This has become the concern of city planners and decision makers to manage floods for future planning of Semarang city, in addition to flood risk management.

2. LAND SUBSIDENCE

2.1 Monitoring Land Subsidence

In the last decade, land subsidence in the city of Semarang has shown an increasing rate of land subsidence. Monitoring of land subsidence observations from various geodetic methods such as leveling, GPS, InSARand gravity methods, reveal the average rate of land subsidence of about 13.5 cm /year, as shown in Table 1.

Table 1. Various observed land subsidence rates in Semarang.

No	Period	Land Subsidence (cm/yr)	Method	Reference
1	1996 - 2000	1 - 10	Levelling	(*Marfai and King*, 2007)
2	1999 - 2003	1 - 17	Levelling	(*Murdohardono et al.*, 2007)
3	2002 - 2005	1 - 15	Microgravity	(*Supriyadi*, 2008)
4	2000 - 2001	1 - 8	GPS	(*Tobing et al.*, 2001)
5	2008 - 2011	1 - 19	GPS	(*Abidin et al.*, 2010, 2012)
6	2016- 2018	1 - 19	GPS	(*Yuwono et al.*, 2019)
7	2002 - 2006	1 - 8	PSI InSAR	(*Kuehn et al.*, 2010)
8	2015 - 2017	1 - 18	DinSAR	(*Yastika et al.*, 2019)

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2.2 Sea Level Rise

Sea level rise has become an international concern with the intergovernmental meeting / Panel to discuss Climate Change (IPCC). The results of the meeting confirmed that sea level rise (SLR) as a result of global warming is considered to be one of the most serious problems faced by coastal communities (IPCC 2001). The Mean Sea level rise of 10-25 cm from the last century is expected to increase by about 0.5 m by 2100 (*Nicholls and Mimura,* 1998).

The physical conditions that are serious because of SLR are erosion, inundation, flooding and salinity of estuaries and salinity of estuary and aquifer aquifers (Barth and Titus 1984). Topographical conditions with low slopes are the most affected locations, such as coastal ridges, coastal plains, deltas, muds, estuaries, lagoons and bays which will be coastal inundations with increasing SLR values.

Semarang is geographically located at latitude 6º 58'S and 100º25 'E with an area of 373.km2 with a population of 1.7 million, with the development of the city of Semarang is quite rapidly leading to the north in the coastal area in the lowlands. This condition leads to urbanization and environmental problems such as coastal erosion, sedimentation and excess groundwater use. Sea level rise has the impact of increasing inundation area per year which will worsen the condition. Semarang, located on the northern coast of Java Island, has experienced tidal flooding caused by rising sea levels. Land subsidence that occurred in the city of Semarang has exacerbated tidal flooding that occurred and resulted in the expansion of tidal flood inundation. Therefore, the study on the impacts of land subsidence cannot be separated from the impact caused by tidal flooding

2.3 Understanding of Flood Assessment

The term 'flood impact' refers to the widespread impacts caused by flooding on people, property, and the environment. Damage is seen as a negative result of the spatial and temporal impact of an event on elements of society (people,buildings, etc.), social processes (disruption of production, services, etc.) and the environment (*Veen et al.,* 2003). Damage can be defined as single or multiple impact.

The impact of flooding caused by land subsidence and sea level rise can be in the form of direct and indirect damages. Direct tangible damage can be in the form of physical damage caused by property through direct contact with floodwaters in the residential, non-residential and infrastructure sectors. Indirect impacts are triggered due to unsolved direct impacts. Indirect impacts can be in the form of economic, social or environmental impacts.

The effects of sea level rise and land subsidence results in (result in) flooding and widespread inundation which then causes many impacts. These impacts are not only physical in the form of damage to buildings and infrastructure but also economic impacts such as increased living costs, decreased income, social impacts such as quality degradation. life, changes in livelihoods and social behavior of the community as well as environmental damage such as increased abrasion, mangrove damage, changes in river flow, the emergence of slum areas, a decrease in the quality of soil and groundwater, and so on (Abidin et al. 2015). Examples of impacts of land subsidence are shown in Figure 1.

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Figure 1. Examples of impacts of land subsidence in Semarang.

3. FLOOD IMPACT ASSESSMENT IN SEMARANG CITY

The vulnerability of land subsidence in northern Semarang due to impacts of land Subsidence and sea level rise is explained by *Sari and Dananjaya* (2020). This factor becomes an important thing in the assessment of the impact of the caused flood. Method used in this study is by calculating score refers to variable which has been determined. The variables are climate/ rainfall, land coverage, slope shape, land system, and elevation. The results of the analysis show that land use and topography are very dominant in flood vulnerability in North Semarang City. In addition, growth and the impacts of climate change can also be driving factors.

According to (*Gumilar et al.,* 2013) people who suffer from land subsidence as a result of tidal floods quickly adapted and made structural changes, such as elevating houses, raising the level of the house or yard, and even constructing a small barrier to keep the water out. Seawater that seeps into the ground will harm the base, floors, and walls and frames (Marfai and King 2007). Not to mention houses that have nearly drowned (in progress), bridges that have been destroyed, pipelines that have been damaged, and other infrastructure. Land subsidence has a physical impact that will result in economic losses such as cracking in buildings and infrastructure (roads and bridges) of sloping and damaged houses. In addition to direct losses, land subsidence also has the potential to result in an increase of tidal flooding in the northern of Semarang.

Economic resilience at prone area was explain by (*Kurniawati and Suwandono,* 2015).This research focuses on the formulation of economic resilience in tidal and annual disaster prone areas in Johar, Semarang. The study shows that the majority of trading activities in Johar Trading Area are vulnerable. It can be seen from the change in the amount of income that there is a change in the number of visitors, where the activity is very much influenced by the number of visitors who come so that it has an impact on the income received. In addition, there were also changes in the number of workers and the number of working hours during the tidal disasters and annual floods. A study of potential economic losses as a result of land subsidence and sea level rise based on inundation distribution is generated from DEM data and PMT data with reference to the IPCC (2007) scenario with a prediction of an SLR of 13.4

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cm in 2030. The results of the study showed potential economy losses reaching Rp. 6.130 trillion with an inundation area of 1,718.2 ha. Taking into account the PMT aspect, the inundation area reaches 5,171.3 ha with a potential loss of up to IDR 28,724 Trillion. (Suhelmi et al., 2014)

Quantitative risk assessment is needed to determine the actual risk that occurs in society. Risk assessment due to flooding in Java Island based on a land uses change scenario (Nafishoh, Meilano, and Riqqi 2018). The assessment is carried out by integrating hazard, vulnerability and risk elements through a Geographical Information System (GIS). Hazard is represented by flood depth, vulnerability is represented by a vulnerability curve that connects the flood depth to the probability of damage, and risk elements are represented by settlement and population.. (Sarah, Satriyo, and Mulyono 2014) studied the estimated impact of land subsidence in Semarang City on physical losses. Estimation of the impact of physical damage such as roads, bridges, houses and buildings. This was done through compilation of secondary data, field surveys, cost-loss analysis and cost estimation. Economic loss analysis is carried out by calculating the costs incurred for repairing buildings and infrastructure damaged by land subsidence. Estimated loss price estimation refers to the unit planning cost of Bappenas for Central Java Province (2000) and DKI Jakarta Province (2013)

Impact tidal flood in Bandarharjo Urban Village is explained by (Pratikno and Handayani 2014). In the period (1985-1995) only RW I had experienced tidal inundation with a height of <10 cm and inundation time <5 hours, while other RW areas had not experienced tidal flooding. During the period (1995-2005) tidal flood inundation had occurred in all RWs in Bandarharjo Village with a height of 11-30cm and a length of 5-12 hours of inundation. This condition got worse in the period (2005-2012), which showed that the average tidal height reached 31-50 cm and the inundation period was> 12 hours.

The ecosystem environment in the coastal area of Semarang City is very vulnerable to the effects of global climate change, especially sea level rises. This has an impact on environmental damage such as in the arts, services, recreation and fisheries(Mehvar et al. 2018). Economic quantification of these losses can be calculated through the stages of the service economic assessment approach, Identification of Inundation Impacts and Impact Monetized.The impacts of land subsidence in urban areas can be categorized as infrastructure, environmental, economic and social impacts. (Abidin et al. 2015). Impact assessment is carried out by mapping the physical impacts of subsidence in big cities such as Jakarta, Semarang, and Bandung. Physical impacts that can be identified include cracking of buildings and infrastructure, as well as the expansion of coastal and inland flood areas The follow-up impact resulting from this direct impact worsens the quality of the environment and life. This will also have an impact on the costs in repair and maintenance without this impact. The social and environmental costs resulting from indirect impacts are generally quite large. The impacts that occur are connected to each other. This is a factor where the impact of land subsidence does not get a fast response. The social and environmental costs resulting from indirect impacts are generally quite large. The impact of land subsidence has a slow characteristic over a long period of time. This is a factor where the impact of land subsidence does not get a fast response. The web of impacts of land subsidence is depicted in Figure 2.
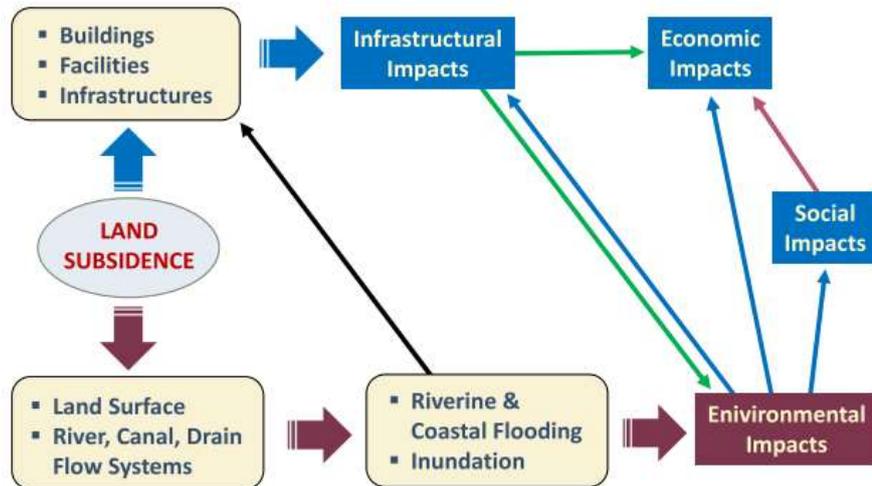
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Figure 2. Various possible impacts of land subsidence (*Abidin et al.,* 2015)

4. DISCUSSION

Many impact studies have been carried out by the City of Semarang, both in the form of direct tangible and indirect tangible impacts. Direct tangible damage results from direct contact with the flood. In conducting a direct damage estimation assessment, there are 4 steps that must be considered , according to (*Messner et al.,* 2007). The first is selection of a study approach that is highly dependent on the spatial scale. Second is to define categories to determine the direct impact to be assessed. Thirdly data collection and acquisition, and fourthly is doing calculations / calculations. The important thing in assessment direct tangible damage of flood impact is availability of data. There are four main data sources.   Firstly, Land use data. Information needed in the assessment includes) the number, location and type of assets (commercial buildings, houses, etc., that are vulnerable to the impact of flooding. Land use data is divided into two, first data traversed by objects such as (property or buildings) and second land use data in the form of homogeneous area data. Secondly, determination of the aasets at risk Thirdly damage functions data. These data are necessary. This section will describe the parameters that determine damage and then how damage functions developed. Fourthly Demage influencing characteristic. Flood characteristics will provide different damage from other damage such as (depth flooding, velocity of flood water, time occurrence, warning time, building constraction, previous experience of flooding. Review of assessment impact of land subsidence and SLR can be seen in Table 2.

The assessment of the direct impact of flooding triggered by PMT is economically carried out using the damage function. Using the depth function will provide an understanding that the depth value and land use value provide different damage values. Depth and land use are factors that determine the magnitude of the losses incurred. The higher the depth, the higher the value of the losses incurred.

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Table 2. Review on Assessment impact of Land Subsidence and SLR in Semarang City

Case	(Suhelmi et.al., 2018)	(Mehvar et al.,2018)	(Sarah et al.,2015)	(Nafishoh et al., 2018)
Hazard	Sea Level Rise ; Land subsidence	Sea Level Rise	Land subsidence Sea Level Rise	Sea Level Rise
Loss Damage	Economy	Coastal	Physic	Economy
Data	Land use	Fishery; Recreational; Value of Service; Art	Land Use	Population and Settlement
Finding	Economic loss	Coastal Economic Services (CES) Loss.	Physical Loss	Risk assessment due to flooding in Java Island based on a land use change scenario
Method	GIS	Monetized Impact	Damage Function	GIS

Case	(Abidin et al., 2015)	(Sari et al., 2020)	(Gumilar et al., 2013)	(Pratikno et al., 2014)
Hazard	Land Subsidence	Sea Level Rise and Land Subsidence	Land Subsidence	Tidal Flood
Loss Damage	Environmental	Vulnerability	Physical damage	Physic
Data	Spatial distribution of physical damage	Variables are climate/ rainfall, land coverage, slope shape, land system, and elevation	Field Survey	Field Survey
Finding	Quantitative risk assessment is needed to determine the actual risk that occurs in society. Risk assessment due to flooding in Java Island based on a land use change scenario	Flood vulnerability in north Semarang	Tidal flooding, tilting and house damage are often found at high land subsidence rates in north Semarang. In addition, the damage to cracks in buildings and intersections occurs at the boundaries of large and small subsidence	Tidal Indudation become worse during periode 1985-2012
Method	Field Survey, Study Leterature	Scoring	Spatial Mapping from field observation	Descriptive Analytic

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There are two approaches to develop the damage function. The first approach is an empirical method through the use of real flood damage data or survey data. The empirical method uses functions based on observed flood characteristics such as depth, speed and damage due to flooding. The second approach is a synthetic approach.

The synthetic approach is an approach through land cover and land use patterns, object types, and questionnaires. How is the damage caused if flood water reaches a certain depth in a property. Data acquisition for physical, social, and environmental impact assessments still relies on direct observations in the form of field surveys and questionnaires. The constraints faced are that it takes a lot of time and money to carry out the data acquisition. The results of the analysis really depend on the sample used, so the level of objectivity depends on the survey conducted.

(*Van Der Veen and Logtmeijer,* 2005) suggest there are several obstacles in damage assessment, namely: (1) there is no agreement regarding the assessment of economy value, (2) constraints on a spatial and temporal scale, (3) there is no clarity regarding the direct impact, (4) concept of stock and flow concept is not clear, and (5) direct and indirect costs are not well defined. To overcome this obstacle, efforts that can be made according to (*Messner et al.,* 2007) are as follows: it is necessary to define the exact time and spatial limits of the study, determine the scarcity price for the evaluation of market goods, ignore the effects of inflation, apply depreciation value, and use the value of benefits and net present costs.

5. CONCLUSION

Several conclusions can be drawn from the above explanation and discussion. Firstly, most of the literature emphasizes the impacts of direct, tangible damages such as those affecting housing, property, critical facilities, trade and industry. The thing that needs to be underlined is that knowledge of infrastructural impat is very limited in which if an infrastructre system failure occurs, it will affect other systems. Lack of data will result in insufficient detailed knowledge of the impacts, especially if it is related to sensitive and confidential data belongs to government agencies. Secondly, the assessment of land subsidence impact still relies on direct field surveys, especially those related to social impacts which are not yet comprehensively available. The three indirect intangible impacts, such as related to health, have not been widely studied, especially related to treatment costs and mental health after a flood. It is very difficult to quantify its impacts when compared to physical impacts.

Several studies on the impact of flooding have been conducted. Approach to the adverse effects of flooding is not only carried out through an assessment but also by quantifying the impact of flooding. This is constrained by limited data and field validation. It is very difficult to be able to accommodate all the impacts caused by flooding. So, we need an intelligent analysis method for impact assessment that can accomodate multiple data sources.

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