SPMS
Spatial Planning & Management Science
SPMS 2(1): 1–17
ISSN 3088-9669

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Evaluation of slope gradient suitability for rulal settlements and environmental quality (case study: slope gradien in Jembayan Tengah Village)

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Received Date: January 19, 2025 Revised Date: February 15, 2025 Accepted Date: February 28, 2025

ABSTRACT

Background: Furthermore, population growth gives rise to an increased demand for land with specific uses, such as housing. In particular, regions with a considerable degree of mining operations, such as Jembayan Tengah Village, are of significant concern. **Methods**: This research employs a quantitative methodology, utilizing techniques of land use digitization and overlaying land use maps with slope gradients obtained from DEMNAS data. **Findings:** The research findings indicate that the Jembayan Tengah Village area is characterised by a predominantly flat slope gradient, with an area of 867.12 hectares and a gradient of 0-8%. Furthermore, the settlement development pattern in Jembayan Tengah Village can be classified as unsafe, given that the majority of settlements are situated on slopes with gradients > 15% equating to 6,615 hectares of the total settlement area. **Conclusion**: The evidence suggests that the development of residential areas in Jembayan Tengah Village is associated with an increased risk of natural disasters and a reduction in the safety of the local population. **Novelty/Originality of this article:** Further research is required to gain a deeper understanding of the primary factors, beyond slope, that influence the suitability of agricultural land.

KEYWORDS: Central Jembayan; land suitability; slope gradient; land use; and settlement.

1. Introduction

Population growth is one of the main parameters or objects in improving the economy of a region. However, an increase in population that is not linear with economic improvement will cause a gap or damage to human resources (HR) and natural resources (SDA). Population growth and environmental problems are the main highlights in improving a country's economy. Population growth has a linear nature with environmental problems where, the higher the level of population growth, the higher the level of demand for housing and land. According to (Tesfaye et al., 2024) explains that land is an important natural resource that provides most human needs and sustains most human activities. Population growth also goes hand in hand with increased conversion of productive land and changes in land use characteristics into complex settlement systems. Rapid population growth in particular poses a major threat as efforts to meet demand damage the environment and exacerbate climate change, further challenging the sustainability of ecosystem services (Surya et al., 2020).

Population growth is also the main driving factor of land conversion and land use in an area. Rapid development and population growth can also affect land transformation or the

Cite This Article:
Firdaus, A. D. Z. (2025). Evaluation of slope gradient suitability for rulal settlements and environmental quality (case study: slope gradien in Jembayan Tengah Village). *Spatial Planning & Management Science, 2*(1), 1-17. https://doi.org/10.61511/spms.v2i1.2025.1737

increasing need for land for settlements and other regional functions. Based on research from (Christian et al., 2021) explains that the factors that influence the existence of transformation activities or land use change consist of physical, economic and cultural factors. These three factors are closely related in that social and cultural conditions in local communities influence land use patterns in an area due to population growth. However, land use change is also an indicator of successful development and progress of an area with certain parameters. Rapid population growth encourages the use and conversion of land into settlements, economic centers and other development facilities. The static surface of the earth is not linear with very static and rapid human growth and encourrages relatively rapid settlement development as a place to live. The higher the population, the greater the level of risk, stress, disaster and threat (Widya et al., 2024). According to (Tesfaye et al., 2024) explains that the continuous increase in human population poses a threat to natural resources by intensifying land cover and land use change to settlements over a period of time.

Land clearing or conversion is a form of exclusive use or directly changing the shape of the land surface into non-agriculture or settlement and can be referred to as land use that is negative to the environment (Setyaningsih et al., 2023). Land transformation or land use change has a significant influence on the sustainability of an ecosystem. In addition, land use change is also based on several factors, namely economic, social, cultural, natural conditions, politics and others. This statement is supported by research (Widya et al., 2024) explains that land conversion or land use change provides various reasons and backgrounds including socio-economic issues, community culture, landscape conditions, political policies and so on. Shifts in land use change play an important role in altering microclimates, biodiversity, ecosystem services, hydrological and ecological cycles, and earth's biotic processes that negatively impact socioeconomic elements and sustainable livelihoods. Land conversion and sub-optimal residential land use can have a greater impact on the sustainability of all sectors (Abd El-Hamid et al., 2020; Negash et al., 2023; Winkler et al., 2021).

Settlement is a built-up land area that has a function as a place to live to obtain a decent life and livelihood (Tiepolo & Galligari, 2021). Settlements are classified into urban and rural settlements based on their physical, environmental activity, economic and socio-cultural parameters. Rural settlements have more complex components and prioritize ecological or environmental aspects. However, the increase in population has a considerable influence on the evolution of rural settlements. According to (Chen et al., 2022a; Lu et al., 2020) explains that the development of rural residential areas will not affect the status of the area as intensive agriculture as a source of community livelihood for a long time. Production-related factors, such as distance from farmland, distance from pasture, distance from business center, farmland area, pasture area, and distance from water, have a significant influence on changes in rural residential areas (Zou et al., 2024). According to (Tiepolo & Galligari, 2021) explains that climate change, environmental degradation, settlement expansion, and poverty are the causes of environmental degradation. In addition, the expansion of rural settlement areas has a higher degradation rate ratio compared to urban settlements.

Rapid residential growth can cause development imbalances that are not in accordance with development parameters and standards. Ecological, economic and social factors are the main failures of rapid residential development. Based on research (Ardahanlioğlu et al., 2020; Li et al., 2022) explains that rapid settlement development leads to suboptimal physical planning and degradation of ecological, hydrological and topographical balances that include terrain fluctuations, hydrothermal and climatic conditions, hydrological cycles and characteristics of land use and vegetation cover that indirectly reflect these natural conditions. Proper planning of residential land suitability is a key parameter in minimizing ecological impacts. In addition, it is necessary to select the right parameters in planning the suitability of residential land.

Land suitability is an important tool for planners and policy makers to efficiently allocate land and minimize the adverse environmental impacts of urbanization, as well as

the corresponding impacts on ecosystem services (Ustaoglu & Aydınoglu, 2020). Increasing land use change or conversion and not based on good planning can have a serious impact on various types of land use. According to (Shrestha et al., 2022) stakeholders and land use-related policies adopted by public officials have not undergone adequate scrutiny. The identification of settlement land suitability is one of the important issues for planning perspective and is inevitable, land suitability assessment and priority areas are considered as prerequisites for land use planning and management, it is used to provide a picture of the suitability of a particular area for a particular land use and to estimate the potential of land for alternative land uses to reduce the negative impacts of sporadic rural settlement development (Karna et al., 2023a; Luan et al., 2021). The research (Chen et al., 2022a) explains that the main factors in the suitability of settlement land include the level of slope, altitude, distance from the river and others. Land suitability analysis considers all aspects to promote optimal development including physical aspects, disaster risk, public facilities, infrastructure and others. In addition, conventional planning and monitoring can affect the accuracy and efficiency of time and cost. Slope is a key parameter in planning sustainable settlement development. The incidence of rural poverty increases by 0.3-0.45% for every 1 m increase in terrain fluctuation, meaning that slope is a major factor in increasing poverty conditions in rural areas (Zhou et al., 2020).

Various approaches can be used in identifying settlement priority areas with a high level of effectiveness, efficiency and accuracy with certain considerations and parameters. A spatial approach based on GIS (Geographical Information System) is one method that can be used to map settlement priority areas with a high level of accuracy, easy interpretation and can estimate on a large or broad scale. In addition, GIS approaches can enable spatial projections based on general information. GIS is a digital database management system designed to manage large amounts of spatially distributed data collected from various sources. It is ideal for site selection studies because it efficiently stores, retrieves, analyzes, and displays information according to defined specifications. In addition, GIS can integrate complex site selection processes by also considering the large number of alternative solutions and evaluation criteria. (Y. Li et al., 2017; Sun et al., 2021).

Several studies have examined land use and change, especially in rural areas (Dibaba et al., 2020; Hailu et al., 2020; Maylany et al., 2022; Regasa et al., 2021a). Other studies have also analyzed the parameters that affect the spatial distribution of rural settlements (S. Chen et al., 2022a; Z. Chen et al., 2022a; Yang et al., 2022). Other researchers have also examined the relationship between slope and environmental quality (Afan, 2019; Hidayati, 2020; Zhang et al., 2021).

Kutai Kartanegara Regency is one of the regencies located in Kalimantan Province with a very high level of land conversion. The high rate of land conversion is caused by a very high population growth rate. Based on data from the East Kalimantan Central Bureau of Statistics (BPS), it is explained that Kutai Kartanegara Regency experienced a population growth rate of 2.14%. Population growth that is not based on optimal development can cause regional degradation in various aspects of ecology, topology and others. In addition, this also has an impact on settlement development that tends to be exploitative or does not pay attention to the capacity and carrying capacity of the environment. According to (Ramadhany, 2023) explained that East Kalimantan's deforestation rate in 2018-2019 amounted to 69,584.6 Ha caused by land conversion activities such as mining, plantations, settlements, infrastructure and agriculture. Most settlement development in East Kalimantan is not in accordance with development planning standards and does not pay attention to key aspects. Rural settlements tend to have dispersed patterns that tend to be more damaging to ecosystems or close to natural resources. The rapid development of settlements further pressures development around natural resources to improve the economy, especially in Jembayan Tengah Village, Kutai Kartanegara Regency. Based on the results of field observations, one of the villages with a level of settlement distribution that tends to be not optimal is Jembayan Tengah Village, Kutai Kertanegara Regency. Settlements tend to be concentrated in the RT 1 area and mostly spread in areas with slopes that tend to be >15%. This is not in accordance with the utilization and allocation of settlement areas.

In Law No.32 of 1990, the Ministry of Environment and Forestry states that slopes of >40% are designated as protected forest areas. Several researchers have also examined the evaluation of slope suitability for land use (Devara et al., 2023; Gafuraningtyas & Wibowo, 2023).

Based on the identification and analysis of these problems, this research aims to identify the structure of land use, the proportion of slope gradient, the spatial distribution of settlements and the impact on environmental quality. In addition, this research also evaluates the suitability of residential land, especially in Jembayan Tengah Village with the regional spatial plan document of Kutai Kartanegara Regency and the land use map of Jembayan Tengah Village based on the level of slope so as not to cause damage and land use that is not in accordance with its function The suitability of slope level is divided into 2, namely slope <15% is categorized as in accordance with development planning and slope >15% is categorized as not in accordance with development planning. In addition, this research can also provide insights for the relevant government to increase evaluation and the importance of integration with the community for optimal land use and in accordance with the standard regional spatial plan and or land use map.

2. Methods

The research method is a tool used to determine the direction of accurate decision making based on the level of suitability of residential land consisting of research time and location, data collection and data analysis. This research was conducted using quantitative approaches and quantitative methods. The use of these methods and approaches is based on the level of effectiveness, efficiency and absolute interpretation. This research was conducted in Jembayan Tengah Village, Loa Kulu District, Kutai Kartanegara Regency, East Kalimantan Province. Astronomically, Jembayan Tengah Village is located at 0.32500°S south latitude and 116.58055°E east longitude. Central Jembayan Village is directly adjacent to several villages and districts including the north bordering with Loh Sumber Village, the south with Jembayan Dalam Village, the west with Jahab Village and the east bordering with Jembayan Village. This research was conducted directly and divided into several stages, namely the data collection stage was carried out in July-August 2024 and data analysis was carried out in August-October 2024 Based on data from Loa Kulu District, Jembayan Tengah Village has an area of 2321.96 Ha with a fairly high population level. Based on the research (Priyandono & Lorensius, 2022a) explained that the total population of Jembayan Tengah Village is 1,964 people with a proportion of 957 men and 1,007 women. The high population in Jembayan Tengah Village is due to the high population growth rate in Kutai Kartanegara Regency. Based on data from BPS East Kalimantan, the population growth rate of Kutai Kartanegara Regency is 2.14%. The detailed research location can be seen in Figure 1.

This research consists of primary and secondary data. Primary data is data obtained based on direct observations in the field which includes coordinate data of business units, places of worship, agricultural land, offices, boundary pal, drone imagery and others. Secondary data is data obtained from supporting documents originating from related companies or governments which include village boundary data, satellite images, demnas and others. The main data in this study is data on the slope level of Jembayan Tengah Village using DEMNAS data. National Digitation Elevation Model (DEMNAS) is a raster data that contains slope and elevation information and is built based on several data sources. The National DEM is built from several data sources including IFSAR (5m resolution), TERRASAR-X (5m resampling resolution from the original resolution of 5-10 m) and ALOS PALSAR (11.25 m resolution), by adding mass point data used in the creation of the Indonesian Rupabumi map (RBI). The spatial resolution of DEMNAS is 0.27-arcsecond, using the EGM2008 vertical datum. In addition, the main data in this study is a land use map of Jemabayan Tengah Village obtained based on the results of drone image digitization.

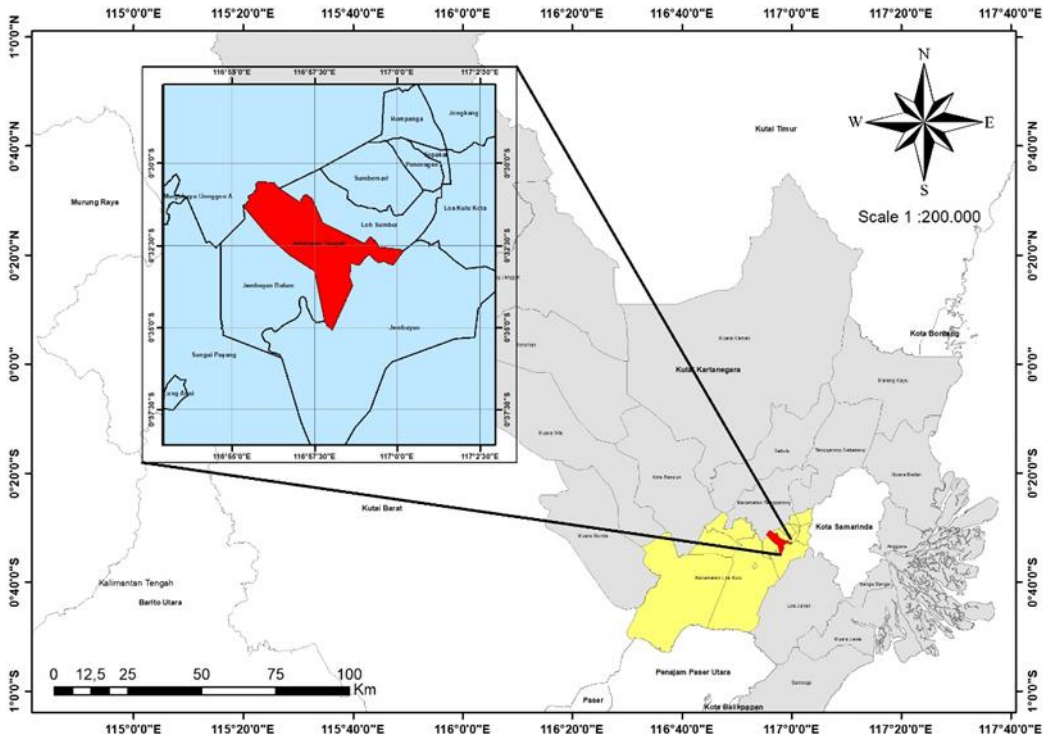

Fig. 1. Research location

2.1 Data analysis

Data analysis in this research consists of 2 stages, namely land use map analysis and slope suitability analysis based on land use map. The analysis has significant parameters and differences where the land use map is only focused on natural resources and land use area while the slope suitability is based on the percentage of settlement area that is suitable for the existing land use map.

2.1.1 Land use distribution analysis

Land use is the utilization of natural resources based on the capacity and carrying capacity of the environment. Land use is a historically complex system formed by natural elements such as geology, landforms, climate, hydrology, soils, and vegetation, as well as human activities in a particular area (Regasa et al., 2021b). Land use is an important part of society because it can increase economic resources derived from existing natural resources. However, human activities that tend to be exploitative can have a negative impact on society, biodiversity and ecosystem sustainability. Land use mapping aims to provide an overview related to optimal land use planning to maximize economic and ecological value in the future. Land use map analysis is carried out based on the results of drone image digitization. Digitation is a representation of the shape in the field into point, polyline and polygon shapes. Point shapes include coordinate points of facilities and infrastructure, polyline shapes of rivers, roads and others while polygons include built-up land forms such as settlements, offices and others.

2.1.2 Slope settlement analysis

Slope is a topographic condition on the earth's surface. Slope analysis is processed using overlay techniques or combining slope data and land use maps of Jembayan Tengah Village using ArcGis 10.8.2 software. The level of slope is divided into 4 classes based on the function and designation of a land. Based on the Regulation of the Minister of Public Works No.41, it explains that the slope level is divided into 5 classes, namely 0-8% including in the

flat category, 8-15% sloping, 15-25% rather steep, 25-40% steep and >40% very steep. In this research, the slope level of <15% is categorized as suitable for residential use and the slope of >15% is not suitable for residential use. Gradients >15% are not suitable for settlement (Hidayati, 2020). Some tools used in slope analysis are overlay, clip and clip by mask in ArcGis 10.8.1 software.

3. Results and Discussion

3.1 Landuse analysis

Land use is a management or utilization of natural resources by humans and their habitats to improve the economy by putting pressure on nature. In research (Regasa et al., 2021a) explains that land use is a historical complex system formed by natural elements such as geology, landforms, climate, hydrology, soil, and vegetation, as well as human activities in a particular area. Along with the increase and development of economic and social society, diversification of utilization becomes one of the parameters of suboptimal land use. There are differences in land use and change at various levels of region or area which are caused by differences in human activity, topology and other distinguishing factors. Jembayan Tengah is one of the villages that has high and strategic natural resources in development to improve the economy. The following classification of land use maps in Jembayan Tengah Village based on the results of direct observation in the field can be seen in Figure 2.

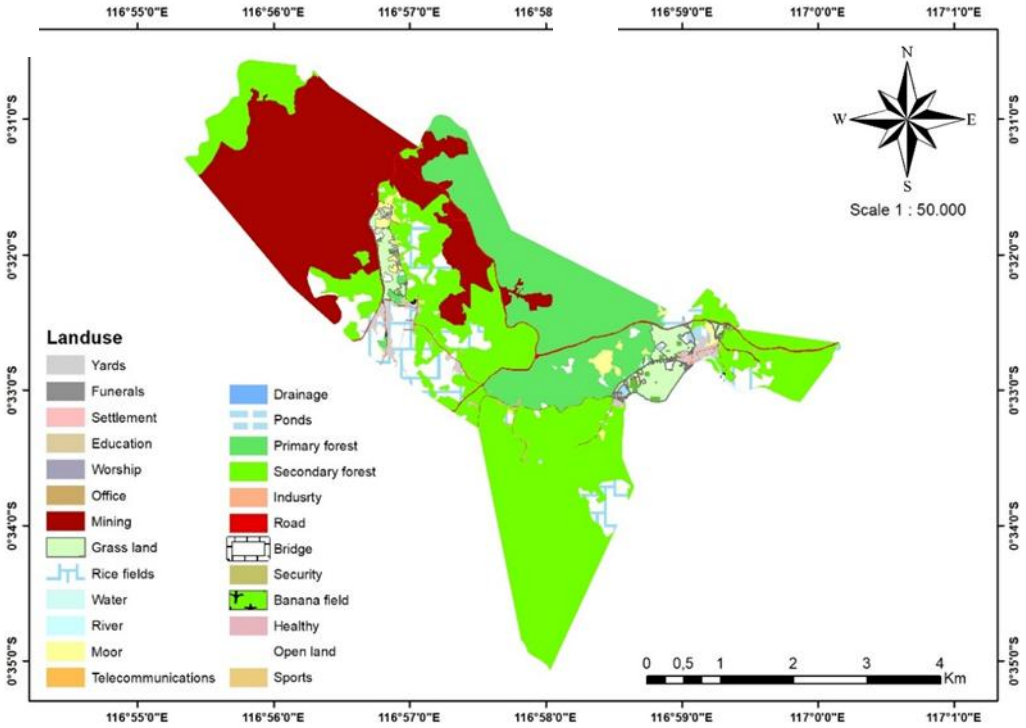

Fig. 2. Distribution of slope gradient class

Based on Figure 2, it explains that Jembayan Tengah Village is dominated by land use in the form of mining, secondary land forest, primary land forest and others. The heterogeneity of land use means that Jembayan Tengah Village has a high level of natural resources and potential for sustainable development. Based on geographical conditions, Jembayan Tengah Village has enormous potential for sustainable economic improvement such as the development of water tourism, fisheries centers, campgrounds, agro-tourism and others (Priyandono & Lorensius, 2022b). The following proportion of land use in Jembayan Tengah Village can be seen in Table 1.

Table 1. Landuse

No	Landuse	Area (Ha)
1	Drainage	0.550
2	Ponds	8.219
3	Primary forest	420.524
4	Secondary forest	910.756
5	Road	2.955
6	Road	24.974
7	Bridge	0.010
8	Security	0.006
9	Banan field	0.346
10	Healthy	0.047
11	Open land	34.508
12	Sports	0.024
13	Yards	25.263
14	Funerals	0.178
15	Settlement	8.294
16	Education	0.464
17	Worship	0.400
18	Office	0.225
19	Mining	613.379
20	Grass land	77.347
21	Rice fields	162.790
22	Water	0.000
23	River	3.180
24	Moor	24.984
25	Telecommunication	0.026
26	Business unit	2.508

Table 1 illustrates that Jemayan Tengah Village is predominantly characterised by primary and secondary dry forests, rain-fed rice fields and mining activities. The majority of primary forests in Jembayan Tengah Village are classified as critical and can be categorized as secondary dry forests. This is attributable to the dearth of community awareness concerning sustainable forest management and utilization strategies that could enhance the community's economic standing. Additionally, the degradation and deforestation observed in Jembayan Tengah Village can be attributed to the encroachment of mining activities on previously undeveloped land. According to the available data, the area designated for mining activities encompasses 613.38 hectares. A review of the available evidence suggests that zone 9 in Jembayan Tengah is the only zone that has been significantly impacted by mining activities. These impacts include social inequality, a lack of water resources, and pollution resulting from mining operations.

In research (Worlanyo & Jiangfeng, 2021) the adverse effects of mining include the loss of vegetation cover, the mass destruction of water bodies, the decline of biodiversity, land use change, and food insecurity. Additionally, increased social crime and conflict, elevated living costs, and air pollution are also consequences of mining operations. Furthermore, it can be observed that the concept of residential development in Jembayan Tengah Village is dispersed throughout the village, with the exception of the zone 8 area, where it is more concentrated. The distribution of residential development is a consequence of the orientation of the land, whereby areas of higher slope gradient are characterised by a greater abundance of natural resources, which can be attributed to the absence of population density in these areas. This is expressed in the study (S. Chen et al., 2022a) which explains that the distribution of rural settlements is due to an increase in natural resource wealth along with an increase in slope.

3.2 Slope gradien classification

Slope is defined as the inclination of the earth's surface between two points, where there is a difference or similarity in surface height. Slope is a fundamental parameter in the planning of residential developments. The slope is derived from the digital elevation model and subsequently evaluated in the classification of topographic parameters (Çellek, 2020). The slope gradient is a frequently utilized indicator by other researchers to ascertain the suitability of land use, including but not limited to settlement and agriculture. The suitability level of slope gradient is generally classified based on the condition and purpose of the utilization of slope gradient. In accordance with PERMEN PU No. 41/PRT/M/2007, which outlines the technical criteria for cultivating protected areas, and KEPPRES No. 32 of 1990, which addresses the management of protected forest areas, it is stipulated that the In Indonesia, slope class is classified into five categories, as follows: 0-8% is categorized as flat, 8-15% is sloping, 15-25% is steep, 25-40% is rather steep, and >40% is very steep. The distribution of slope gradient classes in Jembayan Tengah Village is illustrated in Figure 3.

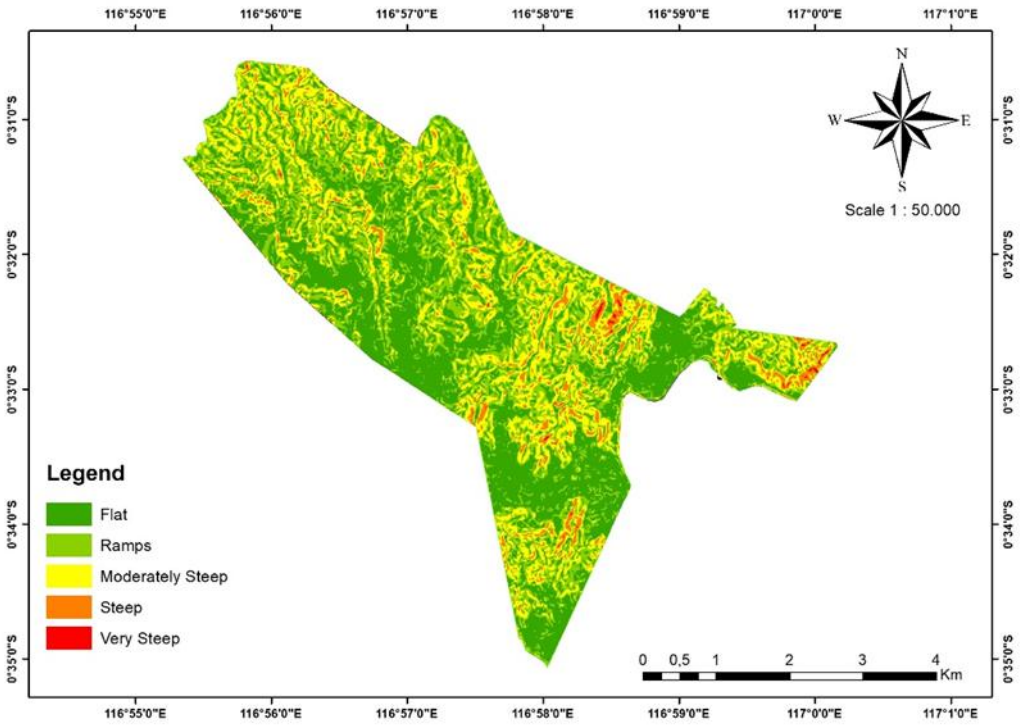

Fig. 3. Distribution of slope gradien class

Figure 3 illustrates that the topography of Jambayan Tengah village is predominantly characterised by flat and gentle slopes, indicating a high suitability for residential development. The slope gradient is a key factor in determining the influence of the force on the movement of objects. This component of the gravitational force is responsible for ensuring the sliding of slopes and certain objects. The results of the analysis of the distribution of slope gradient classes based on the area of each class are presented in Table 2.

Table 2. Distribution of slope gradien class

	Slope class	Slope	Tabel Area (Ha)
1	Flat	0-8%	867,12
2	Ramps	8-15%	762,34
3	Moderately steep	15-25%	556,13
4	Steep	25-40%	109,68
5	Very steep	>40%	4,26

The village of Jembayan Tengah is predominantly comprised of land with a gentle slope gradient, encompassing 867.12 hectares of the total area. Conversely, 4.26 hectares are classified as having a very steep slope gradient. The distinction between each class reflects the varying types of land use or utilization, indicating that approximately 2,185.59 hectares of the area are highly suitable for residential development. The slope gradient has the potential to influence the level of land suitability, which is evaluated based on the characteristics in question (Hadi et al., 2023).

The stability of slopes with steep gradients, particularly those altered by human activity, is inherently low, making them unsuitable for residential land use. There is a direct correlation between slope gradient and environmental risk, as areas with higher gradients tend to experience increased surface runoff and water flow, heightening the likelihood of natural disasters such as landslides. Furthermore, the slope gradient significantly affects environmental quality, influencing both air and water conditions in the surrounding area. Land use decisions are thus heavily shaped by slope classification, as outlined in the 2007 Regulation of the Minister of Public Works No. 41/PRT/M/2007 on technical land cultivation criteria and the 1990 Presidential Decree No. 32 concerning protected forest area management. These regulations highlight that flat to moderately sloped areas are most suitable for residential development. In contrast, areas with slopes exceeding 40% are typically designated as forested or protected zones due to their ecological sensitivity. Land with a slope gradient between 25–40% may be considered for settlement, but only following a thorough investigation of the potential environmental and social impacts such development might entail.

The slope gradient represents a fundamental aspect of settlement development planning, as it serves as the foundation for the assessment of potential ecological impacts and the prediction of natural disasters associated with slope gradient. Other studies have similarly demonstrated the pivotal role of slope in the evaluation of suitable locations for sustainable settlements. For instance, (Aini et al., 2022) delineated the critical parameters influencing the distribution of rural settlements, while (Karna et al., 2023b) conducted a comprehensive land suitability analysis of rural settlements in Nepal. Moreover, other studies have demonstrated the impact of slope on the distribution of rural settlements (Zou et al., 2024), the spatial evolution parameters of rural settlemen (Ji et al., 2022a) and distribution of rulal setllement based on natural factors and traffic accessibility (Z. Chen et al., 2022b).

3.3 *A critical examination of the suitability of slope gradients for landuse*

The analysis of the distribution of slope gradient suitability is a concept that can be used to evaluate related to optimal settlements and has a small level of disaster risk. It is considered the main parameter of the level of suitability of residential land. In this study, the main variable of focus is slope gradient, as the results of observation indicate that there are still some settlements that are built in areas with certain slope gradients and distributed inefficiently. The following is a breakdown of the distribution of settlements in Jembayan Tengah Village, delineated by zone region.

Figure 4 illustrates that the distribution of settlements in Jembayan Tengah Village is random and suboptimal. The data indicate a tendency for settlements to be concentrated in the zone 8 area. In contrast, zone 4 and other regions exhibit a tendency towards a less dense level of settlement. This is due to the fact that the majority of individuals are aware of the consequences of mining operations and the proximity to economic or urban areas. Furthermore, accessibility is a crucial aspect of optimal rural settlement development. The greater the ease of access to rural settlements from economic or urban centers, the more effective and efficient the spatial pattern of rural settlements will be. Additionally, another statement posits that the distribution of rural settlements is contingent upon a multitude of socio-economic factors, including the proximity to medical facilities, educational institutions, and major transportation route (Zou et al., 2024). Nevertheless, this is at odds with the claim that the dispersion of rural settlements has a negligible impact on the

accessibility and proximity to economic and urban centers, particularly in regions with a low economic status (Ji et al., 2022a). A number of studies have been conducted to examine the parameters that affect the distribution of rural settlements. These include an investigation of the topographic distribution and accessibility of such settlements (Z. Chen et al., 2022b), This study examines the distribution patterns and drivers of spatial distribution of rural settlement (Tian et al., 2014). Furthermore, another statement elucidated that the greater the distance between a settlement and a main road or economic center, the lower the settlement density will be. Conversely, the closer a settlement is to a main road or economic center, the higher the settlement density will be (S. Chen et al., 2022b).

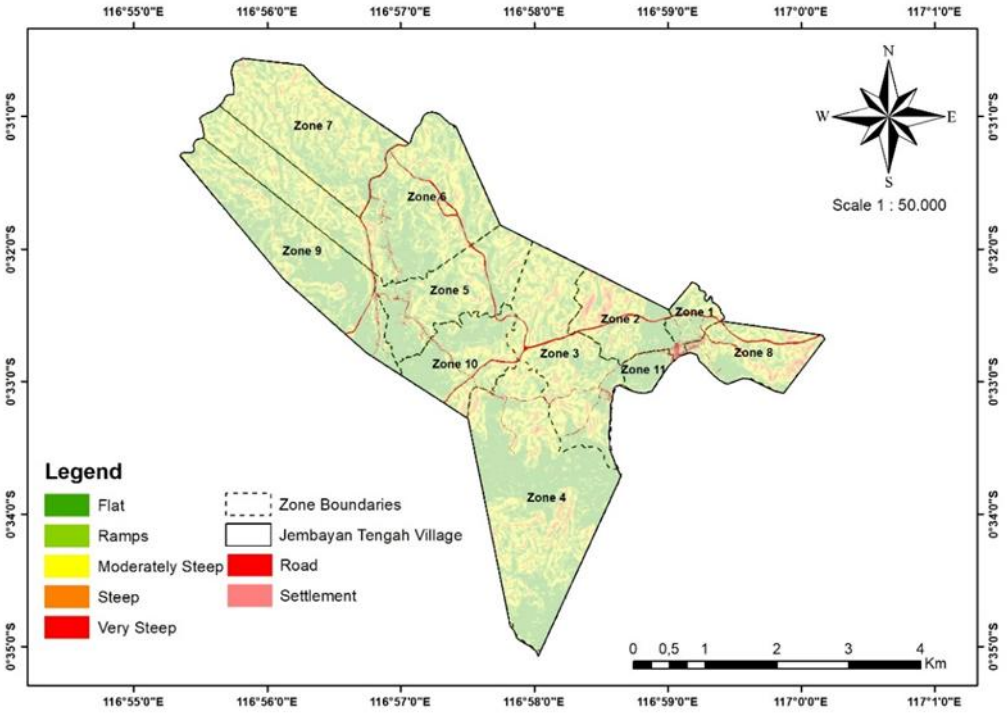

Fig. 4. Overlay distribution of rulal settlement and slope gradien class

Furthermore, the proximity to mining activities is associated with an increased risk of poor settlement quality, pollution, and other adverse effects that can compromise the health and sustainability of the settlement itself. The majority of mining activities are situated in zone 6, zone 9, and zone 7, with the terrain exhibiting moderately steep (15-25%) and steep (25-40%) slope gradients. It is thus imperative to assess the suitability of slope gradients for residential development in order to mitigate the risk of disasters.

The suitability of Gadient is evaluated based on a specific class level. In this study, the slope class with a percentage of less than 15% is identified as the most suitable class or appropriate for residential land use. As evidenced by research conducted by (Hidayati, 2020; Zhang et al., 2021), a reduction in slope gradient correlates with a decline in surface runoff and an increase in erosion rate. This suggests that a reduction in slope gradient is conducive to land use for settlement purposes. In other words, a slope gradient of less than 15% is optimal for settlement. Other studies have also examined the optimization of rural settlement distribution at various slope levels, including those below 5° (S. Chen et al., 2022b) and below 15° (Yang et al., 2022). The data indicates that a reduction in slope gradient is associated with a diminished risk of natural disasters. The following section presents the findings of the analysis conducted to assess the suitability of the terrain in Jembayan Tengah Village for the establishment of settlements.

Table 3. Illustrates the unsuitability of settlements with a slope gradient exceeding 15%

No	Zone	Area (Ha)
1	Zone 1	0,172
2	Zone 2	0,074
3	Zone 3	0,826
4	Zone 4	1,732
5	Zone 5	1,312
6	Zone 6	0,378
7	Zone 7	0
8	Zone 8	1,528
9	Zone 9	0,345
10	Zone 10	0,248
11	Zone 11	0

This analysis employs data from the DEMNAS system, which has been overlaid with the 2024 land use map. This research demonstrates that the majority of settlements in Jembayan Tengah Village have not met the criteria for settlement development. Specifically, approximately 20.24% of settlements align with the slope level <15%, while 79.76% of settlements are situated on slope gradients above >15%. The distribution of rural settlements is also contingent upon the proximity to the river. Zone 8 is situated in close proximity to the river, reflecting a high level of fertility and natural resources. The distribution of non-optimal rural settlements is predominantly observed in zone 4, zone 5, and zone 8. The zone 8 area is characterized by a relatively high level of urbanization, as evidenced by the presence of residential developments comparable to those observed in zone 1, zone 2, and zone 3. The proposed rural residential development in RT 8 is constrained by accessibility and proximity considerations. The distance to the river is approximately 500 meters, which presents a significant barrier to development. The proximity to the river exerts a significant influence on the high fertility and natural resources, as evidenced by zone 8 being the epicenter of agricultural activities. This is further corroborated by the assertion that settlement development is profoundly shaped by the presence of water sources and rivers, which are regarded as an area endowed with an abundance of natural resources and conducive to agricultural pursuits (S. Chen et al., 2022b; Z. Chen et al., 2022b). The implementation of settlement development schemes in proximity to river systems offers a dual benefit the provision of irrigation infrastructure and the maintenance of ecosystem stability (Forleo et al., 2017). The spatial distribution pattern of rural settlements is largely determined by the availability of water sources, particularly rivers, and the proximity to these resources.(Feng et al., 2021a). Furthermore, the integration of human well-being and natural resources is a fundamental aspect of rural settlement planning (Z. Chen et al., 2022b).

However, the distribution of settlements in riverine or riparian areas can also affect the sustainability and ecosystem of the river. This is due to the impact of land conversion activities, such as the expansion of intensive agriculture, the disposal of waste, and the encroachment of forests around the river. These activities are often driven by the high level of poverty in rural areas. As evidenced by the findings of other researchers, climate change, environmental degradation, settlement expansion, and poverty are the primary drivers of environmental degradation. Furthermore, the expansion of rural settlements exhibits a higher ratio of degradation rates compared to urban settlements (Tiepolo & Galligari, 2021). Furthermore, the evolution of land settlement and intensification of agriculture have the potential to exacerbate the degradation of the hydrological cycle within the river basin, resulting in increased erosion rates and other detrimental effects. Human activities in river areas exert considerable pressure on the natural environment, with adverse effects on the quality of the surrounding ecosystem. One notable consequence is the reduction in the extent of swamp forests and wetlands, which has occurred as a result of changes in land use, including the conversion of these areas into settlements and the fulfillment of human needs (Regasa et al., 2021a).

The fragmentation of social conditions is also an indicator of the distribution of rural settlements. zone 4 and zone 5 are among the locations exhibiting a markedly elevated degree of social fragmentation, which exerts a considerable influence on the dispersion of rural settlements that are suboptimal in nature. This is exemplified by the presence of residential land holdings that deviate from the established standard slope gradient, amounting to approximately 3.4 hectares. zone 4 is predominantly populated by individuals belonging to the Madhura ethnic group, whereas zone 5 is primarily inhabited by those who identify as Bugis or hail from the Sulawesi region. Furthermore, this fragmentation impacts the scale of activities and land use change, with the majority of zone 5 encompassing agricultural activities. The primary objective of zone 4 is to facilitate the utilisation of land as a hub for small- to medium-scale industrial activities.

In addition to geographical and geological factors, the social and economic conditions of rural communities are significant determinants of the distribution of rural settlements. Some studies also posit that rural settlements are the consequence of a robust interpenetration between the natural environment and human society, encompassing socio-economic elements (S. Chen et al., 2022b). Moreover, another statement posits that the integration and differentiation of people and land result in socio-economic development becoming an important factor affecting the evolution of rural settlements (Ji et al., 2022b). Moreover, social fragmentation serves as a key explanatory factor for the genesis of the community's economic activities. The majority of zone 4 is closely related to land change and use, with the primary economic resources deriving from agricultural activities such as rice fields and others. In contrast, the economic resources of the community in zone 5, which is predominantly Bugis, originate from small to medium-sized businesses or laying hens. In general, zone 4 exhibits a higher level of land degradation than zone 5. Additional research indicates that the diversity of natural resources and the environment serves as an indicator of variations in land use and evolution (Ji et al., 2022b).

Furthermore, this finding aligns with another statement that correlates the extent of residential land per capita with the socio-economic activities of rural communities. This researcher posited that as the area of rural residential land per capita increases, the agricultural activities within that area tend to diminish (S. Chen et al., 2022b). This is illustrated by zone 4, which demonstrates that the area of rural settlements in zone 4 is more expansive than zone 5, exhibiting a diminished level of environmental damage in comparison to zone 5. This is also attributable to the dearth of agricultural activity or land conversion in the zone 4 area. However, this is at odds with the assertion that an increase in rural settlement density and area scale can enhance the local economy through the promotion of higher agricultural activity (S. Chen et al., 2022b). Furthermore, zone 5 is distinguished by its greater distance or access to urban areas relative to other regions, which has an impact on the evolution of settlements that tend to be centered around the main road. This is corroborated by the assertion that the distance to a highway influences the evolution and distribution of rural settlements (Gosch et al., 2021), and that it is the primary driving force behind the spatial expansion of modern rural settlements (Feng et al., 2021b). Consequently, the anthropogenic pressure of infrastructure construction and development can be employed as a foundation for spatial evolution and distribution in the medium and long term. It is therefore evident that the consideration of geographical, socio-economic, and stakeholder factors represents a crucial aspect of sustainable rural settlement development planning. Furthermore, it can facilitate a comprehensive understanding of the integration of communities and policymakers, thereby enabling the achievement of an optimal balance.

4. Conclusions

Spatial planning or land use in Jembayan Tengah Village is predominantly characterized by primary, secondary, and mining forests, with respective areas of 420.52 hectares, 910.757 hectares, and 613.38 hectares, respectively. Settlements, which encompass an area of 8 hectares, are dispersed and extend over a considerable expanse.

This distribution is based on the level of forest natural resources. Notably, mining constitutes the second-largest land use category, underscoring the substantial natural resource abundance in Jembayan Tengah Village. However, the ongoing mining activities have been observed to inflict considerable damage to the forest ecosystem, thereby impeding the progress of settlement development. Slope is a critical parameter in assessing and evaluating the level of land suitability for settlements, thereby underscoring its substantial influence on environmental sustainability in rural areas. The settlement development patterns that have emerged are characterized by a notable lack of safety, with the majority of settlements situated on slopes with gradients greater than 15% or encompassing 6,615 hectares of the total settlement area. This phenomenon can be attributed to various natural factors, including geographical and socio-economic conditions of the community. This phenomenon has a detrimental effect on the sustainability of the ecosystem. This phenomenon underscores a conspicuous absence of harmonious collaboration between the government and the community in the process of settlement development. Consequently, the evaluation, monitoring, and disaster mitigation related to settlement development in Jembayan Tengah Village must be accorded a high level of priority.

Acknowledgement
The author would like to express their sincere gratitude to everyone who provided support and contributed, directly or indirectly, to the completion of this article.

Author Contribution
The author solely contributed to the study's conception, design, data collection, analysis, and manuscript preparation. The author was responsible for drafting, reviewing, and approving the final version of the manuscript for publication.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available

Conflicts of Interest
The author declare no conflict of interest.

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