



PLANNING MALAYSIA:

Journal of the Malaysian Institute of Planners

VOLUME 23 ISSUE 4 (2025), Page 128 – 143

GOVERNANCE OF HOUSING SPATIAL PLANNING OF SEMARANG CITY IN LANDSLIDE MITIGATION AND THE INFLUENCE OF BIOPHYSICAL, CLIMATIC, AND SOCIO-ECONOMIC FACTORS

Rospita Odorlina Pilianna Situmorang¹, Nurrohman Wijaya², Tria Anggita Hafsari¹, Parlin Hotmartua Putra Pasaribu³ Ricca Anggraeni⁴

¹Population Research Center,

³Ecology and Ethnobiology Research Center,

NATIONAL RESEARCH AND INNOVATION AGENCY (BRIN) INDONESIA

²Department of Urban and Regional Planning,

School of Architecture, Planning, and Policy Development,

BANDUNG INSTITUTE OF TECHNOLOGY (ITB), INDONESIA

⁴Faculty of Law,

UNIVERSITY OF PANCASILA

Abstract

The highland areas of Semarang City are vulnerable to landslide disasters. This study investigated the governance of Semarang's spatial planning and the factors that influence the mitigation of landslide disasters. We used spatial and descriptive analysis to evaluate the data. This study found that most of the designated housing areas in highland areas of Semarang City are laid on vulnerable landslides. Biophysical factors such as steepness levels of up to 40 percent, volcanic rock formations that are susceptible to landslides, and the changes in rainfall intensity due to climatic change have caused vulnerability to landslides. Poor mitigation governance such as land use conversion, unsuitability of spatial plans, huge extraction of groundwater, and weak evaluation and monitoring of spatial planning also increase landslide disasters and risk in Semarang. Incorporating hazard assessment into spatial planning and tightening the implementation of spatial plans are very important to be noticed by the government to reduce landslides.

Keywords: Governance, housing planning, landslides, mitigation, risk reduction, spatial analysis

¹ Corresponding author. Email: rosp001@brin.go.id

INTRODUCTION

Indonesia is one of the countries that is vulnerable to hydrometeorological disasters. A landslide disaster is a natural disaster occurring when there is a sudden and rapid movement of rock, soil, and debris down a slope that can be caused by several factors, such as heavy rain, earthquakes, volcano activities, and human activities. Landslides are simply a type of “mass wasting” of soil and rocks moving along a slope. Landslides or ground movements result from natural dynamic phenomena due to an imbalance that causes a mechanical process, causing part of the slope to move following the force of gravity. Furthermore, after a landslide occurs, the slope will be balanced or stable again to achieve a new condition due to the disturbance of the slope balance.

Landslide disasters have caused severe impacts to humans and ecology. Their impact will be greater because this is related to aspects of land use that are not following their designation. For example, many houses are built on the lower slopes of hills that are prone to landslides. To reduce the impact of landslides, spatial planning must be adjusted, such as estimating the vulnerability of an area predicted from topography (slope), soil type, land cover, and rainfall patterns.

Semarang City, located in Central Java, Indonesia, is one of the business centers in Java due to its role as the capital of Central Java, a freight transportation route from the north coast land transportation route, and one of the port and industrial centers in Java. With these conditions, population growth and the need for built-up areas are very high so this has the potential to result in the improper placement of settlements. Previous studies state that the upper areas of Semarang City are prone to landslides causing negative economic and social impacts on residents, such as damage and loss of housing, damage to infrastructure, and insecurity (Purba et al., 2014; Yufahri and Widjajanti, 2022). Residential space planning plays a vital role in protecting vulnerable communities, promoting sustainable development in the face of these natural hazards, and reducing risk (Wijaya et al., 2017). Therefore, evaluating residential planning is important to be conducted in rapidly developing cities like Semarang.

Previous studies have evaluated the distribution of landslide-vulnerable areas in Semarang (Purba et al., 2014; Susanto and Putranto, 2016). However, limited studies have assessed the comprehensive study to evaluate the suitability of the existing spatial plan of settlement areas for landslide risk management in Semarang City and the relation of climate hydro-meteorological and human factors that can cause landslides. Therefore, the study aimed to investigate the current housing spatial planning towards landslide risk management in Semarang and the influencing factors that can trigger landslide incidents in Semarang, which include biophysical, climatic, and anthropogenic or human factors.

LITERATURE REVIEW

Definition and Basic Principles of Spatial Suitability

Spatial suitability is a key concept in geography, urban planning, and environmental management, referring to the evaluation and identification of areas that are most appropriate for specific activities or purposes based on a range of physical, environmental, and socioeconomic factors. It is a process that seeks to align land characteristics with human needs, ensuring that land use is optimized in ways that balance development goals with sustainability and environmental protection. In practice, spatial suitability analysis involves a complex integration of multiple criteria such as land use, topography, accessibility, and environmental constraints to identify the optimal locations for various types of land uses (Jeong et al., 2013; Omar and Raheem, 2016; Wahyuddin et al., 2021).

To carry out spatial suitability analysis, Geographic Information Systems (GIS) are frequently employed to capture, store, analyze, and visualize the spatial data involved. GIS-based spatial analysis is an essential tool for modern planning and resource management which is making it easier for decision-makers to evaluate different land-use scenarios and optimize resource allocation (Wahyuddin et al., 2021).

Spatial Planning's Contribution to Reduce Landslide Risk

One crucial aspect of spatial planning is its potential to mitigate the risk of landslides. Incorporating landslide susceptibility mapping and hazard assessment into spatial planning can inform land use decisions, guide development away from high-risk areas, and promote the adoption of structural and non-structural mitigation measures. By strategically organizing land use, infrastructure, and disaster response, spatial planning can play a vital role in protecting vulnerable communities and promoting sustainable development in the face of these natural hazards. However, the successful implementation of such strategies often faces challenges. Overcoming barriers related to data availability, institutional coordination, and community engagement requires a holistic, multi-stakeholder approach (Muhamad et al., 2015; Diana et al., 2021).

Factors affecting Landslide Vulnerability and Assessment Methods

Paimin et al., 2006 stated that 2 (two) factors cause landslides, namely natural factors and management factors. Natural factors are (1) consecutive days of cumulative daily rainfall, (2) land slope, (3) geology/rock, (4) presence of faults/fractures/wires, (5) soil depth to impermeable layer; while management factors are: (1) land use, (2) infrastructure, and (3) settlement density. Arsyad (2010) further added that there are at least 3 (three) conditions that cause landslides, namely (1) the slope is steep enough, (2) there is a layer below the ground surface that is impermeable and soft as a gliding field, and (3) there is

enough water in the soil so that the soil layer just above the impermeable layer becomes saturated. Excessive rainfall, earthquakes, volcanoes, forest fires and other similar things, vibration, as well as dangerous human activities such as deforestation in the upstream areas and sloping areas are some of the main causes that can trigger landslides (Highland, 2008; Karnawati, 2005; Isnaini, 2019).

Evaluation of landslides can be conducted through direct observation and the utilization of technology. One way of evaluating landslides is by map analysis. Required maps include bedrock and surface geology, topography, soils, and geomorphology maps (Highland, 2008). The most commonly used method is the overlay method. The overlay method is good for analyzing landslide hazard (Aminatun, 2017), landslide vulnerability (Susanti et al., 2017), landslide capacity, and landslide disaster risk (Naryanto, 2011; Faizana et al., 2015).

Landslides in a Changing Climate

Landslides are one of the hydrometeorological disasters. Hydrometeorological disasters are closely related to climate change (weather and climate) that occurs in the world including in Indonesia (Azizah, 2022). Hydrometeorological disasters are caused by climate and weather anomalies in the atmosphere, especially in increasing frequency and intensity, which are thought to be caused by climate change. In Indonesia, hydrometeorological disasters are closely related to rainfall or precipitation. According to Febrianti (2009), rainfall anomalies will increase the threat of landslides and floods. Rainfall is considered as the main factor causing landslides. Rainfall has the potential to cause landslides provided it has a high intensity (4 inches/hour) and lasts more than six hours. Climate change on a regional or global scale causes changes in the frequency and intensity of tropical cyclones that can cause strong winds and high rainfall (Hadi et al., 2022).

Considering the above conceptual framework and the aim of the study, the framework of this study is provided in Figure 1:

Rospita Odorlina Pilianna Situmorang, Nurrohman Wijaya, Tria Anggita Hafsa, Parlin Hotmartua Putra Pasaribu, Ricca Anggraeni
Governance Of Housing Spatial Planning of Semarang City in Landslide Mitigation and The Influence of Biophysical, Climatic, And SocioEconomic Factors

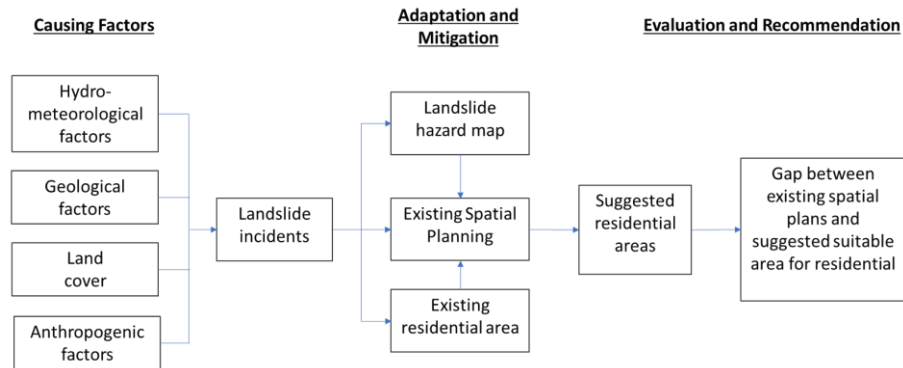


Figure 1. Research Framework

RESEARCH METHODOLOGY

The study area is in Semarang. Semarang is the capital city of Central Java, Indonesia. The city is divided into lowland and highland areas, characterized by different landscapes and challenges. The map of Semarang is provided in Figure 1. The focus study area is the highland areas of Semarang City, located to the south and southeast area which include Gunung Pati and Banyumanik District. These areas are situated at higher elevations.

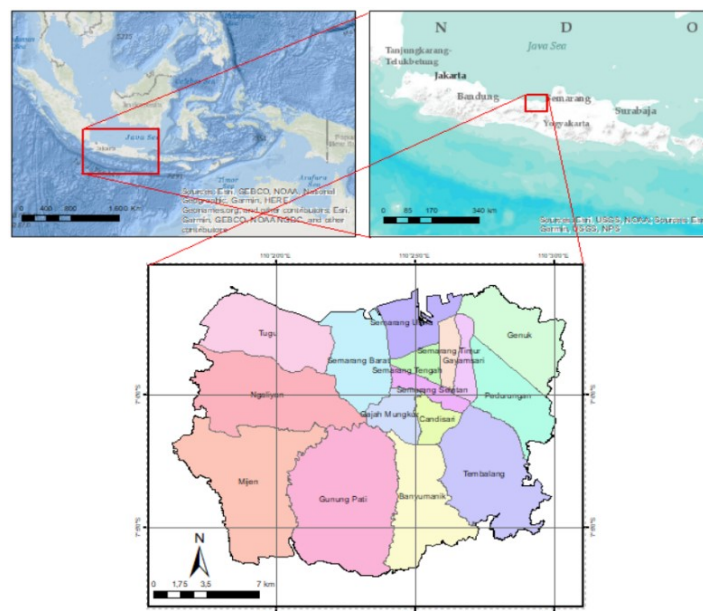


Figure 2. Map of Semarang City

The data consist of digital thematic maps and primary data collected through interviews and field observation. Interviews were conducted with 31 government officers and 26 citizens. The institutions consisted of the spatial planning agency, the regional disaster management agency, of Semarang, the river basin institute, the housing department, the environmental department, and the sub-district government of Semarang City. Community respondents are citizens from the villages of Mangunharjo, Sukorejo, Trangkil, and Tinjomoyo, administratively located in Banyumanik and Gunung Pati.

The spatial analysis used an overlay method of several categories of physical and climatic aspects that potentially cause landslide risk. The categories of landslide risk include soil type, slope, rainfall, land cover, and water potential. The result of this overlaying procedure is a landslide vulnerability distribution/map of Semarang. The levels of vulnerability are categorized into four categories (very low, low, medium, and high) following the category provided by the Indonesia National Disaster Agency or BNPB (2012). The very low and low categories are scored at 0.33, medium at 0.67, and high at 1.00). Analysis of the current spatial planning (*Rencana Tata Ruang Wilayah*, RTRW) and landslide-prone area distribution was carried out to evaluate the suitability of the existing spatial planning of Semarang toward mitigation of landslide disaster in residential areas. The analysis also uses spatial analysis.

To figure out the causing factors of landslide incidents and the unsuitability of spatial plan implementation, we evaluate the biophysics, climate change, and human factors. The evaluation was based on descriptive analysis using tabulation and percentage. Land use change is one of the main factors of landslides. Evaluating the built-up land areas of Semarang using the Sentinel-2 data involves leveraging the satellite's high-resolution multispectral imagery, which includes 13 spectral bands. Launched as part of the European Space Agency's Copernicus program, Sentinel-2 offers valuable data for urban analysis, with image filtering from 2018 to 2024. The analysis uses the Google Earth Engine (GEE), an efficient cloud-based tool that processes images automatically. The Normalized Difference Built-up Index (NDBI), which highlights built-up areas, is calculated using Band 8 (NIR) and Band 11 (SWIR) based on the formula $(\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$, as suggested by Celik (2018).

ANALYSIS AND DISCUSSION

Distribution of Landslide Vulnerable Zone of Semarang City

Landslide distribution prediction in Semarang was obtained by overlaying slope, geological, soil, rainfall, and land use map, and the distribution, and the result is presented in Figure 3. The south, southeast, and southwest areas of Semarang which include Banyumanik, Gunung Pati, Tembalang, and Mijen Districts are

more vulnerable to landslide risk. Gunung Pati and Banyumanik District seem the most vulnerable areas among the other districts.

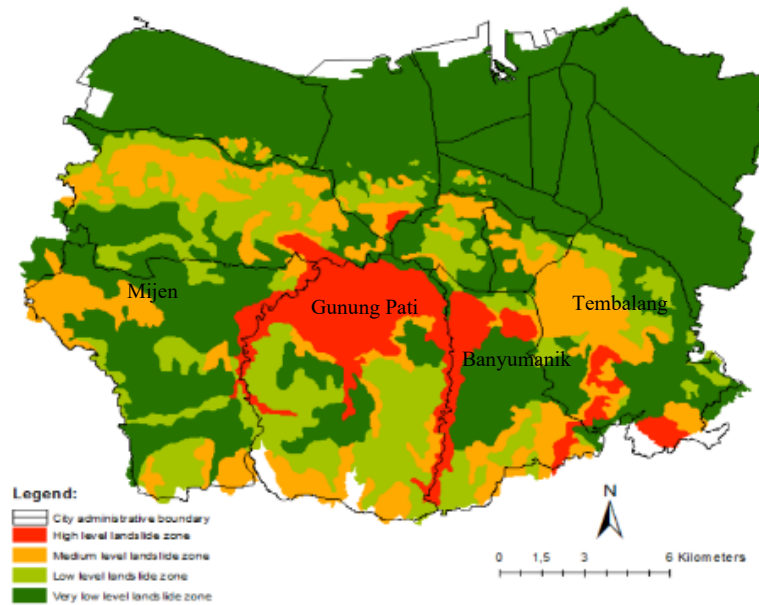


Figure 3. Landslide zone in Semarang City

Analysis on Residential Areas of Semarang Spatial Planning toward Landslide Risk Mitigation

Effective spatial planning that incorporates landslide risk reduction can make a significant contribution to building more resilient communities and mitigating the devastating impacts of these hazards. The distribution of the existing residential areas in Banyumanik and Gunung Pati is in Table 1 and the spatial planning is in Table 2.

Table 1. Spatial analysis of existing housing areas toward landslide risk in Banyumanik and Gunung Pati

Districts	Area (ha)				Percentage (%)		
	Low	Medium	High	Total	Low	Medium	High
Banyumanik	33.71	181.29	15.59	230.58	14.62	78.62	6.76
Gunung Pati	22.79	156.35	68.93	248.08	9.19	63.03	27.79
Total	56.50	337.64	84.52	478.66	11.80	70.54	17.66

Table 2. Spatial analysis of housing spatial plan toward landslide risk in Banyumanik and Gunung Pati

Districts	Area (ha)				Percentage (%)		
	Low	Medium	High	Total	Low	Medium	High
Banyumanik	33.70	174.89	15.61	224.21	15.03	78.00	6.96
Gunung Pati	22.89	146.98	68.86	238.72	9.59	61.57	28.85
Total	56.59	321.87	84.47	462.93	12.22	69.53	18.25

Most existing residential areas in Banyumanik and Gunung Pati Districts are laid on medium risk of landslide (70.54%), and only less of them (11.80%) are safe from landslide risk potential. Even 17.66% of residential areas are at high risk from landslides, and Gunung Pati seems to have more highly risky settlement zones (27.79%). Not much different from the planned areas, the residential planned areas in Gunung Pati and Banyumanik are mostly semi and high risk of landslide as presented in Table 3. Most of the settlement zones (69.5 %) are allocated in prone areas with medium risk to landslide, and 18.25% of the designated area is at high risk of landslide. Comparing between the existing and the planning, both look similar. It indicates that the residential space plan in the city of Semarang is more adjusted to existing settlements which is less suitable to the land function and capacity indicating less awareness of landslide disaster mitigation. As a result, there are many residents living in prone areas such as Sukorejo and Trangkil Village in Banyumanik. They have been struggling with the landslides and land subsidence that have cracked and destroyed their houses. Most of them keep staying in those prone areas due to no option of a place to live.



Figure 4. Figure of the damaged house caused by slow and sudden landslides in Sukorejo Village, Gunung Pati District.

Causing Factors Influencing Landslide in Semarang

Improper land use is one of the factors that cause landslides. This is because each land use has a different level of risk in affecting landslides. Land uses in this area are settlement, plantation, moor, permanent production forest, and paddy field. The dominant land uses are settlements and plantations, especially in areas with a high risk of landslides. The Semarang is experiencing rapid development which results in an increase in built-up land that changed the land use from green space to settlements, administrative centers, economy, and infrastructure. Spatial analysis of built-up areas In Banyumanik and Gunung Pati is presented in Table 3. The built areas increased about by 79.61 percent in Banyumanik and 107.61 percent in Gunung Pati.

Table 3. Spatial analysis on built-up area in Banyumanik and Gunung Pati 2018-2024

Year	Banyumanik (ha)	Gunung Pati (ha)
2018	18.49	8.93
2019	29.97	15.78
2020	29.34	13.71
2021	30.57	15.73
2022	32.01	16.87
2023	35.45	19.54
2024	33.21	18.54

As the capital of the province and a business center, efforts to reduce the rate of population growth from births and migration in Semarang are difficult to handle. Therefore, equitable development in the Java region needs to be improved to prevent migration to the capital city. The risk of landslides in Banyumanik and Gunung Pati also increases because of land use changes in the upstream area of the Semarang, namely the Garang watershed catchment area that influenced the hydrology cycle in Semarang. The study of Saifudin et al. (2017) found that land use change and deforestation in the Garang watershed catchment area from 2000 to 2013 significantly increased the surface water flow to 301,88 mm (an increase of 14.64%). This increase potentially affects erosion and landslides in hilly areas including Banyumanik and Gunung Pati.

Biophysical factor like topography improves the vulnerability of an area from landslides. The South Semarang has a relatively high topography. The slope classes of Gunung Pati and Banyumanik Districts are relatively varied but many tend to have moderately steep (15-25%), steep (25-40%), very steep (>40%), and even very steep (>40%) slope classes. The higher the slope, the greater the potential for erosion or landslides (Pasaribu and Situmorang, 2022). However, especially in areas with high landslide risk in Gunung Pati and

Banyumanik, the dominant slopes are relatively steep (25-40%) and very steep (>40%).

Climate factors such as rainfall are also one of the key factors for landslides. This is because water is an object that plays a major factor in washing away soil. In the 10 years (2014-2023), the average rainfall of Semarang City was recorded at 162.23 mm and was categorized as medium. In normal situations, Semarang City has variations in the amount of rainfall. In January and February, the rainfall of Semarang City is in the high category; June to October is in a low category; while in March, April, May, November, and December is in the medium category. The rainfall pattern in Java Island, which includes Semarang City, is affected by the Monsoonal rainfall pattern (Sofan, 2013). This monsoonal rainfall pattern occurs due to the movement of monsoon winds, particularly western monsoon winds that blow from the Indian Ocean and carry a lot of water vapor. Hence, in this period, Semarang City experiences the rainy season. In this situation, the high-intensity rainfall increases the water saturation of land and rocks and forces the rock layers to landslide (Naryanto, 2011). However, the characteristics of rainfall in Java including Semarang changed in the last 30 years. The annual rainfall and maximum daily rainfall tend to increase by an average of 22.64 mm/year, while the daily rainfall increases by an average of 2.56 mm/year (Suripin and Kurniani, 2016). This potentially causes the increase in water volume and duration of rainfall in the months of high rainfall intensity (usually in January and February).

Geological formation is one of the physical factors causing landslides. Geological formation or rock type contributes greatly to the occurrence of landslides. Sturdy rock types will be stronger to resist water flow than Fraggle rock types. Geological formations in this landslide-prone area are andesite, alluvium, Gajah Mungkur volcanic rocks, Kaligesik volcanic rocks, Damar formation, and Kaligetas formation. The dominant geological formations are Kaligetas Formation and Damar Formation. The Kaligetas Formation is composed of breccia and lava with fine to coarse lava and tuff inserts. The Kerek Formation is composed of clay, Marl, tuffaceous sandstone, conglomerate, volcanic breccia, and limestone. The Damar Formation consists of volcanic breccia, conglomerate as a lens, and tuffaceous sandstone. The Kalibeng Formation consists of Marl, tuffaceous sandstone, and limestone (Thanden et al., 1996).

Soil type is an important factor in influencing landslide occurrence. Soil types have their sensitivity to erosion or landslides. Therefore, each soil type has a different level of erosion or landslide sensitivity. The soil types in this area are dark brown Mediteran, reddish brown latosol, and brown latosol. The most dominant soil types are dark brown Mediteran and reddish-brown latosol. Likewise, the soil types in areas with high landslide risk levels are dark brown

Mediterranean and Reddish-brown Latosol. Concerning landslides, Mediterranean soil types have moderate erosion sensitivity. Meanwhile, latosol soil types are quite sensitive to erosion (Asdak, 2004). The rock and soil type incorporated with watering are the important factors that influence landslide risk (Yufahri and Widjanti, 2022).

Human Factors Influencing Landslide Management and Implementation in Semarang

Planning control is one of the effective and economical ways to reduce landslides and their impact on humans and the environment. Hence, alignment between planning and implementation is essential to reduce landslide disasters and their impacts. We evaluated some factors that influence the landslide's spatial planning by asking about the perception of government officers and local communities (urban citizens of upper areas of Semarang City). The evaluated aspects included spatial planning governance, the role of stakeholders, and awareness of local people, and the result is presented in Figure 5.

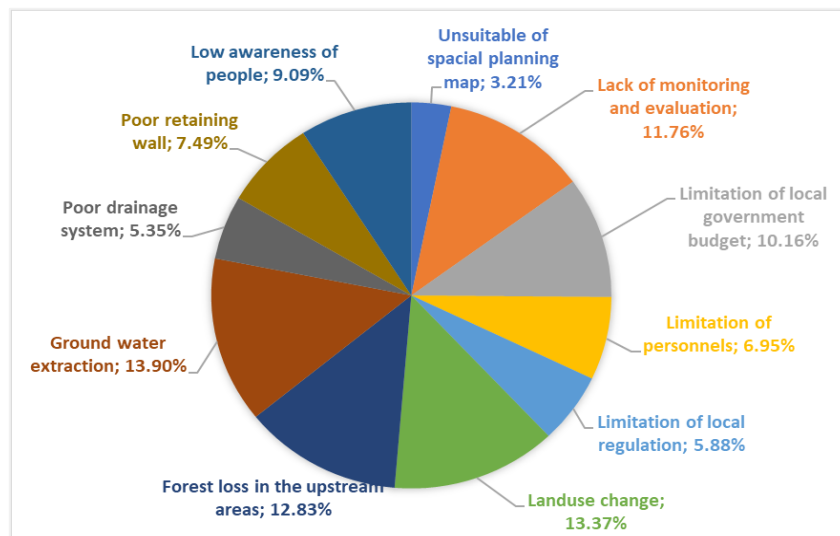


Figure 5: Human factors causing unsuitable landslide spatial plan implementation in Semarang highland based on stakeholders' and community's views

The result in Figure 5 describes that the main causes of landslide incidents in Semarang were groundwater extraction (13.90%), land use change (13.37%), and forest loss in the upstream areas of Semarang (12.83%). Groundwater extraction causes the depletion of groundwater which disrupts the

structure of the soil layer and causes land subsidence. Groundwater is often as primary source of clean water in Semarang, both for fulfilling household, industrial, and hotel needs. Based on our survey, nearly all residents in Semarang use artesian wells with an average depth ranging from 50 to 100 meters. Recent studies have revealed that Semarang City is experiencing significant groundwater vulnerability, with approximately 41.3% of the area classified as highly vulnerable and 50.3% as moderately vulnerable (Marjuanto et al., 2019). Extraction of groundwater in the lowland and highland areas of Semarang has led to groundwater depletion, which causes land subsidence and landslides, also similarly stated by Kodoatie and Sjarief (2005) in their study. In the lowland areas of Semarang, groundwater extraction has caused land subsidence of up to 10 cm per year which causes tidal flooding (rob) and seawater intrusion. In the upper areas, depletion of groundwater causes land movement and landslides. As the city's population has increased, the water demand has risen, leading to a higher rate of groundwater extraction. This is particularly problematic in Semarang, where residents still rely on non-piped water sources, further exacerbating the issue of groundwater availability. The permit for groundwater drilling in Central Java has been released by the Central Java Governor in Regulation No. 3 of 2018. However, this regulation is not properly implemented and lacks monitoring and sanctions.

Forest loss and land use change cause the reduction of water infiltration by the expansion of urbanization and rapid construction of buildings and roads. Deforestation also increases the risk of landslides due to the loss of plant roots that play a role in retaining soil, especially in steep areas. Deforestation has increased particularly in the upstream areas of Semarang. The changing of forests generally occurs due to development and population growth which convert forests into agriculture, tourism, residential areas, and other built-up areas.

Unsynchronized implementation of spatial planning is also caused by weak governance practices. Figure 7 indicates that local governments have weak monitoring and evaluation (11.76%) toward the planning and real implementation, limitation of budget (10.16%), and shortage of personnel (officers) to monitor the areas (6.95%). The city of Semarang has enacted Regional Regulation Number 5 of 2021 to govern spatial planning in Semarang City called RTRW regulation. The RTRW regulation has urgency as a blueprint for the utilization of space for regional development activities. However, keeping in mind the empirical practices of drafting regional regulations, political and economic considerations have greatly influenced the formulation of RTRW regulations on spatial planning. Many industries and settlement areas have been arranged on the beach border which opposes the principles of environmental sustainability. In Banyumanik and Gunung Pati, many housing estates, hotels,

and restaurants have been placed on hillsides and steep areas with inadequate drainage systems and retaining walls that increase the potential risk of landslides.

Weak monitoring and inconsistency in the implementation of Semarang spatial planning (RTRW) are suspected to be the causes of landslide incidents in Semarang. The areas that are designated for protection functions become densely populated residential areas, such as settlements in Trangkil Village, Sukorejo, in Gunung Pati District that are experiencing landslide incidents and severe house cracks. Surprisingly, government institutions at various levels seem to be out of sync in implementing this spatial planning policy. Housing in Trangkil has been built for decades with permits from the local government and other technical institutions during its development. However, when the local people came to apply for land ownership rights for settlements, there were rejections from the Land Agency due to the inconsistency of the land use function and designation. This condition often occurs in Indonesia, and people continue to live in these areas due to economic limitations and low public awareness. Weak monitoring was acknowledged by most of the officers from the agencies that we interviewed. They argued that supervision was less than optimal due to limited field personnel and lack of financial support. Moreover, we realized that the weakness of law enforcement towards citizens and business actors who violated the spatial planning regulations worsened spatial governance.

The role of local people in environmental protection is very important to reduce landslides and their risks. However, public awareness seems low (9.09%). Even though they have faced landslide incidents and their houses have cracked, they are still living in the villages due to the no options and weak awareness. Infrastructure such as retaining walls and drainage systems are built to reduce landslides. The responders perceived that the development of infrastructure to reduce landslides and the risk in the highlands of Semarang City are still low.

CONCLUSION

The highland areas of Semarang City are vulnerable to landslide disaster, and the designated housing areas in Banyumanik and Gunung Pati are laid on vulnerable landslides, which is 69.53 % at medium risk and 18.25% at high risk. Various factors have resulted in the vulnerability to landslides in Banyumanik and Gunung Pati including biophysical factors such as steepness levels of up to 40 percent, volcanic rock formations that are susceptible to landslides, and the changing rainfall intensity which is noted to increase an average of 22.64 mm/year due to climatic change. However, poor landslide disaster mitigation management is the main factor causing the increasing number of landslide disasters in Semarang. The improper management included deforestation and land cover change in the upstream water catchment areas of Semarang. The built-

up areas increased by 79.61 % in Banyumanik and 107.61 % in Gunung Pati from 2018 to 2024. Huge extraction of groundwater for housing and industrial demand have caused depletion of groundwater which causes land subsidence in lowland areas and landslides in upper areas of Semarang. Weak evaluation and monitoring of the spatial planning and implementation at the site level also indicate an inconsistency of government in reducing landslide disaster risk in Semarang. Limitations of personnel and budget and lack of people awareness have caused the spatial plan implementation to face various problems.

ACKNOWLEDGEMENTS

We acknowledge the Spatial Planning Agency of Semarang City and the Regional Disaster Management Agency of Semarang for providing secondary data and support to the fieldwork

FUNDING SOURCES

This study was funded by The National Research and Innovation Agency (BRIN) and the Institute of Cultural Anthropology and Development Sociology, Leiden University.

ETHICAL CLEARANCE

This research had received and implemented ethical clearance lined in the ethical clearance approval on social studies and humanities research Number 428/KE.01/SK/05/2024 issued by Ethical Committee on Social Studies and Humanities, National Research and Innovation Agency, Indonesia.

REFERENCES

- Aminatun, S. (2017). Landslide Disaster Risk Analysis Study as a Basis for Infrastructure Development in Sriharjo Village, Imogiri District, Bantul Regency. *Jurnal Teknisia*, 22(2): 327-382.
- Arsyad, S. (2010). *Konservasi Tanah dan Air*. Bogor: IPB Press.
- Asdak, C. (2004). *Hidrologi Dan Pengelolaan Daerah Aliran Sungai*. Yogyakarta: Gajah Mada University Press.
- Azizah, M., Subiyanto, A., Triutomo, S., Wahyuni, D. (2022). The Effect of Climate Change on Hydrometeorological Disasters in Cisarua District - Bogor Regency. *PENDIPA Journal of Science Education*, 6(2): 541-546.
- BNPB, (2012). *National Disaster Regulation No 02 year of 2012 relating General Guidelines for Disaster Risk Assessment*
- Celik, N. (2018). *Change Detection of Urban Areas in Ankara through Google Earth Engine*. 41st International Conference on Telecommunications and Signal Processing, TSP 2018. <https://doi.org/10.1109/TSP.2018.8441377>
- Diana, M. I. N., Muhamad, N., Taha, M. R., Osman, A., & Alam, M. M. (2021). Social vulnerability assessment for landslide hazards in Malaysia: A systematic review

- study. *Land*, 10(3), 1–19. <https://doi.org/10.3390/land10030315>
- Faizana, F., Nugraha, A. L., and Yuwono, B.D. 2015. Landslide Disaster Risk Mapping of Semarang City. *Jurnal Geodesi UNDIP*, 4(1):223-234
- Febrianti, N. (2009). *Impact Analysis of Rainfall Changes on Landslide Forecasts in West Java*. Prosiding Seminar Nasional Proyeksi Iklim dan Kualitas Udara 2010-2014, LAPAN 28-29 Juli 2009.
- Hadi, A.S., Nazarudin, L., Chandra, N., Meisda, D.F., So'langi, L.N., Fauziyah, A.R., Sudirman, M. (2022). *Atlas of Hydrometeorological Disaster Projections (Landslides)*. Pusat Informasi Perubahan Iklim, Kedeputan Bidang Klimatologi, Badan Meteorologi dan Geofisika.
- Highland, L.M. and Peter Bobrowsky. 2008. *The Landslide Handbook - A Guide to Understanding Landslides*. United States Geological Survey. Geological Survey of Canada.
- Isnaini, R. (2019). Analisis Bencana Tanah Longsor di wilayah Jawa Tengah. *Islamic Management and Empowerment Journal*, 1(2), 144-145.
- Jeong, J S., García-Moruno, L., & Blanco, J H. (2013). A site planning approach for rural buildings into a landscape using a spatial multi-criteria decision analysis methodology. *Landuse Policy*, 32, 108-118. <https://doi.org/10.1016/j.landusepol.2012.09.018>
- Karnawati, D. (2005). *Natural Disasters of Land Mass Movement in Indonesia and its Countermeasures*. Yogyakarta: Jurusan Teknik Geologi Fakultas Teknik Universitas Gadjah Mada.
- Kodoatie, R. J., & Sjarief, R. (2005). *Pengelolaan Sumber Daya Air Terpadu*. Yogyakarta: Andi Offset
- Marjuanto, A. A., Putranto, T. T., & Sugianto, D. N. (2019). *Mapping of Groundwater Vulnerability Index in the Alluvial Plain of Semarang City Using the Susceptibility Index Method*. E3S Web of Conferences, 125(2019). <https://doi.org/10.1051/e3sconf/201912501010>
- Muhamad, N., C. -S. Lim, M. I. H. Reza and J. J. Pereira. (2015). *Urban hazards management: A case study of Langat River basin, Peninsular Malaysia*. International Conference on Space Science and Communication (IconSpace), Langkawi, Malaysia, 2015, pp. 438-443, doi: 10.1109/IconSpace.2015.7283776.
- Naryanto, H.S. 2011. Landslide Risk Analysis in Karanganyar Regency, Central Java Province. *Jurnal Dialog Penanggulangan Bencana*, 2(1): 21-32.
- Omar, N.Q., Raheem, A.M. (2016). Determining the suitability trends for settlement based on multi criteria in Kirkuk, Iraq. *Open geospatial data, softw. stand.* 1, 10. <https://doi.org/10.1186/s40965-016-0011-2>
- Paimin, Sukresno, dan Purwanto. 2006. *Sub-watershed Degradation Rapid Scan*. Puslitbang Hutan dan Konservasi Alam. Bogor.
- Purba, J. O., Subiyanto, S., & Sasmito, B. (2014). Pembuatan peta zona rawan tanah longsor di kota Semarang dengan melakukan pembobotan parameter. *Jurnal Geodesi Undip*, 3(2), 40-52.
- Pasaribu, P. H. P. and Situmorang, R.O.P. 2022. Relationship of slope, soil type, and land use on erosion hazards. *Inovasi*, 19(2), 147-158.
- Saifudin, I., Suripin, S., & Suharyanto, S. (2017). *Kajian Respon Perubahan Penggunaan*

- Lahan Terhadap Karakteristik Hidrologi DAS Garang* [Doctoral dissertation, Postgraduate Program].
- Sofan, P. (2013). Karakteristik Pola Curah Hujan di Wilayah Indonesia Berdasarkan Data Satelit TRMM (1998-2011). Bunga Rampai Penginderaan Jauh Indonesia 2013.
- Suripin, S., & Kurniani, D. (2016). Pengaruh Perubahan Iklim terhadap Hidrograf Banjir di Kanal Banjir Timur Kota Semarang. *Media Komunikasi Teknik Sipil*, 22(2), 119-128.
- Susanti, P.D., Miardini, A., and Harjadi, B. (2017). Vulnerability analysis as a basic for landslide mitigation in Banjarnegara Regency. *Journal of Watershed Management Research*, 1(1): 49-59.
- Susanto, N., & Putranto, T. T. (2016). *Analisis level kesiapan warga menghadapi potensi bencana longsor Kota Semarang*. Teknik, p-ISSN, 0852-1697.
- Thanden, RE., H. Sumadirdja, PW. Richards, K. Sutisna, 1996. *Peta Geologi Lembar Magelang dan Semarang, Jawa skala 1:100.000*. Pusat Survey Geologi, Bandung.
- Wahyuddin, S., Buchari, H., Wahab, I. I., Rahmat, Z., & Fadli, Z. (2021). Land suitability analysis using geographic information system (GIS): A case study in Soppeng district. *Journal of Physics: Conference Series*, 1918(4). <https://doi.org/10.1088/1742-6596/1918/4/042154>
- Wijaya, N., Bisri, M. B. F., Aritenang, A. F., & Mariany, A. (2017). *Spatial planning, disaster risk reduction, and climate change adaptation integration in Indonesia: progress, challenges, and approach*. Disaster Risk Reduction in Indonesia: Progress, Challenges, and Issues, 235-252. https://doi.org/10.1007/978-3-319-54466-3_9
- Yufahri, M. O., & WIdjajanti, R. (2022). Kajian Lahan Terbangun pada Kawasan Rawan Bencana Longsor di Kecamatan Tembalang, Kota Semarang. *Teknik PWK (Perencanaan Wilayah Kota)*, 11(3), 224-237

Received: 2nd May 2025. Accepted: 10th September 2025