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# Spatial Mapping Based on the Settlement Carrying Capacity Value in Gunungpati District, Semarang City

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**Abstract:** The City Regional Spatial Plan (RTRW) for Semarang City stipulates that Gunungpati District has a role in developing residential cultivation areas with the determination of several protected area types as well as functioning as a strategic environmental carrying capacity area for the city. Based on Semarang City BPBD, 29 landslides occurred between 2016-2021, which damaged houses, facilities, and residential infrastructure. This study aims to produce spatial mapping for residential area designations through the calculation of its carrying capacity so as to obtain the carrying capacity value or classification of the ability of each village area to accommodate the number of residents. This can then be used as one of the basic considerations in determining the development of residential areas in Gunungpati District. This study uses the quantitative method to determine the residential land's carrying capacity through spatial mapping data processing based on geographic information systems (GIS) using scoring, weighting, and overlay techniques. The spatial mapping produces a landslide vulnerability map with vulnerability classifications covering very low (1.468,17 Ha) to very vulnerable (466.53 Ha) classes as well as cultivation function, buffer, and protected areas distribution in Gunungpati District. The final results show that each region can accommodate the population increase of each village in Gunungpati District, with Jatirejo Village scoring the highest in DDPm value (26.9) and Sukorejo Village scoring the lowest (5.7).

**Keywords**: Landslides, carrying capacity, settlement

## INTRODUCTION

Gunungpati District, as a suburban area, is included in the VIII city territory section (BWK) in Semarang City. Topographical conditions are characterized by various slopes. This condition includes plains to very steep classes accompanied by land morphology in the form of lowlands to very steep hills (Peraturan Daerah Kota Semarang Nomor 14 Tahun 2011). Based on RTRW Kota Semarang Tahun 2011-2031, Gunungpati District has allotted functions for cultivation areas, one of which is a residential area covering trade and services, tourism, public facilities, housing, and education. Other functional provisions cover several types of protected areas, namely: areas that provide protection to the areas under them, reserves and nature conservation, local protection, and disaster-prone protection. Based on data from

Badan Penanggulangan Bencana Daerah (BPBD) Kota Semarang from 2012 to early 2021, the frequency of landslides (villages) was recorded with details as shown in Figure 1.

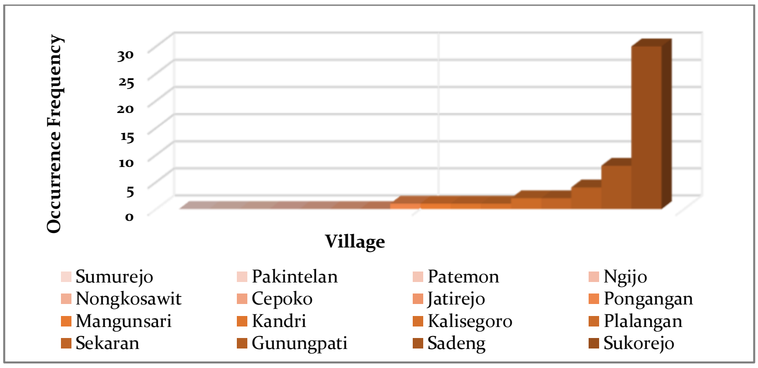


Figure 1. Landslide Disaster Frequency Graph in Gunungpati District
Source: Semarang City BPBD, 2021.

The landslide disaster that took place in Gunungpati District caused damage to several houses, public facilities, and infrastructure in residential areas. Some damage was found in Sukorejo Village, specifically in the Trangkil Baru Housing Neighborhood Unit 10 Community Unit 06. This damage happened on Tuesday, 02 February 2021, which was made obvious by collapsed buildings and cracks in housing facilities, damage to road infrastructure and lighting, as well as public mosque facilities that experienced cracks. Another landslide disaster occurred in Bukit Manyaran Permai Gunungpati Housing Community Unit 05 Neighborhood Units 01, 05, and 07, located in Sadeng Village, on Sunday, February 28, 2021. This incident impacted houses that were damaged to the point where they were unfit to live in, with the number of affected dwellings for Neighborhood Unit 01 as many as five houses, Neighborhood Unit 05 as many as one house, Neighborhood Unit 07 as many as two houses (Author's Primary Observation, 2021).

Several urban villages with a high level of vulnerability to landslides based on their frequency of occurrence and ground motion include Sukorejo, Sadeng, Pongangan, Kalisegoro, Kandri, Sekaran, Gunungati, Nongkosawit, Pakintelan, dan Patemon Villages. Landslides in the sub-district generally occur in the rainy season. Disasters occur because they are triggered by high-intensity rains, which can cause losses and hinder people's activities and mobility (BPBD Kota Semarang, 2021).

Table 1. Landslide Disasters in Gunungpati District

| No. | Village \ Year | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| 1 | Sukorejo | ✓ RT 09 RW 07<br>✓ Deliksari Housing RW 06 RT 03<br>✓ RW 03 RT 01 and 09, RW 04 RT 03 | ✓ RW 12 RT 02<br>✓ Kalialang Baru RW 08 RT 01<br>✓ Kalialang Baru RW 07 RT 03<br>✓ Kradenan Asri RW 11 RT 01 | ✓ Kalialang Baru RW 07 RT 01<br>✓ Deliksari Housing RW 06 RT 06<br>✓ Kalialang Lama RW 11 RT 01 | ✓ RW 06 RT 04 at Deliksari Street<br>✓ RW 07 RT 01 at Kalialang Baru Street | ✓ RW 01 RT 03<br>✓ RW 07 RT 01<br>✓ RW 06 RT 06<br>✓ RW 06 RT 09 Kalialang Street<br>✓ RW 05 RT 04 Dewi Sartika East 8 Street |
| 2 | Sadeng | - | Bukit Manyaran Housing RW 05 RT 07 | Bukit Manyaran Permai Housing RW 05 RT 07 | Bukit Manyaran Permai RW 05 RT 01 | ✓ RW 05 RT 01 Talangsari Street<br>✓ RW 05 RT 05 Bukit Manyaran Permai Street |
| 3 | Pongangan | - | - | RW 05 RT 05 | - | - |
| 4 | Kandri | - | - | RW 01 RT 03 | - | - |
| 5 | Gunungpati | - | - | - | RW 06 RT 03 Malon Village | ✓ RW 03 RT 04 Parengsari Makam Siwogo Village<br>✓ RW 05 RT 04 Sekalongan Village |
| 6 | Mangunsari | - | - | - | - | RW 05 RT 01 |
| 7 | Kalisegoro | | | | | RW 04 RT 01 |

Source: BPBD Kota Semarang, 2021

The population growth of Gunungpati District in 2015-2019 reached 12.23%. This figure is quite high for the scope of Semarang City. The increase in population will trigger an increase in the need for residential land, so this should be the focus of attention in planning the development of residential areas in Gunungpati District.

Land carrying capacity is the ability of land resources to support human activities. Land carrying capacity is an important instrument for human-land relations research (Hu, Huijuan & Ling Han, 2023). Cities globally are growing rapidly, so the contradiction between urban development and urban carrying capacity is increasingly prominent. Various indicators of urban carrying capacity assessment have been introduced as the main instrument for investigating the performance of urban carrying capacity. However, the understanding of the effectiveness of these urban carrying capacity indicators didn't get enough attention in previous studies. It is not so clear whether the proposed popular indicators are also suitable for communicating the status of urban carrying capacity practically and vice versa (Liu, 2023).

Pedoman Daya Dukung dan Daya Tampung Lahan Lingkungan Hidup Tahun 2014 stated that determining the value of settlements' carrying capacity or an area's ability to accommodate living residents can be used as one of the basic considerations in developing residential areas. Determination of carrying capacity value can be done by taking into account spatial aspects, one of which includes the distribution of settlement allocation limitation areas. The limitation of settlement designation is for land with a very low level of suitability for land development (including protected areas). This is due to natural physical conditions that cannot support the development and are prioritized as non-built areas (Suganda dkk, 2017).

The development of Semarang City residents who continue to shift towards the eastern to southern suburbs (suburbanization) of the city (Pigawati dkk, 2017) shows an increase in the need for residential land. The consequence of this increased land needs is accompanied by limited available land in accordance with the concept of *land-man ratio*, which is the occurrence of pressure on land due to a decrease in the ratio of land to humans. (Haidir & Rudiarto, 2019) Physically, the land in Gunungpati District has varied natural physical conditions, both the region's topography and morphology, accompanied by the presence of special conditions with the existence of protected areas.

Non-physically, population growth continues to rise with the limited condition of available land, so some of these factors become the basis for consideration in determining the designation of residential areas. An increase in population indicates the development of the Semarang City area is showing symptoms of the spread effect of settlement, namely the impact of the spread of residential areas both in the center and suburban areas. Conditions require spatial arrangement and control to prevent environmental degradation or damage (Prianggoro dkk, 2015).

The designation of residential areas in Gunungpati Subdistrict needs to be directed according to its function so as not to disturb the ecological functions of existing protected areas (Dewi & Rudiarto, 2017). The results of this spatial mapping become material in calculating the carrying capacity value of residential land to be able to produce carrying capacity values or classifications of regional capabilities in each village to accommodate the population. This can be used as one of the basic considerations in determining the development of residential areas in Gunungpati District.

Next, this study wants to know the value of carrying capacity in accommodating residents. The value of the carrying capacity of this land is used for residential area development based on the vulnerability factor of landslides and the provisions of regional functions in Gunungpati District. Spatial mapping supported by recent references and methods can be implemented in other locations. Processing methods for spatial mapping on landslide disaster susceptibility analysis and Area function analysis refer to Decision Letter of the Minister of Agriculture No.837 of 1980 dan No.683 of 1981, Regulation of the Minister of Public Works Number 20 of 2007 as well as Buchori & Susilo, 2012 and Yogiswara et al, 2020. To carry out the analysis, it is necessary to consider the conditions in the study area and the basic rules used so they can support the analysis. The aspect that distinguishes this spatial mapping from other studies is the scoring for soil type, rainfall, and land use variables. Scores made for the soil type and rainfall variables are referenced from the Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981. However, the modifications made are based on soil types in the study area, where not all soil types are found in Gunungpati District. Scores applied to land use not only refer to SK Menteri Pertanian No.837 Tahun 1980 dan No.683 Tahun 1981 but also consider the efficacy of studies conducted by Buchori & Susilo, 2012; Nugraha et al., 2014.

## METHODS

This study used secondary data based on a literature review along with data from Spatial Planning Office (DISTARU), Regional Development Planning Agency (BAPPEDA), Regional Agency for Disaster Management (BPBD), and Semarang City Central Agency on Statistics (BPS). Secondary data included physical land data, which includes: slope, soil type, rainfall intensity, rock lithology type (geology), and soil movement vulnerability zone in Gunungpati District. Natural physical data were sourced from the 2020 Semarang City Spatial Planning Office map and references in the 2011-2031 Semarang City City Regional Spatial Plan (RTRW) with a scale of 1:25,000. Physical land use data were obtained from the Semarang City Spatial Planning Office map with adjustments to the results of digitized high-resolution *Google Earth* satellite images in 2020 using a scale of 1:25,000. Digitization of satellite imagery was carried out on the type of residential land use, facilities, and infrastructure. Spatial data on protected areas were sourced from the digital map of Semarang City RTRW for 2011-2031, as well as disaster data that occurred in Gunungpati District obtained from the Semarang City Regional Agency for Disaster Management (BPBD) in 2020. Non-physical data sources include demographic data on the number and growth rate of Gunungpati District population, which was sourced from the Central Agency on Statistics (BPS) for Semarang City in 2014-2019.

This research used a quantitative research method. The determination of the carrying capacity of residential land is carried out by means of mathematical analysis. The authors used numerical data supported by the use of geographic information system (GIS) based mapping spatial analysis. Mapping was carried out using scoring, weighting, and *overlay* techniques supported by the consistency of map data usage in 2020 with a scale of 1: 25,000 according to the reference on the city spatial plan map. The spatial analysis included analysis of landslide hazard and area function analysis.

### Landslide Disaster Vulnerability

Landslide susceptibility varies from area to area based on factors such as surface geology, moisture availability, proximity to seismically active zones, and slope angle (Hussain et al, 2023). Quantitative techniques dominated in landslide vulnerability modeling. Techniques could be deterministic (analytically-driven), heuristic (knowledge-driven), or data-driven statistics, including bivariate, multivariate, and machine learning approaches. The use of a statistical approach in practice actually depends on a reliable inventory that reflects the actual factors that cause slope collapse. (Affandi et al, 2023) Gunungpati Subdistrict is an area in Semarang City that is prone to landslides, considering the physical condition of the subdistricts land is a plateau with varying slope classes and acts as a *recharge* and upstream area in Semarang City (Hadiyansah et al, 2019). According to (Faizana et al, 2015), one of the factors that greatly influenced the potential for landslides to occur is the tilt of the slope. However, in the analysis of landslide vulnerability in Gunungpati District, modified variables from Buchori & Susilo (2012) were used, which included: slope, soil type, rainfall, geology (rock lithology), soil movement vulnerability zone, and 2020 land use with a scale of 1:25,000. The research variable for spatial analysis of landslide vulnerability was calculated using scoring with intervals from the lowest to the highest using the provisions: the higher the score on the variable indicator, the higher the vulnerability to landslides.

**Slope Tilt Score**

The scoring provisions of the slope variable were set to 5 classifications, namely: flat, inclined, slightly steep, steep, to very steep. The score was determined based on the steepness level of the slope variable class. The higher the steepness of the slope on the land, the higher the score indicates a high potential for landslides to occur. Steep to very steep slope conditions with slopes reaching more than 40% tend to have a high potential for landslides. Development of built-up land (cultivation) is optimally allocated in areas with low slopes and included in the morphology of lowlands. Classification of soil types was determined based on the degree of sensitivity to erosion. This is based on the characteristics and components of soil material. The highest scores are in soil types with a high level of erosion sensitivity. They had low soil material characteristics and components in terms of carrying capacity and ability in the aspect of area development.

Table 2. Slope Variable Score Classification

| No | Slope (%) | Classification | Score |
|---|---|---|---|
| 1 | 0-2 | Flat | 1 |
| 2 | 2-15 | Inclined | 2 |
| 3 | 15-25 | Slightly Steep | 3 |
| 4 | 25-40 | Steep | 4 |
| 5 | > 40 | Very Steep | 5 |

Source: Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981 with author's modified analysis, 2021.

**Ground Movement Zone Score**

Ground movement is a dynamic natural phenomenon. This is a natural form of slope instability but can also be the result of human activity, which is characterized by gravitational slope movement followed by the movement of rock and soil masses down the sloping plane (landslide) (Sainyakit & Siregar, 2017). Ground movement is a movement process that triggers landslides of rock and soil material or landslides. The ground motion zone in Gunungpati District was divided into 4 classes, namely very low zone (score 2), low (score 3), moderate (score 4), to high (score 5).

Table 3. Classification of Ground Movement Scores

| No | Zone | Score |
|---|---|---|
| 1 | Very low | 2 |
| 2 | Low | 3 |
| 3 | Moderate | 4 |
| 4 | High | 5 |

Source: Regulation of the Minister of Public Works Number : 22 /Prt/M/2007 with author's modified analysis, 2021.

**Geological Score (Rock Lithology)**

Each type of formation has a characteristic rock lithological arrangement with varying stability properties. Each formation has a sensitivity to erosion or rocky soil erosion, which depends on the characteristics, resilience, and composition of the physical properties of the material (Iskandar et al, 2006; Soedarsono, 2012; Wardhana et al, 2014; Putranto et al, 2015); The resilience in question is in the aspect of resistance to building foundations for the development of cultivation areas. The condition of the geological formation formed is based on the age factor of the formation process, which is represented in the geological stratigraphic sheet.

Table 4. Classification of Geological Variable Scores

| No | Geological Formation | Stratigraphy (Age) | Score |
|---|---|---|---|
| 1 | Alluvium | Holocene | 1 |
| 2 | Young Volcanic Rocks (Gajahmungkur and Kaligesik) | Plistocene-Holocene | 2 |
| 3 | Jongkong Formation (Andesite) | Plio-Plistocene (quarter) | 3 |
| 4 | Kaligetas and Damar Formations | Plio-Plistocene | 3 |
| 5 | Kerek Formation | Miocene | 4 |
| 6 | Kalibeng Formation | Plio-Pliosene | 5 |

Source: Buchori & Susilo, 2012; Yogiswara et al, 2020 with author's modified analysis, 2021.

The value of the geological formation variable score was determined based on the characteristics of each type of rock lithology with reference to the stratigraphy (old to early on the geological stratigraphic sheet) spread across Gunungpati District. The order of the geological formation types in the area based on their stratigraphy includes rock formations of the Kerek Formation, Kalibeng Formation, Kaligetas Formation, Damar Formation, Andesite Breccia or Jongkong Formation, Kaligesik and Gajahmungkur Volcano Rocks, and Alluvial Deposits.

**Soil Type Score**

Soil type classifications are divided into five classes, from insensitive to very sensitive classes, which are supported by the characteristics of each soil type (Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981). Soil characteristics were reviewed based on the shape of the material, structure, and sensitivity to landslides. The characteristics of latosol soil types were soils that had undergone advanced weathering and contain primary organic minerals, low in nutrients and acid. Meanwhile, Mediterranean soil types were derived from limestone parent rock material, low organic content, acidic to alkaline, heavy soil texture, and lumpy structure (Fiantis, 2015). Latosol soils were classified as slightly sensitive, and Mediterranean soil types were classified as somewhat sensitive to the process of eroding avalanches of soil material (Chusniyah & Yudianto, 2019). The higher the set score, the soil type is categorized as having high vulnerability to landslides, and the low strength of cohesion attraction between soil particles makes the particles easily carried away by the flow (water flow easily escapes). Score 3 for the highest landslide vulnerability on mediterranean soil types, score 2 on latosol soil types, and score 1 for the lowest vulnerability on alluvial soil types.

Table 5. Soil Type Score Classification

| No | Soil Type | Score |
|---|---|---|
| 1 | Alluvial | 1 |
| 2 | Latosol | 2 |
| 3 | Mediterranean | 3 |

Source: Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981with author's modified analysis, 2021.

**Rainfall Score**

Rainfall intensity was one of the variables that played a role in determining the classification of area functions. Rainfall with higher intensity tends to have a higher score. This shows that rainfall influences the decomposition of soil material particles, so it has a major effect on the potential for soil material movement in terms of its sensitivity to the processes of erosion and landslides.

Table 6. Classification of Rainfall Variable Scores

| No | Rainfall | Score |
|---|---|---|
| 1 | < 2000 mm/yr | 1 |
| 2 | 2000-3000 mm/yr | 2 |
| 3 | >3000 mm/yr | 3 |

Source: Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981; Buchori & Susilo, 2012 with Author's Modified Analysis, 2021.

**Land Use Score**

Scoring identification on land use variables is in the form of bodies of water or blue open spaces, which were classified as unsuitable for the development of residential areas. Meanwhile, the suitable category includes agricultural land, as well as the very suitable category in the form of dry land and settlements (Nugraha et al., 2014). Bare land (without vegetation) is determined to have the highest score for landslide vulnerability, residential land, and vegetation land for both gardens and paddy fields in the moderate to moderate category, and the lowest vulnerability includes areas in the form of a body of water such as rivers and reservoirs (Buchori & Susilo, 2012; Yogiswara et al, 2020). The highest score in this analysis was determined by referencing Buchori & Susilo (2012). The land condition in Gunungpati District is divided into several types, both in the form of built-up and non-built-up land. Types of existing land use in Gunungpati District are divided into several types, namely: blue open space, green open space, vacant land, agriculture, and settlements.

Table 7. Land Use Variable Classification Score

| No | Land Use | Score |
|---|---|---|
| 1 | Forest, Garden (RTH) | 1 |
| 2 | Settlements, Agriculture | 2 |
| 3 | Moor, Field | 3 |
| 4 | Shrubs | 4 |
| 5 | Sand Dunes, Vacant Land | 5 |
| 6 | Body of Water (Blue Open Space) | 0 |

Source: Buchori & Susilo, 2012; Nugraha et al., 2014 with Author's Modified Analysis, 2021.

Determination of the distribution of land for the level of vulnerability to landslides was carried out using several parameters with varying weight percentages, including slope (30%), geology (rock lithology) and rainfall (20%), infiltration rate and *land cover* (10%), groundwater content and fracture/earthquake zone (5%), which shows the magnitude of the level of influence of variables on the potential for landslides to occur (Buchori & Susilo, 2012). The weight percentage (accumulated total weight of 100%) for each variable shows the high magnitude of the variable's influence on landslide risk. The variable parameter with the highest percentage weight indicates the higher the effect of this variable is on the potential for landslide hazard. Parameters and weights used in the Table. 8.

Table 8. Parameters and Weight Percentage

| No | Parameter | Weight |
|---|---|---|
| 1 | Slope Tilt (%) | 30% |
| 2 | Ground Movement Zone | 25% |
| 3 | Geology (rock lithology) | 20% |
| 4 | Soil Type | 10% |
| 5 | Rainfall | 10% |
| 6 | Land Use | 5% |

Source: Buchori & Susilo, 2012 with Author's Modified Analysis, 2021.

The final score for each indicator on the variable is obtained based on the multiplication between the score and the percentage of weight which was then accumulated to produce the lowest and highest final scores. Intervals with a total of five classes were taken into account as a classification description of the level of vulnerability to landslides. The following is a formula for determining the length of the vulnerability level classification class (Indarti & Abdi, 2017).

$$Class\ Length = \frac{(R)\ Highest - Lowest\ Score}{(B)\ 5}$$

Description

| | |
|---|---|
| Class Length | : Class Interval Range |
| Range (R) | : Highest - Lowest Score |
| Number of Classes (B) | : 5 (five) classes |

Based on the calculation of the length of the vulnerability level classification class, a classification is produced, which was divided into five landslide vulnerability classes, including very low, low, moderate, high, and very high (presented in Figure 8. Gunungpati District Landslide Vulnerability Map). The results of the landslide vulnerability level classification scores are represented through a map of the spatial distribution of landslide vulnerability in the Gunungpati District area. The landslide vulnerability class was divided into five classes. The results of *overlaying* all variables produced intervals of vulnerability scores as follows:

- Very low : 1.40 - 2.20
- Low : 2.25 - 2.70
- Moderate : 2.75 - 3.10
- Vulnerable : 3.15 - 3.45
- Very Vulnerable : 3.50 - 4.20

**Area Functions**

Area function analysis used slope and soil type variables based on their level of vulnerability to erosion, rainfall which was then modified according to the provisions of the Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981 and Buchori & Susilo (2012) dan Yogiswara et al (2020). The score was determined based on the characteristics of the land's physical condition on its ability to develop the area according to its designation.

The scoring results for each variable class were then combined (*overlayed*) with the three variables and accumulated with the overall total score. This was done to produce a classification of area functions based on the provisions of the Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981, Regulation of the Minister of Public Works Number 20 of 2007, concerning Physical and Environmental, Economic, and Socio-Cultural Analysis Techniques, as well as Regulation of the Ministry of Public Works No. 41/PRT/M/2007 related to residential designation areas.

Table 9. Area Function Types Classification

| No | Area Functions | Score Value |
|---|---|---|
| 1 | Protected Area | >175 |
| 2 | Buffer Area | 125 - 174 |
| 3 | Annual Plant Cultivation Area | < 125 |
| 4 | Seasonal Crop Areas | < 125 |
| 5 | Residential Area | < 125 |

Source: Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981 and Regulation of the Minister of Public Works Number 20 of 2007.

Protected areas were established while taking into account the guidelines from Government Regulation Number 47 of 1997 that determined the criteria for protected areas, including 1) land with a slope > 40%, 2) land with soil type classified as very sensitive to erosion with a slope > 15%, 3) disaster-prone areas including erosion-prone with a slope > 45%, 4) area with an altitude > 2000 mdpl, 5) tourism forest area, and 6) area around springs, rivers, reservoirs, beaches, and lakes (locally protected). The results of *overlaying* the land distribution were calculated by scoring the variables spatially according to the provisions from Decision Letter of the Minister of Agriculture No. 837 of 1980 and No. 683 of 1981, and Regulation of the Minister of Public Works Number 20 of 2007 with the delineation distribution of protected areas in RTRW Kota Semarang. In addition, the criteria for protected areas in Government Regulation Number 47 of 1997 were also used to produce area functions in the Gunungpati District area.

**Residential Land Carrying Capacity**

Settlements are the support for primary human activities. This is indicated by the increase in the need for residential land. The increase in population caused the limited land available for settlement development (Mutiara et al, 2019). Based on Act Number 1 of 2011, settlements are part of a residential area consisting of more than one housing unit accompanied by facilities, infrastructure, utilities, and other supporting activities in urban or rural areas. Maria, et al (2018) stated that the carrying capacity of a land is the productive capacity of land resources in supporting the population to meet certain living standards related to production conditions, land productivity, living standards, and supported populations. The calculation analysis of residential land carrying capacity was carried out with reference to the Guidelines to Determine the Carrying Capacity and Capacity of Environmental Land in 2014 by using parameters of population size, standard area of space requirements, and area of land suitable for settlements.

Determination of the carrying capacity value of residential land was carried out using: population, area of protected areas, and disaster-prone areas in the study area variables. The settlement carrying capacity was calculated based on the Guidelines to Determine the Carrying Capacity and Capacity of Environmental Land in 2014, which is formulated as follows:

$$DDPm = \frac{LPm}{Jp} \div \alpha$$

Description

DDPm : Settlement Carrying Capacity

JP : Total Population

$\alpha$ : Coefficient of Area of Space Needs/capita ($m^2$/capita), referring to SNI Number 03-1733- 2004 with an area of the need for space/capita is 26 m2/capita.

LPm : Area of land suitable for settlement ($m^2$)

Determination of restricted area distribution included the function of protected areas and disaster-prone areas (including landslide disasters). This was done to evaluate the area of land suitable for settlement. The area of land suitable for settlements was land outside protected areas and disaster-prone areas, so it is formulated as follows:

$$LPm = \mathrm{LW} - (\mathrm{LKL} + \mathrm{KRB})$$

Description

LW : Area

LKL : Protected Area

LKRB : Disaster Prone Area

Provisions for the final results' classification of settlement land's carrying capacity calculation are:

DDPm > 1 : Able to accommodate residents to settle

DDP = 1 : There is a balance between the residing population with the existing area

DDP < 1 : Unable to accommodate residents to settle in the region

The results of calculating the DDPm value can be determined through the optimal total population size, which is estimated to be accommodated in each village in the subdistrict in the future (Ariani et al, 2020). According to the calculation formula in Guidelines to

Determine the Carrying Capacity and Capacity of Environmental Land in 2014, the calculation of the carrying capacity value used the variable land area suitable for settlements which was obtained based on the results of the difference between the area and the limited land area for settlement development in the form of protected areas and high disaster-prone areas obtained from the results of the analysis process in the previous stage.

An increase in population will have an impact on the carrying capacity of the region in accommodating the lives of the population so that limited land conditions will follow the reduced carrying capacity. It is necessary to study the area of limitations in settlement development and demographic conditions to determine the value of carrying capacity in the subdistrict area. The results of determining the spatial distribution of landslide vulnerability and the spatial distribution of area functions are combined or *overlaid* to produce a spatial area that can be used as input in determining the calculation of the carrying capacity of settlements to determine the value of the area's ability to accommodate the population in Gunungpati District.

## RESULTS AND DISCUSSION

### Spatial Distribution of Landslide Vulnerability Levels

### Land Slope

The percentage of land slope has implications for the high velocity of surface water flow. This is also supported by the presence of gravity, so the strength in transporting soil material is higher (Aji & Parman, 2015). The slopes in Gunungpati District are divided into 5 classes, namely: class 0-2% plain area covering 450 Ha, class 2-15% covering 3,929 Ha, class 15-25% covering 940 Ha, class 25-40% covering 443 Ha, and the highest class, which is > 40%, has an area of 211 Ha, very steep category. Slopes in the form of plains and slopes are the most dominant slope class. Steep to very steep classes are mostly located in the subdistricts that are reviewed based on their conditions, which are parts of the highlands bordering the Garang and Kreo River landscapes as well as the border area between Gunungpati and Mijen District and Banyumanik Districts.

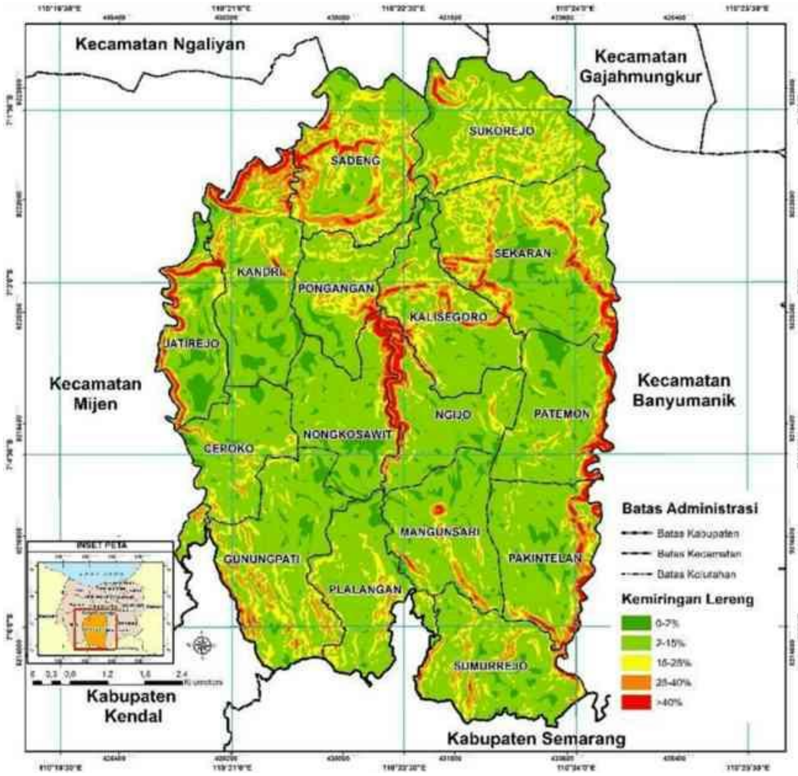


Figure 2. Gunungpati district slope map
Source: Semarang City Spatial Planning Office 2021.

**Ground Movement Zone**

The distribution of medium to high-ground motion zones is mostly in the northern region and a small portion in the district's southern region. The ground movement zone with a low level of vulnerability is generally located in the middle of the subdistrict, which is dominated by a low percentage of slopes and plains. The higher the ground movement vulnerability indicates the potential for landslides to occur in the area's land. The higher the potential zone of ground movement that occurs, the higher the chance of further processes of soil material movement occurring, namely landslides on land with a certain percentage of slope.

Spatially, the susceptibility of ground motion in Gunungpati District is divided into 4 classes: very low, low, moderate, and high movement zones. Each class area for the very low zone is 870 Ha, low is 2,223 Ha, moderate has an area of 905 Ha, and high vulnerability has an area of 1,977 Ha. The central part of the subdistrict is mostly in the zone of very low to low ground motion. The northern area includes Sadeng Village, Sukorejo, parts of Kandri, Ponngan, Kalisegoro, and Jatirejo. These areas have a high vulnerability zone of ground movement. The other villages, namely Cepoko, Pakintelan, and Patemon village, are high-class zones, which in their existing conditions are indicated by high area morphology, very steep slopes, and river landscapes.

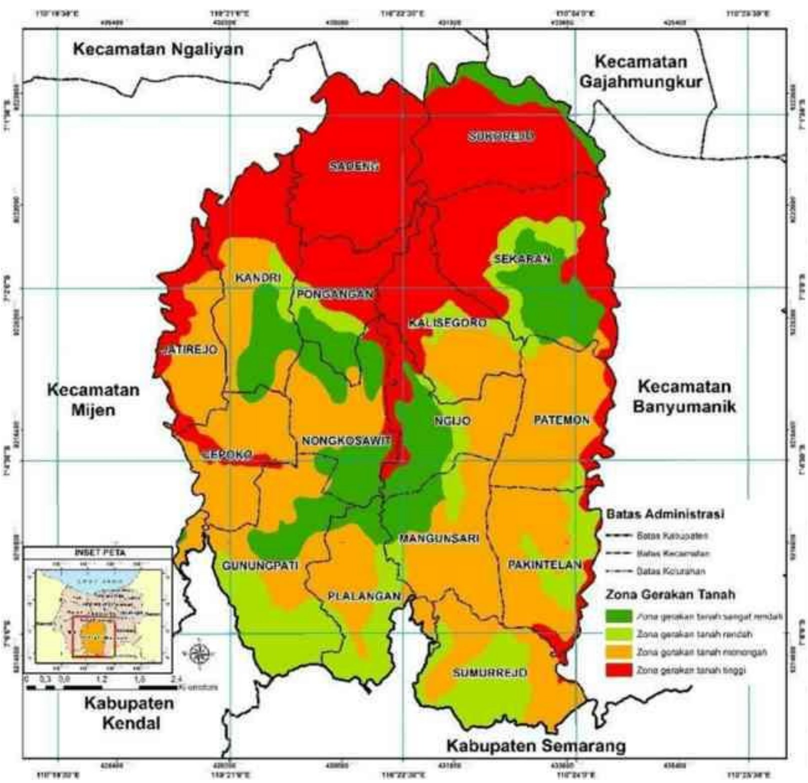


Figure 3. Gunungpati district land movement zone map
Source: Semarang City Spatial Planning Office 2021.

**Geological Formation**

Through the study's results of each rock type's characteristics, the scoring results for the Kalibeng formation were obtained. Those with the highest scores are potentially the most vulnerable to landslides. Alluvial deposits have the lowest susceptibility scores. The Kalibeng formation has low porosity and is impermeable to water, so it's hard when dry and will crumble (soft) when wet (Soedarsono, 2012). The vulnerability of landslides was determined based on the period of their formation. Old types of rocks (miocene) have the highest vulnerability. Meanwhile, young rock types (Pleistocene to Holocene) have the lowest vulnerability to landslides (Buchori & Susilo, 2012).

The lithology of sedimentary rock types (old age) has a fairly high vulnerability to the potential for landslides. The lithology of andesite and volcanic breccia types of igneous rocks has a moderate category of landslide vulnerability. The lithology of sand, clay, and cracal deposits (alluvium type) have a low vulnerability category (early age) (Yogiswara et al, 2020). The types of rocks found in Gunungpati District are (sedimentary rocks) including the kalibeng formation (Tmkb) and kerek formations (Tmk), (igneous rocks) including damar (Qtd) and jongkong (Qpj) formations, elephantmungkur volcanic rocks (Qhg) and kaligesik (Qpk), as well as the type (alluvium deposits) in the form of alluvial formations (Qa).

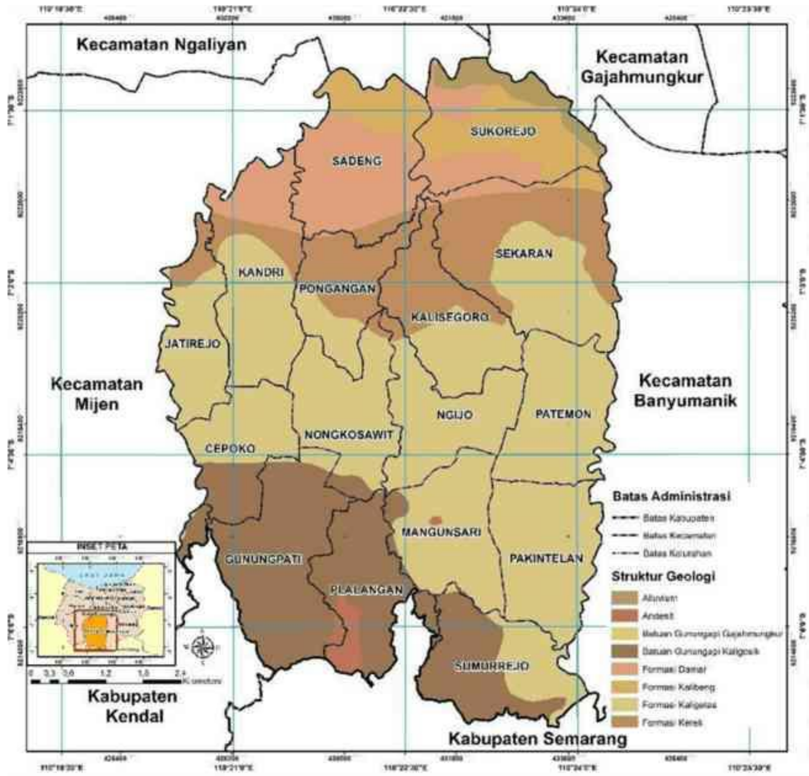


Figure 4. Gunungpati district geological formation map
Source: Semarang City Spatial Planning Office 2021.

**Soil Type**

Latosol and mediterranean soils are scattered in several locations in Gunungpati District. The highest landslide vulnerability score is on the mediterranean soil type and the lowest is on the latosol soil type. The type of soil in the northern part of the district is a mediterranean type that is included in the category of being somewhat sensitive to the process of erosion. Soil types in Gunungpati District are divided into three, namely: the brown latosol soil type, reddish brown latosol, and dark brown mediterranean. The brown latosol soil type has an area of 1,035 Ha, reddish brown latosol has an area of 3,484 Ha, and dark brown mediterranean has an area of 1,464 Ha. The dark chocolate mediterranean soil type is scattered in the north of the Kandri, Sadeng, Pongangan, Sekaran, Sukorejo, and a small part of Kalisegoro Subdistrict. The reddish-brown latosol type is in the central side of the subdistrict, and the chocolate latosol type is mostly in the southern region.

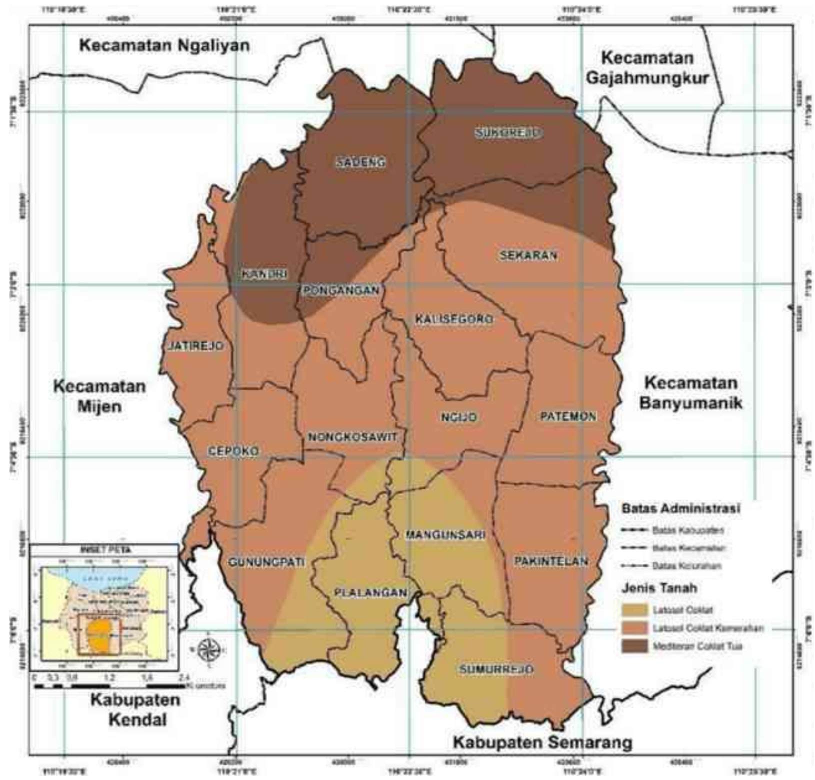


Figure 5. Gunungpati district soil type map
Source: Semarang City Spatial Planning Office 2021.

**Rainfall**

Proper quantification of rainfall variations caused by climate change in climate zone transitions remains a challenge (Panda et al, 2023). The higher the intensity of rainfall, the higher the potential for soil material landslides. The intensity of rainfall affects the ability to erode (destroy) the components of rainwater on the soil material within a certain time (Aji & Parman, 2015). Rainfall intensity in Gunungpati District is less than 2000 mm/year in each village. Rainfall in the area of Gunungpati District is known to be 100 - 200 mm per month. This value is equivalent to rainfall of < 2000 mm per year. Overall, the sub-districts have the same rainfall intensity in each village.

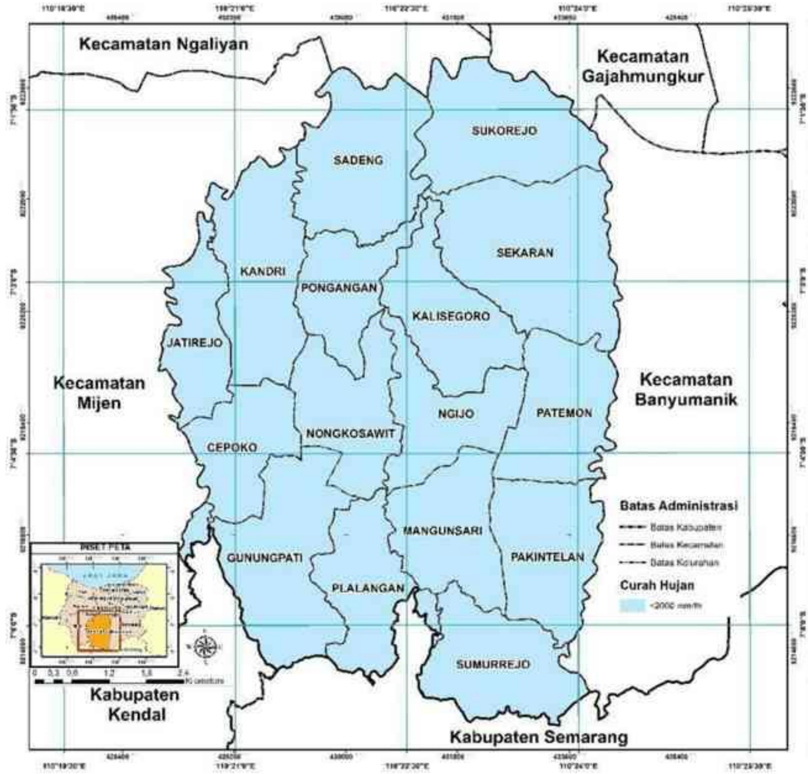


Figure 6. Gunungpati district rainfall map
Source: Semarang City Spatial Planning Office 2021.

**Land Use**

Land use is a form of land allocation function as a result of activities or interventions carried out by humans in utilizing the available land. Land use has a relationship with the land conversion aspect. In terms of development implementation, this is based on the community's need for land so that it has the opportunity to trigger the incompatibility of land-use functions (Khadiyanto, 2005; Eko & Rahayu, 2012). Gunungpati District has a type of land designation consisting of cultivated and protected areas. Cultivation areas include government functions, offices, sports, education, trade and services, agriculture, health, worship, transportation, housing, and tourism. Protected areas include areas around reservoirs and rivers. Reservoirs and rivers in the subdistrict are Jatibarang Reservoir, Garang, Kalikripik, and Creo Rivers.

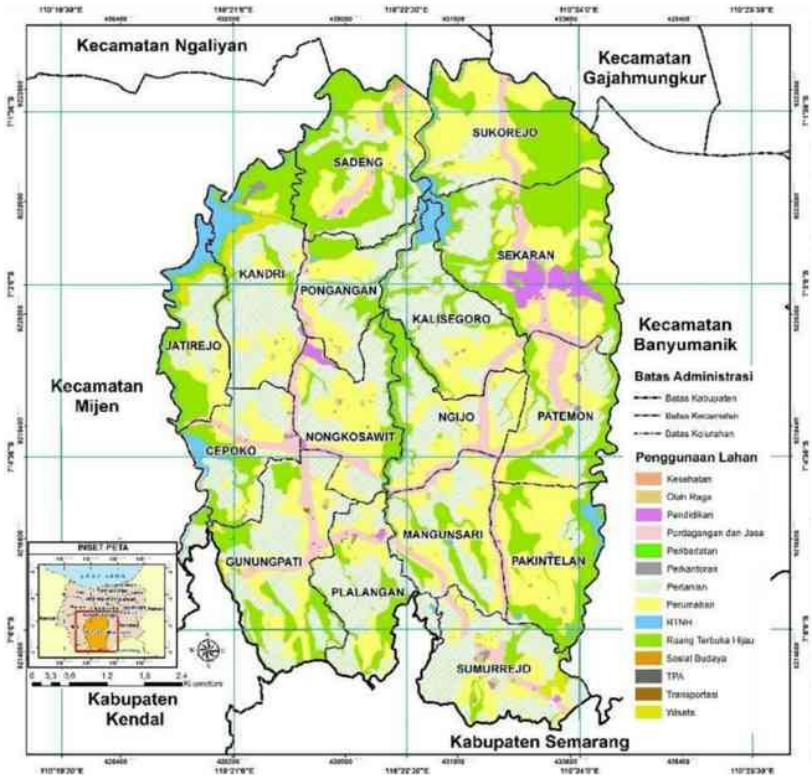


Figure 7. Gunungpati District land use map
Source: Semarang City Spatial Planning Office 2021 and Digitized Satellite Image in 2020.

From the results of the scoring & weighting analysis of the variables used, namely slope (%), ground motion zone, geology (rock lithology), soil type, rainfall, land use, and *overlay*, a map of landslide-prone locations is produced. Interval classes with high scores (vulnerable and very vulnerable) are mostly in Sukorejo, Sadeng, Sekaran, Ponngan, and Kalisegoro Villages. Details of the area of landslide vulnerability classes in Gunungpati District based on the results of class analysis are: very low (1,468.17 Ha), low (2,247.19 Ha), moderate (913.17 Ha), vulnerable (875.73 Ha), and very vulnerable with an area of (466.53 Ha).

The location of high to very high vulnerability is in the northern region of the subdistrict. It is based on the topographical conditions of the inclined plains but has the vulnerability of high-ground movement. Soil types are somewhat sensitive to erosion and are accompanied by geological conditions of rocks classified as vulnerable to potential landslides. Some other high-vulnerability locations are Cepoko, Patemon, Pakintelan, Nongkosawit, and Ngijo Villages. The existing condition of the land at this location has steep slopes with hilly morphology, so there is a high potential for landslides to occur.

The analysis results showed that Sukorejo, Sadeng, Pongangan, Kandri, Gunungpati, Mangunsari, and Kalisegoro subdistricts are on a high vulnerability land. This is evidenced by the occurrence of landslides in some settlements in the region. Land with vulnerable to very vulnerable to landslides should optimally be directed as non-built-up areas and designated as conservation lands. This is to minimize the potential for landslides that trigger degradation. Directions in determining the location of residential areas need to be allocated to areas that are not included in areas with a high vulnerability level to landslides.

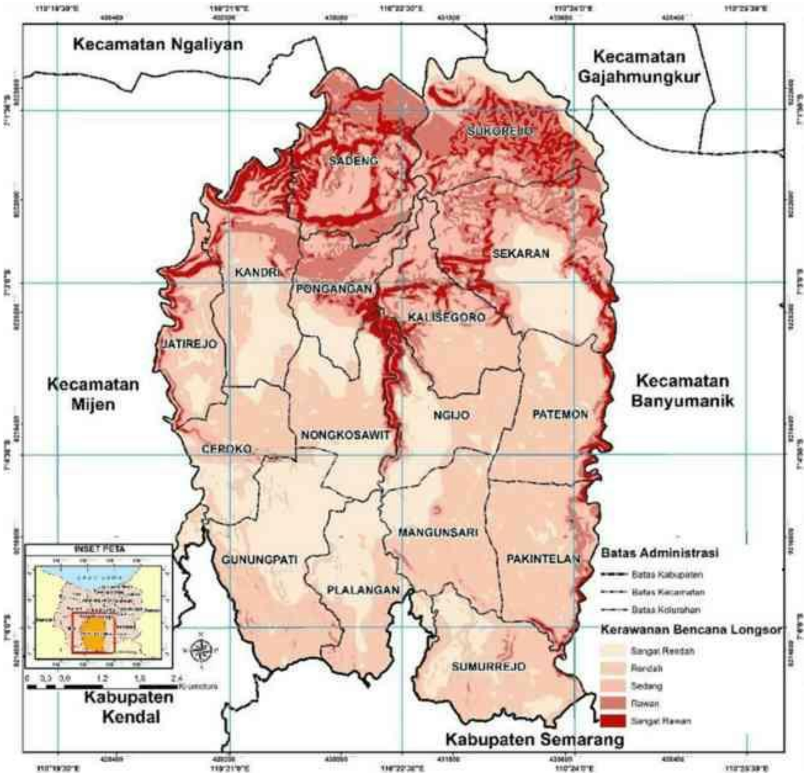


Figure 8. Gunungpati District landslide vulnerability map
Source: Author's analysis, 2021.

**Spatial Distribution of Area Functions**

The implementation of regional development needs to consider the physical condition of the region, including aspects of regional function. The regional functions are determined by reviewing the characteristics of the physical condition of the region, which includes variables such as slope tilt, soil type based on the level of erosion sensitivity, and classification of rainfall intensity. According to Huzaini and Rahayu in (Arifin et al, 2013) Gunungpati District has vegetation land that plays an essential role in Semarang City's ecosystem function, namely as a protected and buffer area in terms of its land criticality, as well as the function of vegetation land productivity in cultivation areas. Land zoning determination needs to take into account the provisions on the area function of (Dwisapta & Sri, 2013), including the provisions on protected areas that are designated to function as non-built-up areas and are directed not to carry out land-cultivation activities (*zero tillage*) in built-up areas (Nugraha, 2008).

The area function is determined using the scoring method. The scoring results of each variable are accumulated to produce the total score value. The calculation results show a score of 70-110 for the cultivation area and 125-165 for the buffer area. The delineation of protected areas is determined according to the criteria in the Government Regulation Number 47 of 1997 and the provisions in the Semarang City 2011-2031 RTRW. The following is the result of area function mapping.


Figure 9. Gunungpati District Map of Function
Source: Author's analysis, 2021.

Variables of a slope, soil type based on its level of vulnerability to erosion, and rainfall were mapped *overlaid* to obtain a wide distribution and classification based on the function of the area in Gunungpati District, namely: protected, buffer, and cultivation areas. The highest protected area is in Sekaran Village, with an area of 208.23 Ha. The lowest protected area is Pongangan Village, with 18.76 Ha. Villages in Gunungpati District have the highest buffer area in Sadeng Village, with an area of 117.1 Ha, and villages with the lowest buffer area are in Patemon Village, with 0.9 Ha.

Table 10. Function Area in Gunungpati District (Ha)

| Village | Area (Ha) | | |
|---|---|---|---|
| | Protected | Buffer | Cultivation |
| Gunungpati | 80.63 | 27.44 | **400.68** |
| Plalangan | 44.58 | 7.12 | 266.07 |
| Sumurejo | 35.06 | 17.73 | 314.72 |
| Pakintelan | 83.35 | 17.94 | 261.52 |
| Mangunsari | 43.98 | 10.86 | 283.19 |
| Patemon | 105.50 | 0.92 | 241.47 |
| Ngijo | 83.06 | 6.81 | 218.45 |
| Nongkosawit | 44.69 | 2.61 | 281.55 |
| Cepoko | 39.96 | 4.22 | 225.69 |
| Jatirejo | 86.41 | 5.04 | 153.45 |
| Kandri | 125.12 | 31.67 | 283.88 |
| Pongangan | 18.76 | 34.03 | 206.94 |
| Kalisegoro | 71.41 | 15.86 | 256.31 |
| Sekaran | **208.23** | 54.33 | 363.16 |
| Sadeng | 149.19 | **117.08** | 190.48 |
| Sukorejo | 149.72 | 87.32 | 314.72 |

Source: Author's analysis, 2021.

**Classification of Settlement Land Carrying Capacity Values**

In implementing the development of settlement areas, it is necessary to pay attention to two elements, namely: land carrying capacity and environmental carrying capacity. Land carrying capacity is the ability to support community activities based on land potential and its ability to accommodate residents (Ernamaiyanti, 2019)**.** The development of residential areas is determined by considering spatial aspects. This is able to have a significant impact on energy consumption, materials, resources, and environmental ecological functions (Siqueira et al, 2019) so that they are directed to realizing areas with (*built-up areas*). The center of human activity must be integrated and connected with the sustainability of green space (high-quality *green*). This is done to achieve a balance of resilient and sustainable areas in accordance with the *Sustainable Development Goals* on aspects of achieving *resilient and sustainable cities* (Shekhar et al, 2019).

Table 11. Carrying Capacity Area of Gunungpati District Settlement

| Village | Area (Ha) | | | |
|---|---|---|---|---|
| | Region | Protected Area | Disaster-Prone Areas (KRB) | Decent Land for Settlement |
| Gunungpati | 5.094.182 | 806.320 | 9.163 | 4.278.699 |
| Plalangan | 3.190.019 | 445.766 | 0 | 2.744.253 |
| Sumurejo | 3.683.340 | 350.633 | 107 | 3.332.600 |
| Pakintelan | 3.628.189 | 833.535 | 17.220 | 2.777.434 |
| Mangunsari | 3.380.370 | 439.823 | 0 | 2.940.547 |
| Patemon | 3.478.897 | 1.054.960 | 3.238 | 2.420.699 |
| Ngijo | 3.083.248 | 830.583 | 39.943 | 2.212.722 |
| Nongkosawit | 3.288.456 | 446.854 | 17.325 | 2.824.278 |
| Cepoko | 2.698.699 | 399.573 | 66.095 | 2.233.031 |
| Jatirejo | 2.448.972 | 864.061 | 68.857 | 1.516.055 |
| Kandri | 4.406.778 | 1.251.238 | 186.557 | 2.968.983 |
| Pongangan | 2.597.387 | 187.637 | 1.193.863 | 1.215.888 |
| Kalisegoro | 3.435.783 | 714.119 | 1.139.046 | 1.582.618 |
| Sekaran | 6.257.221 | 2.082.325 | 1.280.477 | 2.894.419 |
| Sadeng | 4.567.468 | 1.491.890 | 683.063 | 2.392.515 |
| Sukorejo | 4.510.470 | 1.497.225 | 866.292 | 2.146.953 |
| **Total** | **59.749.481** | **13.696.542** | **5.571.245** | **40.481.694** |

Source: Author's Analysis, 2021.

Based on the results of spatial data processing, this feasible land can be used for the development of residential areas. This aims to accommodate the increase in the number of residents residing in the area. Based on the amount of decent land area of settlements, Gunungpati Village has the highest area of 4.278.699 $m^2$ and the lowest area is in Pongangan Village, with a decent land area of 1.215.888 $m^2$. The calculation of the carrying capacity of residential land in Gunungpati District uses the variable population, the coefficient value of space requirements according to standards, as well as the area of land suitable for settlements in each village to produce a value for the carrying capacity of residential land.

Table 12. Carrying Capacity Value of Gunungpati District Settlements

| Village | Total Population | Land Suitable for Settlement ($m^2$) | DDPm Value |
|---|---|---|---|
| Gunungpati | 5.094.182 | 4.278.699 | 22.31 |
| Plalangan | 3.190.019 | 2.744.253 | 25.74 |
| Sumurejo | 3.683.340 | 3.332.600 | 19.26 |
| Pakintelan | 3.628.189 | 2.777.434 | 18.82 |
| Mangunsari | 3.380.370 | 2.940.547 | 20.81 |
| Patemon | 3.478.897 | 2.420.699 | 17.06 |
| Ngijo | 3.083.248 | 2.212.722 | 20.48 |
| Nongkosawit | 3.288.456 | 2.824.278 | 20.69 |
| Cepoko | 2.698.699 | 2.233.031 | 26.61 |
| Jatirejo | 2.448.972 | 1.516.055 | 26.91 |
| Kandri | 4.406.778 | 2.968.983 | 23.66 |
| Pongangan | 2.597.387 | 1.215.888 | 8.18 |
| Kalisegoro | 3.435.783 | 1.582.618 | 17.57 |
| Sekaran | 6.257.221 | 2.894.419 | 12.64 |
| Sadeng | 4.567.468 | 2.392.515 | 12.05 |
| Sukorejo | 4.510.470 | 2.146.953 | 5.73 |

Source: Author's Analysis, 2021.

Overall, Gunungpati Subdistrict has a DDPm value in each village >1 or is classified as able to accommodate the increase in the number of residents living in the area. The highest carrying capacity value of residential land is in Jatirejo Village. This shows the high ability of the region to accommodate an increase in the number of residents to settle, with a value of 26.9. In 2019, Sukorejo Village was the area with the lowest carrying capacity value in Gunungpati Subdistrict, which was 5.7.

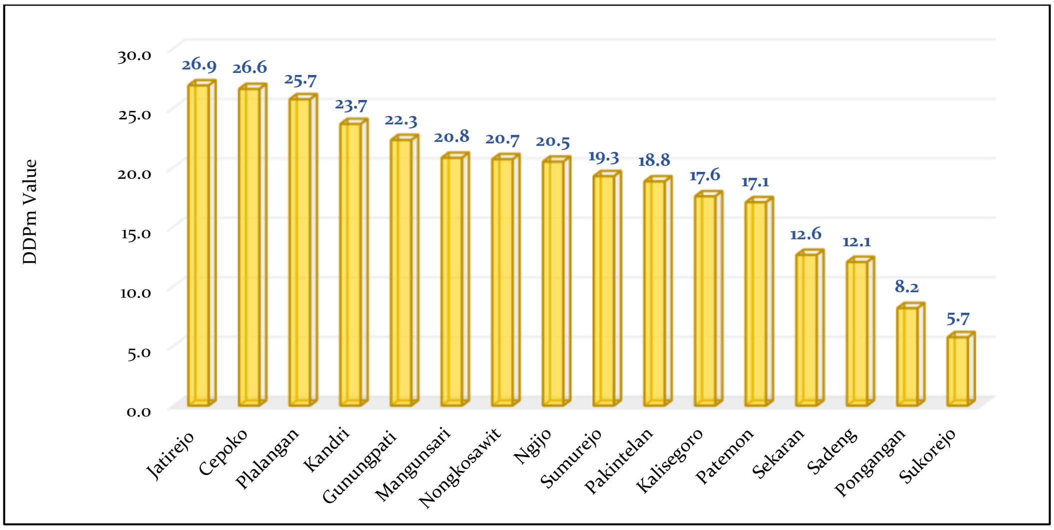


Figure 10. Carrying Capacity Graph of Gunungpati District settlements
Source: Author's analysis, 2021.

The results of this calculation indicate that the increase in population triggers the density of residential land, which is then followed by a decrease in the available land area and a decrease in the ability of the area to accommodate the increase in population to settle. The number of people who will continue to grow yearly is followed by an increase in the demand for residential land.

Calculation of the optimal population in each village is determined by multiplying the current population by the DDPm value so that the optimal population is obtained (the limit of the number of residents accommodated to achieve optimal conditions). The optimal number of residents mostly tends to still be able to accommodate settlers with a high enough number until the next few years. This is supported by the condition of land use built up in subdistricts that are classified as low and the availability of land in the category of suitable to be developed as settlements that tend to be quite high.

Table 13. Optimum Population of Gunungpati District

| Village | DDPm Value | JPO (person) |
|---|---|---|
| Gunungpati | 22.31 | **164.565** |
| Plalangan | 25.74 | 105.548 |
| Sumurejo | 19.26 | 128.177 |
| Pakintelan | 18.82 | 106.824 |
| Mangunsari | 20.81 | 113.098 |
| Patemon | 17.06 | 93.104 |
| Ngijo | 20.48 | 85.105 |
| Nongkosawit | 20.69 | 108.626 |
| Cepoko | 26.61 | 85.886 |
| Jatirejo | **26.91** | 58.310 |
| Kandri | 23.66 | 114.192 |
| Pongangan | 8.18 | 46.765 |
| Kalisegoro | 17.57 | 60.870 |
| Sekaran | 12.64 | 111.324 |
| Sadeng | 12.05 | 92.020 |
| Sukorejo | 5.73 | 82.575 |

Source: Author's Analysis, 2021.

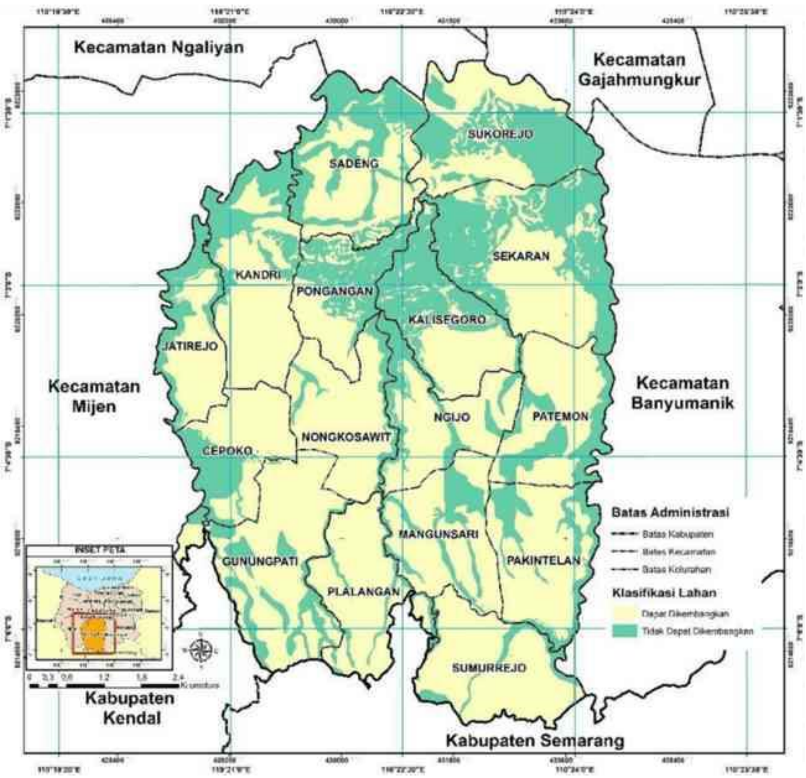


Figure 11. Gunungpati District Land Development Classification Map
Source: Author's Analysis, 2021.

The land classification in Gunungpati subdistrict is divided into two, namely land that can be developed and land that cannot be developed. The results of combining these parameters obtained output in the form of delineation of areas classified as able to be developed and cannot be developed for residential areas in Gunungpati District. The results of land distribution on the map show that land classified as unsuitable for development is widespread in the central and northern parts, including the Villages of Pongangan, Sukorejo, Kalisegoro, Sekaran, and Sadeng which are part of the landslide-prone zone. Other non-developable lands are located in the subdistrict border area. If it is adapted to the existing conditions, the land is included in a hilly area with steep slopes. Some of them are blue open spaces.

## CONCLUSION

The vulnerability of landslides in Gunungpati District has a high category of landslide vulnerability in the northern part of the district. The classification results are divided into five, including very low vulnerability with an area of 1,468.17 Ha, low 2,247.19 Ha, moderate with 913.17 Ha, vulnerable with 875.73 Ha, and very vulnerable with 466.53 Ha. The function of Gunungpati District area is distributed as follows: cultivation areas (4,161.58 Ha) and buffer zones (441.01 Ha), which can be used for the development of residential areas, and protected areas (1,369.65 Ha).

The carrying capacity of Gunungpati District settlements is calculated by taking into account the area of protected areas, disaster-prone areas, space requirements coefficient values, and population. The result is that all villages have a DDPm value of more than 1 (> 1), indicating the region's ability to accommodate residents until the next term.

Jatirejo Village has the highest DDPm value, with a value of 26.9 (high capacity). The lowest DPPm value is in Sukorejo Village, which is 5.7. This figure shows that the carrying capacity value is almost close to the maximum capacity of the population of 1 (one). Land that belongs to the category cannot be developed. This land can be found in the central and northern parts, which include Pongangan, Sukorejo, Kalisegoro, Sekaran, and Sadeng Village. This area is also included in the landslide-prone zone. With this condition, this area is not directed to be developed as a built area. The determination of residential areas should be directed to be developed in locations that are capable of being developed based on the physical condition of the land.

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