



The Pattern of Settlement Distribution in Disaster Prone Areas of Semarang City

Chindy Dhia Tsabit N.^{1,a)} and Bitta Pigawati^{1, b)}

¹*Department of Urban and Regional Planning, Diponegoro University, Semarang, Indonesia*

^{a)} chindydhia@gmail.com

^{b)} Corresponding author: bitta.pigawati@gmail.com

Abstract. The increase in population in Semarang City affects the trends in land use. Limited availability of land in contrast to the increasing demand for land has prompted residents to choose a place to live in a location not following its designation. Several settlements in Semarang City have developed in disaster-prone locations. This study aimed to determine the characteristics of settlements in disaster-prone areas, including aspects of land use, levels of vulnerability to natural hazards, and settlement distribution patterns. The research is a descriptive quantitative study with a spatial approach and utilizes images from remote sensing and Geographic Information systems (GIS). The results show that the settlements covering an area of 5,577 hectares or 33.5% of the total settlement area of Semarang City are in disaster-prone areas. Most disaster-prone areas have a moderate level of vulnerability. There are three patterns of settlement distribution in the study area, namely clustered, random, and dispersed patterns. Most districts in Semarang City have a random pattern of disaster-prone settlements. The settlement distribution pattern reflects the characteristics of each disaster-prone area.

Keywords: Patterns of settlement distribution, disaster-prone areas, Geographic Information System (GIS)

INTRODUCTION

The rapid development of the city is the result of several factors, one of which is population dynamics [1]. The growth in urban land use is likely to continue as long as the population continues to increase [2]. Population growth can change the trend of land use in line with the growth of activities in the city [3], [4]. The more population in a city, the more increasing demand for land as a container for various activities that develop in the city [5].

Increased population activity has a linear effect on land demand [6]. Meanwhile, the increasing need for land is not proportional to the availability of land. The fact is that an increase in population has an impact on increasing land requirements and is further related to land conversion [4], [7]. Currently, land conversion occurs in areas that do not match their land potential. Land conversion also occurs in disaster-prone areas.

The increase in population causes changes in land use in Semarang City. Semarang City as the capital of Central Java Province has experienced a progressive increase in population. In a period of 5 years, from 2015 to 2019, there was an increase in the population of 84,942 people with an average population growth rate of 1.64% [8]. The largest percentage of land use in the downtown area of Semarang is designated as a settlement area [9]. The need for land for settlements in Semarang City increases along with population growth. The social condition of the population and low economic capacity is one of the reasons for choosing the location of a settlement in an area that is not feasible [10]. This then encourages settlements to choose to live in disaster-prone areas. The topography of Semarang City which consists of beaches, land, and hills with a slope of 0-40% causes the Semarang City to be in a disaster-prone area. There has been an expansion

of residential land in several locations in Semarang City, some of which are in disaster-prone areas. There are three disaster-prone areas in Semarang City, namely flood-prone areas in Central Semarang, South Semarang, and Gayamsari Districts. Meanwhile, land movement prone to disasters occurs in Central Semarang, Gayamsari, and East Semarang Districts, while landslides prone to disasters are in Gajahmungkur District [11].

This research aims to examine the distribution patterns of settlements in disaster-prone areas. The settlement pattern is a reflection of the adjustment of the population to the environment, which is influenced by socio-economic and cultural factors [12]. This research is important because based on the distribution pattern and characteristics of settlements in disaster-prone areas, preventive and mitigation measures can be taken to minimize casualties and property. This research uses a descriptive quantitative method with a spatial approach.

METHODOLOGY

This was descriptive quantitative research using a spatial approach. The method used to obtain variables to describe settlement distribution patterns in disaster-prone areas is based on the spatial approach to analyze the data obtained from remote sensing.

Data in this study are secondary data in the form of the image of Semarang City in 2020. Those images were then processed to obtain land use maps to be used in the analysis of settlement distribution patterns in disaster-prone areas in Semarang City. Besides images from remote sensing, other data used in the research are statistical data and data from field observation as supporting data.

Settlement distribution pattern reveals the characteristics of the settlement [10], [13], [14]. The nearest neighborhood analysis is used to determine the distribution patterns [15]. Nearest neighborhood analysis also can be used to define settlement distribution patterns [12]. The analysis is conducted by converting polygons into points using ArcGIS software. The result of the analysis, i.e. the distribution of settlement areas in Semarang, was then analyzed using the mathematical equation of Nearest Neighborhood Analysis. The mathematical model of the analysis is as follows.

$$T = \frac{ju}{jh} \quad (1)$$

where

T = Nearest Neighborhood Index

ju = observed mean distance between each feature and its nearest neighbor

jh = the expected mean distance for the features given in a random pattern

Explanations:

- When $T = 0 - 0,7$, the pattern exhibits clustering, where the locations are nearby and tend to form a cluster pattern in a particular location.
- When $T = 0,7 - 1,4$, the pattern is a random pattern, where the distance between locations is irregular.
- When $T = 1,4 - 2,15$, the pattern is a dispersed pattern, where the distance between locations is relatively the same.

Besides the analysis on settlement distribution patterns, analysis on vulnerability to natural hazards was also conducted. The analysis is carried out by measuring variables using scoring and map overlay. The measured variables are defined as variable indicators levels of vulnerability to natural hazards are grouped into 3 classes. The determination of the class interval of each parameter is carried out using the logarithmic method [16]. Table 1 shows the scores and indices used in the Assessment of Levels of Vulnerability to Natural Hazards

TABLE 1. Vulnerability level of assessment to Natural Hazards

Score	Index value (score value / max score) x 100 %	Value name
1	0 – 33,3 %	Low
2	33,4 – 66,6 %	Medium
3	66,7 – 100 %	High

Five (5) variables used in determining the level of disaster vulnerability consist of population density, number of disasters, productive land area, building density, and land use in protected areas. These variables

are based on General Guidelines for Disaster Risk Assessment by the National Disaster Management Agency (BNPB).
The research framework is presented in Figure 1.

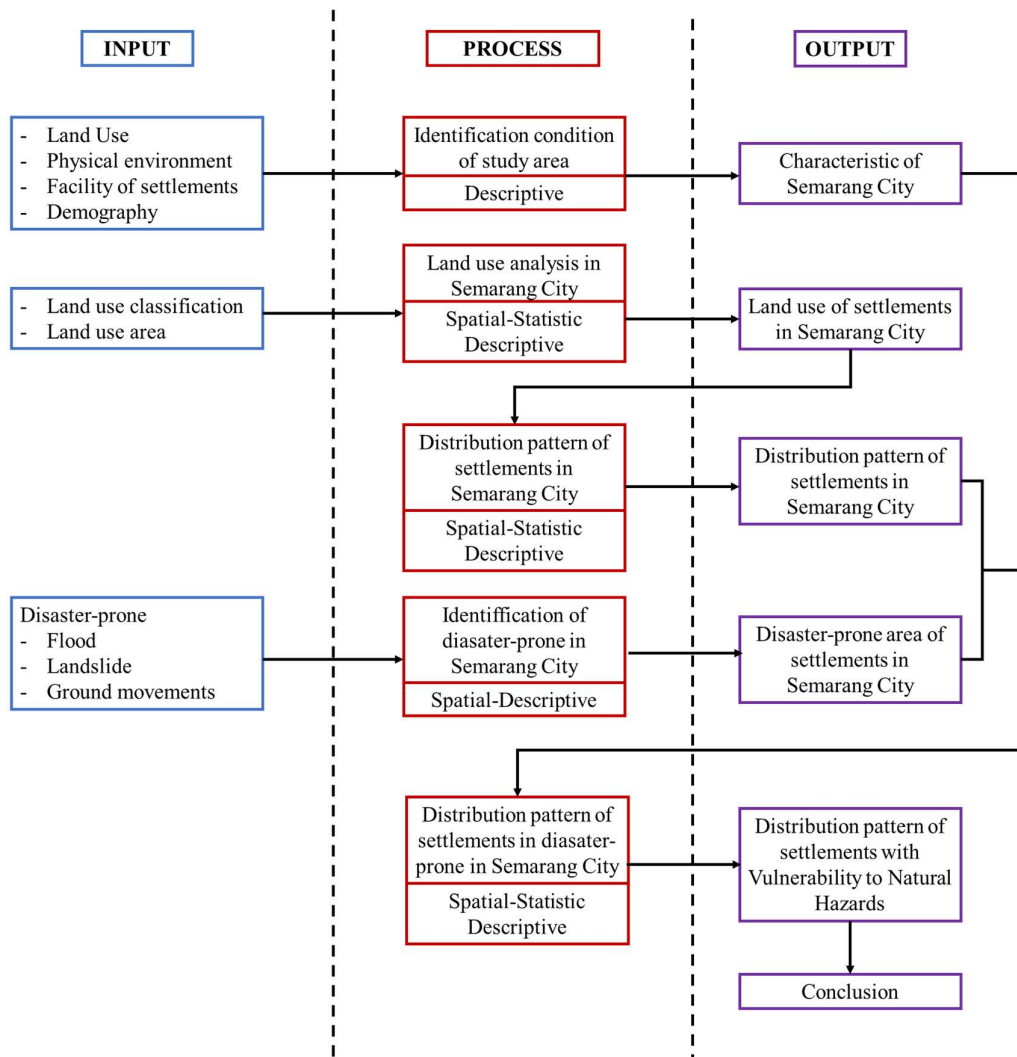


FIGURE 1. Research Framework (Author, 2020)

RESULT AND DISCUSSION

Land Use in Semarang City in 2020

Semarang City has a total area of 37,370 Ha. The results of the analysis show that the total area of built-up areas in Semarang is documented as 18,150 Ha (48.57%) and the total area of non-built-up areas is documented as 19,220 ha (51.43%). Table 3 shows the land use in Semarang City.

Land use in Semarang City in 2020 was dominated by settlement and agricultural areas. The settlement area in Semarang had a total area of 16,670 hectares (44.8%) and the agricultural area had a total area of 14,485 hectares or 38.8%. The settlement area is concentrated in the center of the city while agricultural areas are mostly located in western Semarang, namely in Ngaliyan, Mijen, Gunungpati, Banyumanik, and Tembalang District.

Distribution Pattern of Settlements in Semarang City

Based on the result of the analysis, the Nearest Neighborhood Index was calculated, so that the settlement distribution patterns in Semarang City can be determined. Settlement distribution patterns in Semarang City consist of three patterns, namely random pattern, clustered pattern, and dispersed pattern. Table 2 shows the index and the settlement distribution patterns in Semarang City.

TABLE 2. Distribution Pattern of Settlements in Semarang City

No	District	Distribution Pattern of Settlements	
		T Value	Pattern
1	Pedurungan, Semarang Tengah, Tugu	0,00 - 0,70	Clustered
2	Gunungpati, Banyumanik, Gajah Mungkur, Semarang Selatan, Tembalang, Genuk, Semarang Timur, Semarang Barat	0,70 - 1,40	Random
3	Mijen, Candisari, Gayamsari, Semarang Utara	1,40 - 2,15	Dispersed

Settlements in Semarang City are mostly in random patterns, characterizing sporadic settlement centers. This is possible because of the unplanned settlement development in an area. Districts that have random patterned settlements are Gunungpati, Banyumanik, Gajahmungkur, Semarang Selatan, Tembalang, Genuk, Semarang Timur and Semarang Barat.

Clustered patterns are observed in some districts, such as Pedurungan, Semarang Tengah, Tugu, and Ngaliyan. The pattern is a result of social class and access to supporting facilities. Residents tend to choose residential areas based on several factors like locations, education, criminal rate, environment quality, and land prices [17], [18].

Disaster-prone Areas in Semarang City

There are three areas with vulnerability to natural hazards, namely flood, landslide, and geological fault. Semarang City is dominated by areas with vulnerability to flooding, documented as 2.940,82 Ha (46,91%) [19]. The total areas with vulnerability to landside are 2.065,21 Ha (32,94%) and total areas with vulnerability to geological fault are 1.262 Ha or 20.15%. Table 3 presents the areas with vulnerability to natural hazards in Semarang City in 2020.

TABLE 3. Areas with Vulnerability to Natural Hazards in Semarang City

No	District	Disaster-prone Area								Non-Disaster-prone Area		District Area	
		Flood		Landslide		Ground movement		Total Disaster-prone Area		Ha	%	Ha	%
		Ha	%	Ha	%	Ha	%	Ha	%				
1	Tugu	136.18	4.3	52.4	1.6	0	0	188.58	5.9	2989.42	94.1	3178	100
2	Smg barat	277.22	12.8	314.03	14.4	76	3.5	667.25	30.7	1506.75	69.3	2174	100
3	Smg utara	154.02	14.0	0	0	0	0	154.02	14.0	942.98	86.0	1097	100
4	Smg tgh	64.02	10.4	0	0	0	0	64.02	10.4	549.98	89.6	614	100
5	Smg timur	165.23	21.5	0	0	0	0	165.23	21.5	604.77	78.5	770	100
6	Gayamsari	332.99	53.9	0	0	0	0	332.99	53.9	285.01	46.1	618	100
7	Genuk	376.92	13.8	0	0	0	0	376.92	13.8	2362.08	86.2	2739	100
8	Pedurungan	491.35	23.7	0	0	0	0.0	491.35	23.7	1580.65	76.3	2072	100
9	Tembalang	249.26	5.6	186.72	4.2	89	2.0	524.98	11.9	3895.02	88.1	4420	100
10	Smg selatan	102.65	17.3	27.31	4.6	45	7.6	174.96	29.5	418.04	70.5	593	100
11	Candisari	0	0	330.35	50.5	52	8.0	382.35	58.5	271.65	41.5	654	100
12	Banyumanik	0	0	485.75	18.9	163	6.3	648.75	25.3	1920.25	74.7	2569	100
13	Gajah mgkr	210.41	23.2	381.86	42.1	102	11.2	694.27	76.5	212.73	23.5	907	100
14	Gunungpati	153.01	2.8	65.68	1.2	515	9.5	733.69	13.6	4677.31	86.4	5411	100

No	District	Disaster-prone Area								Non-Disaster-prone Area		District Area	
		Flood		Landslide		Ground movement		Total Disaster-prone Area		Ha	%	Ha	%
		Ha	%	Ha	%	Ha	%	Ha	%				
15	Mijen	111.89	1.9	37.95	0.7	123	2.1	272.84	4.7	5482.16	95.3	5755	100
16	Ngaliyan	115.67	3.0	183.16	4.	97	2.6	395.83	10.4	3403.17	89.6	3799	100
Kota Semarang		2941	7.9	2065.2	5.5	1262	3.4	6268	16.8	31102	83.2%	37370	100

Pedurangan District is the area which is dominated by flood-prone areas, covering a total area of 491,35 Ha or 23,7%, while other districts in northern Semarang with flood-prone areas are Genuk, Gayamsari, Semarang Utara, Semarang Barat, and Tugu. The condition is related to the relatively low topography and is directly adjacent to the Java Sea.

Areas with vulnerability to landslides are mostly located in the suburbs of Semarang City. The suburbs of Semarang City are hilly areas with uneven surfaces. While the districts in the downtown area of Semarang City which are prone to landslides are Gajahmungkur District, Candisari District, and Semarang Barat District.

Disaster-prone areas in Semarang City are categorized into three levels of hazards, namely high risk to natural hazards, the moderate risk to natural hazards, and low risk to natural hazards. The categorization is based on five (5) criteria, namely, population density, numbers of natural hazards in recent years, arable land, housing density, and land use in the protected area. The levels of vulnerability to natural hazards were determined based on the scores and indices as shown in Table 1. The 3 types of disaster-prone that occur in the city of Semarang can be explained as follows

The following is the weight assessment and scoring on 5 predetermined criteria for each disaster-prone area.

- A. **Flood**, most of the districts in Semarang City are categorized as the moderate risk to hazard. Those districts have various scores in every criterion of vulnerability to natural hazards. Semarang Utara District is categorized as high risk to hazard. The district has a relatively high score in every criterion of vulnerability to natural hazards (population density, numbers of natural hazards in recent years, arable land, housing density, and land use in protected areas).
- B. **Landslide**, districts that are categorized in moderate risk to landslide have various scores which range from moderate to high in every criterion of vulnerability to natural hazards. Those districts are categorized by 2-6 occurrences of natural hazards in the recent year, moderate area of arable land (2.400 – 4.800 ha), the moderate density of house building, and moderate land use in protected areas (660 – 1.320 ha). Those districts are Tugu, Tembalang, Semarang Selatan, Candisari, Banyumanik, Gajahmungkur and Gunungpati.
- C. **Ground Movements**, besides land and coastal areas with various topography conditions, Semarang City also has unique geomorphological conditions. Ground movement in Semarang City only occurs in a few districts. There are 7 districts that are included in the moderate landslide-prone area, including Tugu, Candisari, Banyumanik, Tembalang, South Semarang, Gajahmungkur and Gunungpati districts. Districts with moderate landslide susceptibility levels are characterized by a history of 2-6 disasters within 1 year, medium productive land area (2,400-4,800 ha), moderate building density (880 – 1,760 ha), and moderate protected area land use (660 ha) – 1,320 ha).

Land use for settlement in Semarang City is prone to natural hazards namely, flood, landslide, and ground movement. The total settlement area in the disaster-prone area in Semarang City is 5.577 Ha or 33.5% of the total settlement area in Semarang City. Most of the land use for settlement areas in disaster-prone areas is observed in Gunungpati District (636 Ha) and Banyumanik District (617 Ha). Semarang Utara District and Ngaliyan Districts are the areas exposed to high risk of natural hazards. Semarang Utara District has a high risk to flood while Ngaliyan District has a high index (68.9%) for the risk of landslide and ground movement.

Distribution Pattern of Settlements with Vulnerability to Natural Hazards in Semarang City

Settlement patterns show constant interdependence between physical elements and humans. The nearest neighborhood analysis is used to determine the spatial pattern of distribution of settlement with vulnerability to natural hazards.

A. Distribution Pattern of Settlements with Vulnerability to Flood in Semarang City

Most settlements in flood-prone areas are distributed dispersed patterns. The dispersed pattern is usually observed in settlements with moderate vulnerability to flooding. The characteristics of settlement in flood-prone areas can be defined as follows:

1. Most of the settlements are located in northern Semarang (Northern Coastal Area)
2. Spatial distribution of settlements shows regular patterns of settlement centers with a consistent distance between centers and those centers are evenly located in all areas.
3. Settlements pattern in coastal areas are more suitable to linear and tends to follow the road network [4], [20].

Distribution patterns of settlements with all levels of vulnerability to flood are presented in Figure 2.

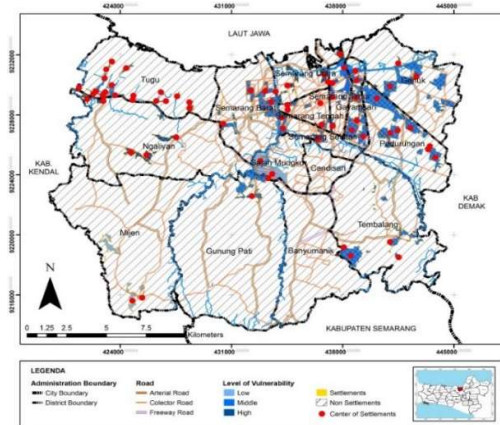


FIGURE 2. Map of Distribution Pattern of Settlements with Vulnerability to Flood in Semarang City

B. Distribution Pattern of Settlements with Vulnerability to Landslide in Semarang City

Distribution patterns of settlements with vulnerability to flooding consist of three patterns, namely, random, clustered, and uniform. Table 4 shows the patterns in settlements with vulnerability to landslides in Semarang City

TABLE 4. Distribution Pattern of Settlements with Vulnerability to Landslide

No	Class of vulnerability to landslide	District	Nearest Neighborhood Index	Distribution pattern of settlements
1.	Low vulnerability to landslide	Kecamatan Mijen	0,53	Clustered
2.	Medium vulnerability to landslide	Kecamatan Tugu, Tembalang, Semarang Selatan, Candisari, Gajahmungkur, Banyumanik, Gunungpati	0,96	Random
3.	High vulnerability to landslide	Kecamatan Semarang Barat dan Ngaliyang	1,59	Dispersed

Settlements with vulnerability to landslides are generally in random patterns. Based on the pattern, the settlements with vulnerability to landslide are characterized by:

1. Settlements with vulnerability to landslides are located randomly in the center of southern Semarang
2. The centers of the settlements are randomly located and tend to be sporadic.
3. The settlements are randomly distributed in hilly areas because the residents tend to settle in areas that are not steep, flat, and relatively safe [20].

C. Distribution Pattern of Settlements with Vulnerability to Ground movement in Semarang City

Most settlements with vulnerability to ground movement are in a cluster pattern. The pattern is characterized by groups of settlements that are relatively concentrated or clustered. This pattern is caused by the factors of social class and access to facilities. Residents tend to decide on the residential area which is accessible to various supporting facilities, thus forming clustered settlements. Settlements with high accessibility as well as a good topography will facilitate mobilization, so it's on the area can develop the potential in meeting needs independent, especially in the economic aspect [21]. The pattern is observed in southern Semarang which is a hilly area.

Figure 3 shows spatial point patterns in settlement with vulnerability to ground movement.

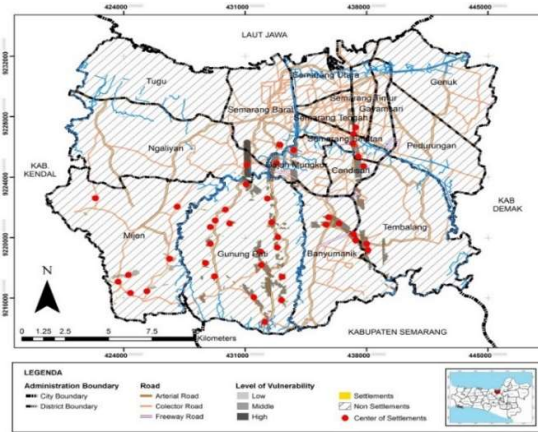


FIGURE 3. Map of Distribution Pattern of Settlements with Vulnerability to Ground movement in Semarang City

D. Distribution Pattern of Settlements with Vulnerability to Natural Hazard in Semarang City

From the observation, three variations of the distribution pattern of the settlement were formed in disaster-prone settlement areas, namely cluster pattern, random pattern, and dispersed pattern. Figure 4 shows spatial statistics of distribution patterns observed in disaster-prone settlement areas in Semarang.

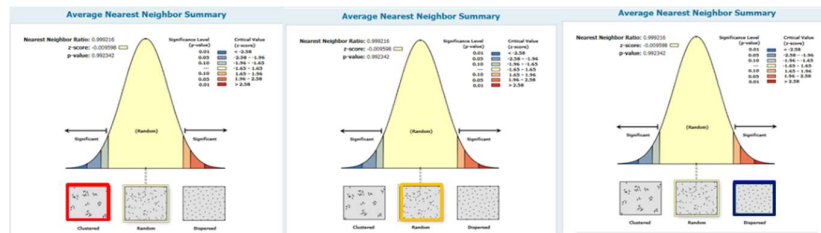


FIGURE4. Spatial Statistics of Distribution Pattern of Settlements with Vulnerability to Natural Hazards

Table 5 shows the index and distribution pattern of settlement with vulnerability to natural hazards

TABLE 5. Distribution Pattern of Settlements with Vulnerability to Natural Hazards

No	District	Vulnerability to natural hazards	Nearest Neighborhood Index	Distribution pattern of settlements
1	Mijen	Low	1,75	Dispersed
2	Gunungpati	Medium	0,95	Random
3	Banyumanik	Medium	0,83	Random
4	Gajah Mungkur	Medium	1,06	Random
5	Semarang Selatan	Medium	0,97	Random
6	Candisari	Medium	1,62	Dispersed
7	Tembalang	Medium	1,01	Random
8	Pedurungan	Medium	0,53	Clustered

No	District	Vulnerability to natural hazards	Nearest Neighborhood Index	Distribution pattern of settlements
9	Genuk	Medium	1,45	Random
10	Gayamsari	Medium	1,92	Dispersed
11	Semarang Timur	Medium	0,62	Clustered
12	Semarang Utara	High	1,11	Random
13	Semarang Tengah	Medium	0,47	Clustered
14	Semarang Barat	Medium	1,14	Random
15	Tugu	Medium	0,60	Clustered
16	Ngaliyan	High	0,75	Random

Most districts that are vulnerable to natural hazards were observed as districts with scattered settlement patterns. A scattered settlement pattern is characterized by irregular locations of settlements. The irregular pattern is determined by the needs of the residents (looking for an area that is not steep, morphology flat, and relatively safe area) which resulted in sporadic development of settlements [22]. A scattered settlement pattern was observed in districts with a moderate to high risk of vulnerability to natural hazards. Those districts are Gunungpati, Banyumanik, Gajah Mungkur, Semarang Selatan, Tembalang, Genuk, Semarang Utara, Semarang Barat and Ngaliyan.

Figure 5 presents the distribution pattern of settlement with vulnerability to natural hazards in Semarang City.

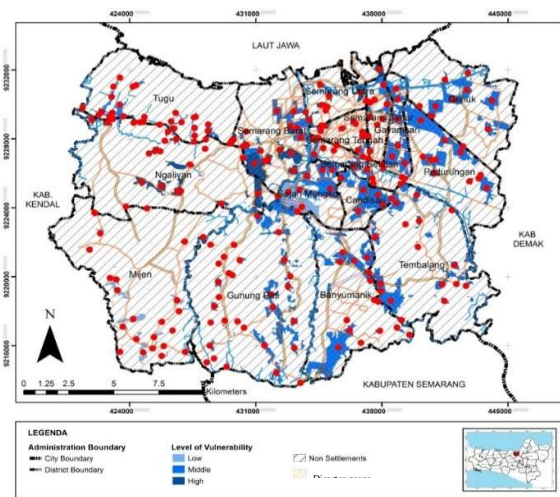


FIGURE 5. Map of Distribution Pattern of Settlements with Vulnerability to Natural Hazards in Semarang City

CONCLUSION

The development of settlements in the city of Semarang is in line with the population growth. In 2020, the land use for settlement areas in Semarang City was 16,670 hectares or 44.8% of the total land in Semarang City. Land use for settlement areas has occurred in several locations including in disaster-prone areas. There are at least three disaster-prone sectors, namely areas prone to flooding, landslides, and ground movement, with low to high levels of vulnerability. The level of vulnerability to natural hazards is influenced by several factors, including population density, the occurrence of disasters in recent years, arable land, density of housing buildings and land use in protected areas.

Most of the disaster-prone areas in Semarang City have a random pattern of settlement distribution. Settlements with random patterns are generally characterized by the irregular distance between one settlement location and another. Settlements with random patterns are possible because settlements develop

sporadically following the needs of the population for housing. This kind of pattern tends to exist in sub-districts with moderate to high levels of disaster vulnerability.

The results show that the settlements in disaster-prone areas indicate that settlement development has not considered the potential, conditions, problems, prospects, and various challenges faced by the regions as mandated in the spatial planning directives. The development of settlements in disaster-prone areas requires disaster mitigation efforts even in areas with moderate levels of vulnerability, namely Semarang Tengah, Gayamsari, Candisari, Tembalang, Banyumanik, Genuk, Pedurungan, Gunungpati, Tugu, and Mijen.

REFERENCES

- [1] J. Muchran, W. Ilham, M. Siddiq, and Susilawati, "Model Perencanaan Ruang Terbuka Hijau Taman Lingkungan di Kota Banjarbaru, Kalimantan Selatan," *EnviroScienteeae*, vol. 11, pp. 19–32, 2015.
- [2] S. Angel, J. Parent, D. L. Civco, A. Blei, and D. Potere, "The dimensions of global urban expansion: Estimates and projections for all countries, 2000-2050," *Prog. Plann.*, vol. 75, no. 2, pp. 53–107, 2011.
- [3] M. Arief and B. Pigawati, "Kajian Kerentanan Di Kawasan Permukiman Rawan Bencana Kecamatan Semarang Barat, Kota Semarang," *J. Tek. PWK*, vol. 4, no. 2, pp. 332–344, 2015.
- [4] R. F. Putri, L. S. Budiman, N. M. Adalya, and N. U. Fauziyanti, "Trend Analysis of Land Cover Changes , Population and Settlement Distribution to Land-use Assessment in Kebumen Regency," *J. Geogr.*, vol. 16, no. 1, pp. 25–31, 2019.
- [5] A. S. M. Azmi, W. A. R. W. M. Salleh, and A. H. Nawawi, "Cognitive Behaviour of Residents Toward Living in Landslide Prone Area: Ulu Klang," *Procedia - Soc. Behav. Sci.*, vol. 101, pp. 379–393, 2013.
- [6] J. Mandasari, M. Arifin, and M. Ali, "Settlement Arrangement Based on Landslide Mitigation (Case Study: Capagallung, West Bacukiki District, City of Parepare)," *Procedia - Soc. Behav. Sci.*, vol. 227, no. 22, pp. 442–450, 2016.
- [7] H. S. Sudhira, T. V. Ramachandra, and K. S. Jagadish, "Urban sprawl: Metrics, dynamics and modeling using GIS," *Int. J. Appl. Earth Obs. Geoinf.*, vol. 5, no. 1, pp. 29–39, 2004.
- [8] K. S. BPS, "Kota semarang 2020."
- [9] B. Pigawati, N. Yuliasuti, F. H. Mardiansjah, and M. A. Suryani, "Changes of Settlement Environmental Quality in Semarang City Center Changes of Settlement Environmental Quality in Semarang City Center," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 313, 2019.
- [10] B. Pigawati, N. Yuliasuti, and F. H. Mardiansjah, "Pembatasan Perkembangan Permukiman Kawasan Pinggiran Sebagai Upaya Pengendalian Perkembangan Kota Semarang," *TATALOKA*, vol. 19, no. 4, p. 306, Nov. 2017.
- [11] K. S. BPBD, "Data Bencana Alam di Kota Semarang Tahun 2019," 2018.
- [12] B. Pigawati, N. Yuliasuti, and F. H. Mardiansjah, "Settlements Growth and Development in Semarang City Centre Area , Indonesia," 2019.
- [13] Rifai, "Analisis perkembangan fisik kota palu dengan citra landsat," *J. Ruang*, vol. 3, pp. 45–54, 2011.
- [14] M. Coonbes and S. Raybould, "Public policy and population distribution: Developing appropriate indicators of settlement patterns," *Environ. Plan. C Gov. Policy*, vol. 19, no. 2, pp. 223–248, 2001.
- [15] E. R. Rakhmawati, Sriyono, and D. L. Setyowati, "Analisis Pola Sebaran Permukiman Berdasarkan Topografi di Kecamatan Brangsong Kabupaten Kendal," *Geo Image*, vol. 3, no. 2, pp. 1–8, 2014.
- [16] K. Lilik, R. Yunus, robi amir Muhammad, and P. Narwawi, "Indeks Rawan Bencana Indonesia," pp. 1–226, 2011.
- [17] B. Pigawati, N. Yuliasuti, and F. H. Mardiansjah, "The Settlements Growth in Mijen District, Suburb of Semarang," in *IOP Conference Series: Earth and Environmental Science*, 2018, vol. 123, no. 1.
- [18] S. R. Rani, I. G. Sugiyanta, and Sudarmi, "Analisis Perkembangan Daerah Permukiman di Kecamatan Pringsewu Kabupaten Pringsewu pada tahun 2010 - 2017," vol. 2017, no. September, pp. 160–164, 2018.
- [19] Pemerintah Kota Semarang, *Peraturan Daerah Kota Semarang Nomor 14 Tahun 2011 tentang Rencana Tata Ruang Wilayah Kota Semarang Tahun 2011-2031*. 2011.
- [20] S. Utami, Soemarno, Surjono, and M. Bisri, "Disaster Risk and Adaptation of Settlement along the River Brantas in the Context of Sustainable Development, Malang, Indonesia," *Procedia Environ.*

- Sci.*, vol. 20, pp. 602–611, 2014.
- [21] F. N. Yusrina *et al.*, “Analisis Pola Permukiman Menggunakan Pendekatan Nearest Neighbour Untuk Kajian Manfaat Objek Wisata Di Kecamatan Prambanan Kabupaten Klaten,” *J. Geogr. Edukasi dan Lingkung.*, vol. 2, no. 1, pp. 46–55, 2018.
- [22] H. Setianto and Murjainah, “Hubungan Pola Persebaran Permukiman dengan Kualitas Airtanah di Kecamatan Plaju Kota Palembang,” *J. Geogr.*, vol. 16, no. 1, pp. 60–71, 2019.