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Spatial Analysis of Population Pressure and Agricultural Land Carrying Capacity in Slawi District, Tegal Regency

Fandi Maulana Akhmad[1], M. Fikri Amrullah[1]

[1] *Department of Geography, Semarang State University, Sekaran, Gunungpati, Semarang, Central Java 50229, Indonesia*

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Corresponding author:
Fandi Maulana Akhmad
Email:
fandimaulana@students.unnes.ac.id

ABSTRACT

Population growth and rising demand for housing have accelerated agricultural land conversion in the Slawi District, Tegal Regency, raising concerns about the capacity of available land to support the local population. This study aimed to analyze the spatial patterns of population pressure and the carrying capacity of agricultural land at the village level in the Slawi District. A quantitative approach was employed using the Soemarwoto (1985) Model II framework to calculate the population pressure index (TP) and agricultural land carrying capacity (DDLP). Secondary data were obtained from the Agriculture, Fisheries, and Forestry Extension Center, the Food Security and Agriculture Service, and the Central Bureau of Statistics. The data were quantitatively processed and spatially mapped using GIS to identify variations among villages. The results show that the Slawi District experiences high population pressure, indicated by a TP value of 1.21 people/ha, while its agricultural land carrying capacity is classified as low, with a DDLP value of 0.83. At the village level, areas with higher population pressure generally show lower agricultural land carrying capacity, indicating an inverse relationship between the two indicators. These findings demonstrate that the distribution of land resource capacity in the Slawi District is spatially uneven, and that several villages are under greater pressure than others. The study concludes that strengthening land-use control and protecting sustainable agricultural land are important to reduce the risk of continued land conversion and declining land support capacity.

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1. INTRODUCTION

Population growth and land use change have become major concerns in regional development because they directly affect the sustainability of agricultural resources and local food systems. In rapidly developing areas, increasing demand for housing, infrastructure, trade, and services often accelerates the conversion of agricultural land into built-up land. This process can reduce the capacity of agricultural land to support the population that depends on it and may weaken long-term food security. In this study, population pressure refers to the extent to which the demand of the population exceeds the support capacity of available agricultural land, whereas agricultural land carrying capacity refers to the ability of agricultural land to sustain livelihoods and food needs within a given area. Understanding the relationship between these two concepts is important for evaluating whether land resources remain sufficient under ongoing population growth and spatial development (Ariani & Susilo, 2022; Dian et al., 2023; Ardyanita et al., 2023).

This issue is highly relevant in the Slawi District, Tegal Regency, which functions as the administrative center and one of the main economic activity areas in the regency. The district has experienced substantial population growth and increasing development pressure in recent years. Based on data from the Central Bureau of Statistics, the population of Slawi District increased by approximately 12,492 people between 2015 and 2025. In addition, data from the Food Security and Agriculture Service show that the total reduction in rice field area in Tegal Regency reached 1,208 ha during 2012–2022, with 217 ha of this decline occurring in Slawi District, equivalent to approximately 17.96% of the regency-wide reduction. These figures indicate that the Slawi District is facing considerable pressure on agricultural land as development expands for housing, public facilities, trade, and services (Rakuasa & Achmadi, 2024).

Previous studies have shown that population pressure is closely associated with agricultural land carrying capacity. Rachmansyah et al. (2022) reported that higher population pressure was followed by lower agricultural land carrying capacity, although their study focused only on dryland rice farming. Imansyah et al. (2020) also found that increasing population pressure reduced the ability of agricultural land to support food production; however, their study was limited to the village scale and used a different analytical framework. Other studies have discussed agricultural land carrying capacity and land conversion in different regional settings, confirming that growing population demand and shrinking agricultural land tend to reduce land support capacity (Talumingan & Jocom, 2017; Giwangkoro et al., 2023). These studies provide an important basis; however, they do not sufficiently explain how population pressure and agricultural land carrying capacity vary spatially among villages within a rapidly developing district center.

Therefore, the research gap in this study is not merely the absence of map visualization but the limited empirical understanding of village-level spatial variation in population pressure and agricultural land carrying capacity within a district that is simultaneously experiencing population growth, land conversion, and administrative-economic concentration. In addition, the application of the Soemarwoto framework to the specific case of the Slawi District has not been clearly documented in previous studies. This study analyzed the spatial patterns of population pressure and agricultural land carrying capacity at the village level in the Slawi District. The working hypothesis was that villages with higher population pressure tend to have lower agricultural land carrying capacity. The results strengthen the empirical basis for land-use planning and sustainable agricultural land protection in rapidly developing local areas.

2. METHOD

2.1. Study Area

This study was conducted in the Slawi District, Tegal Regency, Central Java, Indonesia (Figure 1). Slawi District was selected because it functions as the administrative center of Tegal Regency and as one of its main economic activity areas, where rapid urban development has increased pressure on agricultural land. According to the Central Bureau of Statistics of Tegal Regency, the total area of Slawi District in 2025 was 15.61 km², with a population of 84,104 people and a population density of 5,388 people/km². Kalisapu Village had the largest population (14,329 people), whereas Kagok Village had the smallest population (4,202 people). In terms of population density, Kudaile Village had the highest density (9,801 people/km²), while Dukuhwringin Village had the lowest density (3,443 people/km²).

Agricultural land data from the Agriculture, Fisheries, and Forestry Extension Center (BP3K) of Slawi District show that the district had 272.55 ha of productive agricultural land in 2025. This land was mainly used for food crops, including rice, maize, shallots, chili, and cassava, with a cropping frequency of up to three planting seasons per year. The Slawi District was chosen as the study area because ongoing land conversion and increasing development pressure make it a relevant case for assessing population pressure and agricultural land carrying capacity.

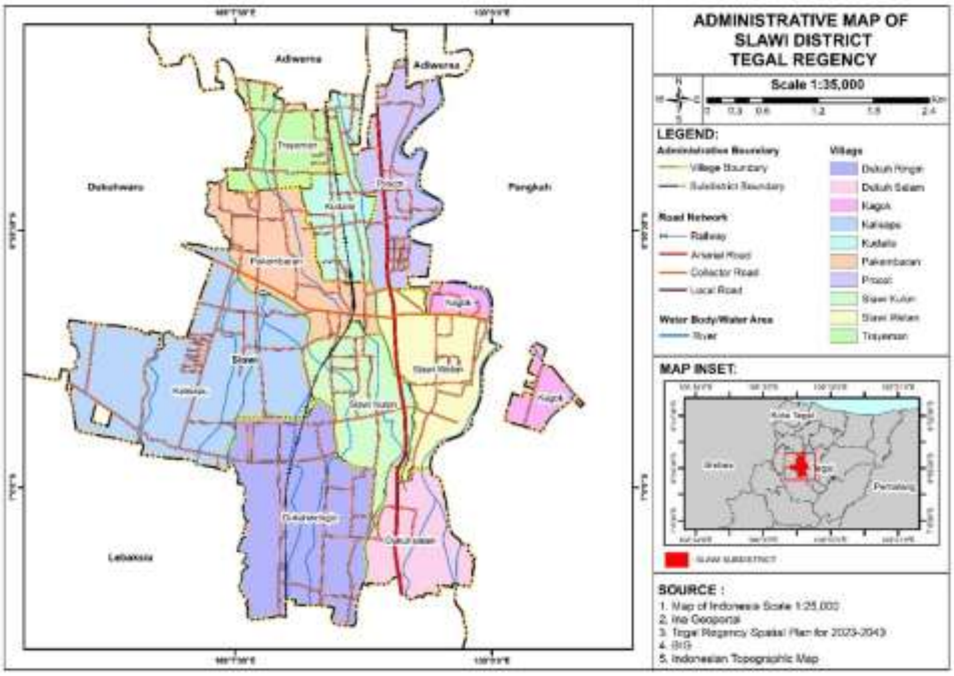

Figure 1. Study Area Map

2.2. Data Sources and Research Design

This study employed a descriptive quantitative design using secondary data and spatial analysis. The main variables included the total population, farmer population, total agricultural land area, irrigated rice fields with two harvests per year, irrigated rice fields with one harvest per year, rainfed rice fields, and dry land. Secondary data for 2025 were compiled from three institutions: the Agriculture, Fisheries, and Forestry Extension Center (BP3K) of Slawi District, the Food Security and Agriculture Service of Tegal Regency, and the Central Bureau of Statistics of Tegal Regency.

To ensure data comparability, all variables were harmonized to the same reference year (2025). Population and farmer population data were aligned at the village level using the administrative units reported by the Central Bureau of Statistics. Land categories from the BP3K and the district agricultural agency were cross-checked and grouped into four analytical categories required by the Soemarwoto model: irrigated rice fields with two harvests (LSI2), irrigated rice fields with one harvest (LSI1), rainfed rice fields (LST), and dry land (LLK). The farmer proportion (f) was calculated as the ratio of the farmer population to the total population in each village.

2.3. Data Processing and Spatial Analysis

All numerical calculations were performed using Microsoft Excel. The calculated results were spatially visualized using ArcGIS 10.8 to map the distribution of population pressure and agricultural land carrying capacity across villages in the Slawi District. The mapping procedure involved joining village-level statistical results to the village administrative boundary layer and classifying the results based on the analytical thresholds of each indicator. The classification criteria for population pressure (TP) and agricultural land carrying capacity (DDLP) are presented in Table 1.

Table 1. Classification of Population Pressure and Agricultural Land Carrying Capacity

Indicator	Value range	Classification
TP	TP < 1	No population pressure
TP	TP = 1	Optimal land use
TP	TP > 1	Population pressure
DDLP	DDLP < 1	Low carrying capacity
DDLP	DDLP = 1	Optimal carrying capacity
DDLP	DDLP > 1	High carrying capacity

2.4. Validation Procedures

Field validation and institutional interviews were conducted to verify the consistency of secondary data and to confirm actual land-use conditions in the study area. Interviews were conducted with relevant officers from BP3K Slawi District and the Food Security and Agriculture Service of Tegal Regency, as these institutions are responsible for agricultural land records and regional agricultural monitoring. Field observations were conducted in selected village locations representing areas with relatively high and low agricultural land availability. These validation steps were used to confirm the existence or absence of agricultural land, support the interpretation of village-level spatial patterns, and clarify villages with very limited or no agricultural land.

In particular, Kudaile village was treated as a special case because no agricultural land area was recorded for the study year. For this reason, the TP and DDLP values for Kudaile village were not calculated, and the village was excluded from the ratio-based interpretation for these indicators. However, Kudaile village was retained in the spatial discussion as an administrative unit that reflects the extreme condition of agricultural land loss in the district.

2.5. Analytical Framework

Population pressure and agricultural land carrying capacity were calculated using the Soemarwoto (1985) Model II framework, as presented by Muta'ali (2015). This model was selected because it is widely used in Indonesian regional and land-resource studies to assess the relationship between population pressure and the support capacity of agricultural land. In this model, the non-agricultural income proportion (α) was set at 35%, following the standard coefficient commonly applied in the Soemarwoto Model II approach to represent the share of farmer household income derived from non-agricultural activities. In this study, the coefficient was used as a model assumption rather than as a locally estimated parameter.

The population pressure index was calculated using Equation (1).

$$TPt = (1 - a).Z \frac{ft.\ Pt}{Lt} \tag{1}$$

Where TPt is the population pressure index in year t (people/ha), α is the proportion of farmer income derived from non-agricultural activities (0.35), Z is the minimum land area required to support a decent farming livelihood (ha), ft is the proportion of farmers in the total population, Pt is the total population in year t (people), and Lt is the total agricultural land area in year t (ha).

The Z value was calculated using Equation (2):

$$Z = \frac{(0.25\ \mathrm{LSI2}) + (0.5\ \mathrm{LSI1}) + (0.5\ \mathrm{LST}) + (0.76\ \mathrm{LLK})}{(LSI2 + LSI1 + LST + LLK)} \tag{2}$$

Where LSI2 is the area of irrigated rice fields with two harvests per year (ha), LSI1 is the area of irrigated rice fields with one harvest per year (ha), LST is the area of rainfed rice fields (ha), and LLK is the area of dryland (ha).

The farmer proportion was calculated using Equation (3).

$$ft = \frac{Farmer\ Population}{Total\ Population} \tag{3}$$

The agricultural land carrying capacity was calculated using Equation (4).

$$DDLP = \frac{1}{TP} \tag{4}$$

Where DDLP is the agricultural land carrying capacity index, and TP is the population pressure index.

3. RESULTS AND DISCUSSION

3.1 Population Pressure Analysis

The calculation results show that the Slawi district had a population pressure value of 1.21, which is classified as population pressure (TP > 1). This result indicates that the pressure of the population on available agricultural land has exceeded the land support threshold at the district level. Village-level results also show variations in population pressure across the Slawi district, reflecting differences in population size, farmer proportion, and agricultural land availability among villages.

Based on the current table, villages with TP < 1 include Dukuhwringin (0.46), Dukuhsalam (0.46), Kalisapu (0.37), and Slawi Wetan (0.84), indicating that agricultural land in these villages still provides relatively better support for the existing population. Villages with TP > 1 include Kagok (1.11), Procot (3.01), Pakembaran (4.03), Slawi Kulon (1.27), and Trayeman (1.63), which indicate higher pressure on agricultural land. which indicate higher pressure on agricultural land. The Kudaile village was not calculated because no agricultural land area was recorded for the study year.

Table 2. Population Pressure Index (TP) in Slawi District

Village	Land Area (ha)	*f* (%)	z (ha)	ITP	Classification
Dukuhwringin	102,00	0,029	0,27	0,46	No population pressure
Dukuhsalam	14,24	0,005	0,28	0,46	No population pressure
Kagok	7,95	0,012	0,27	1.11	Population pressure
Kalisapu	111,24	0,015	0,28	0,37	No population pressure
Kudaile	-	0,011	-	-	Not calculated
Pakembaran	4,44	0,010	0,27	4,03	Population pressure
Procot	2,70	0,007	0,25	3.01	Population pressure
Slawi Kulon	6,64	0,004	0,29	1,27	Population pressure
Slawi Wetan	18,73	0,010	0,26	0,84	No population pressure
Trayeman	4,59	0,005	0,33	1,63	Population pressure
Slawi District	272,55	0,012	0,50	1,21	Population pressure

Overall, the district-level results confirm that the population pressure on agricultural land in the Slawi district is relatively high. In villages with TP > 1, the available agricultural land is insufficient to support the local population, indicating a greater imbalance between land resources and population demand. In contrast, villages with TP < 1 show relatively lower pressure, suggesting that available agricultural land remains more proportional to population needs.

Figure 2 shows that villages with higher population pressure are concentrated in parts of the district where agricultural land is limited. This spatial pattern suggests that land pressure is unevenly distributed across the Slawi District. Although factors such as proximity to transportation routes, built-up area expansion, and concentration of urban activities may explain this pattern, these factors were not directly measured in the analytical model. Therefore, they should be interpreted as contextual conditions rather than demonstrated causal variables. This interpretation is consistent with previous studies, which have shown that areas undergoing rapid land conversion and urban development tend to experience greater pressure on agricultural land (Mahendradhata et al., 2024; Syahibal & Suryani, 2023; Gani et al., 2026).

The findings support the working hypothesis that population pressure tends to increase where agricultural land becomes limited. They also reinforce previous studies reporting that high population pressure reduces the ability of agricultural land to sustain rural livelihoods and food-related needs (Mardhatil et al., 2020; Rachmansyah et al., 2022). In this study, the main contribution is showing that this pressure is not spatially uniform but varies among villages within the same district.

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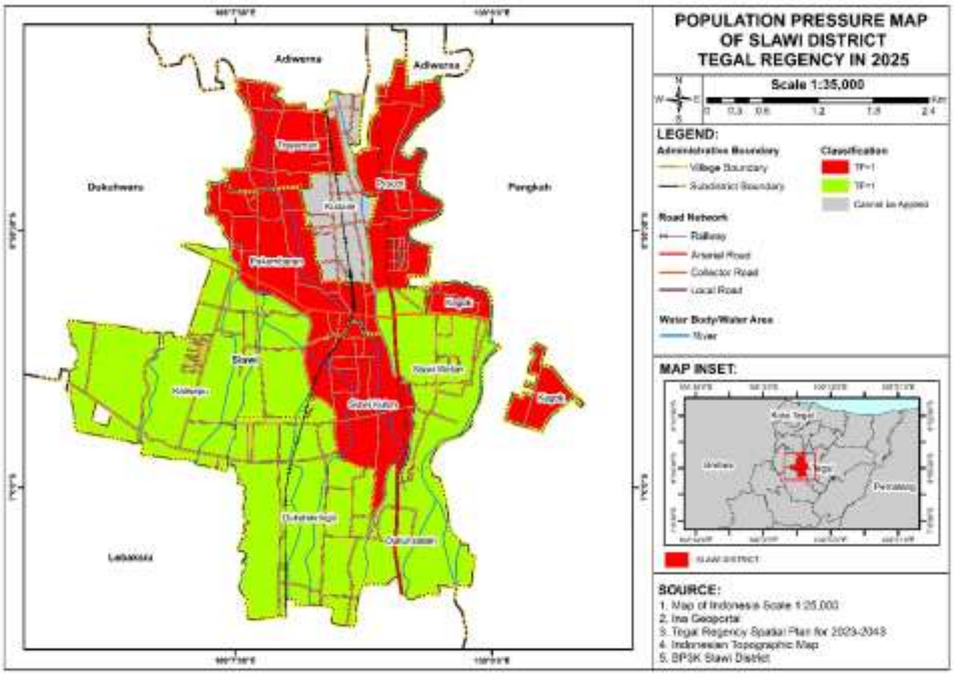

Figure 2. Map of Population Pressure in Slawi District 2025

3.2 Agricultural Land Carrying Capacity Analysis

The agricultural land carrying capacity of the Slawi district was 0.83, which is classified as having a low carrying capacity (DDLP < 1). This result indicates that the available agricultural land at the district level is insufficient to optimally support the population dependent on it. Similar to population pressure, village-level DDLP values also vary, showing differences in land support capacity among villages.

Villages with high carrying capacity (DDLP > 1) include Dukuhwringin (2.15), Dukuhsalam (2.16), Kalisapu (2.71), and Slawi Wetan (1.19). These villages still have relatively better agricultural land support capacity compared with other villages in the district. By contrast, Kagok (0.90), Pakembaran (0.25), Procot (0.33), Slawi Kulon (0.79), Trayeman (0.61) fall into the low carrying capacity (DDLP < 1) category. Kudaile Village was not classified because no agricultural land area was recorded for the study year.

Table 3. Agricultural Land Carrying Capacity (DDLP) in Slawi District

Village	DDL	Classification
Dukuhwringin	2,15	High carrying capacity
Dukuhsalam	2,16	High carrying capacity
Kagok	0,90	Low carrying capacity
Kalisapu	2,71	High carrying capacity
Kudaile	-	Not calculated
Pakembaran	0,25	Low carrying capacity
Procot	0,33	Low carrying capacity
Slawi Kulon	0,79	Low carrying capacity
Slawi Wetan	1,19	High carrying capacity
Trayeman	0,61	Low carrying capacity
Slawi District	0,83	Low carrying capacity

Figure 3 shows that villages with low agricultural land carrying capacity are concentrated in areas where agricultural land is limited, whereas villages with higher carrying capacity retain more productive land resources. This spatial pattern suggests that land support capacity is uneven across the district. As in the previous subsection, factors such as accessibility, concentration of economic activities, and expansion of built-up land may provide contextual explanations for this pattern;

however, these factors were not directly tested in the analytical design. Therefore, the map should be interpreted mainly as a representation of spatial variations in DDLP values rather than as direct evidence of causation.

The results also show an inverse relationship between population pressure and agricultural land carrying capacity. Villages with higher population pressure generally have lower DDLP values, whereas villages with lower population pressure tend to have higher DDLP values. This pattern is consistent with previous research, which indicates that increasing population pressure reduces the capacity of agricultural land to support livelihoods and food production (Rachmansyah et al., 2022). In practical terms, the results indicate that continued land conversion and growing population demand may further weaken agricultural land support capacity if not accompanied by stronger land-use control and agricultural protection measures.

This finding is important because it directly addresses the research objective and helps fill the empirical gap identified in the introduction. The present study not only confirms the inverse relationship between population pressure and agricultural land carrying capacity but also shows that the relationship varies spatially at the village level within the Slawi district. This village-level spatial evidence provides a more detailed basis for identifying areas facing greater land pressure and lower support capacity.

From a policy perspective, the findings suggest the need for stronger protection of sustainable agricultural land, tighter control of land conversion, and more adaptive agricultural management in villages with low DDLP values. However, these recommendations should be interpreted as policy implications derived from the observed spatial pattern and not as direct outcomes tested by the model. Future studies may strengthen this analysis by incorporating temporal land-use change data, direct accessibility variables, and more detailed socioeconomic indicators.

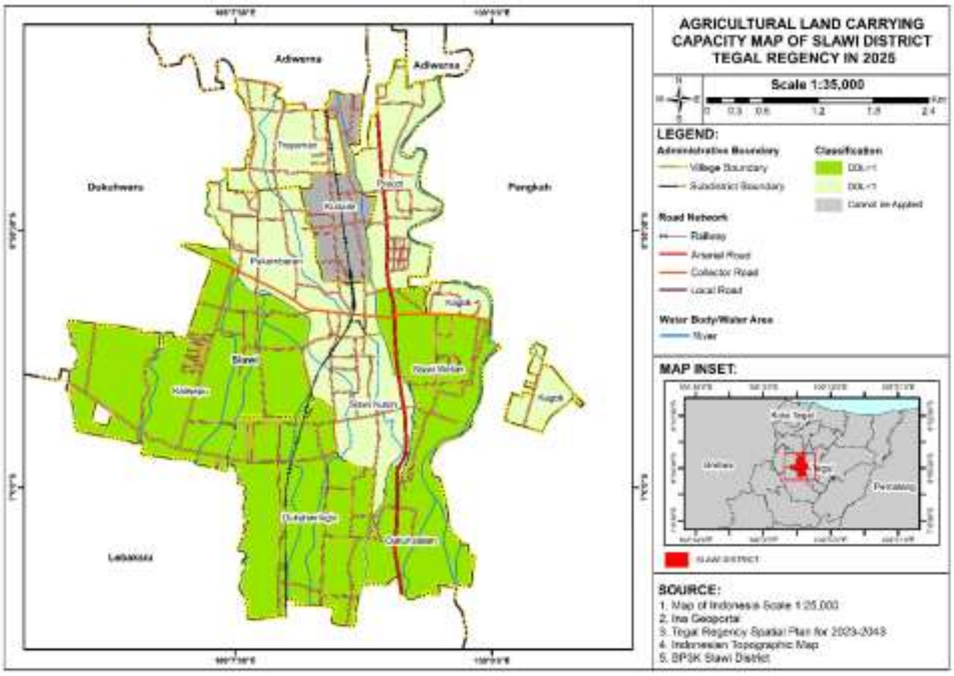

Figure 3. Spatial Distribution of Agricultural Land Carrying Capacity in Slawi District, 2025

4. CONCLUSIONS

This study concludes that the Slawi District experiences high population pressure on agricultural land, indicated by a population pressure index (TP) value of 1.21, while its agricultural land carrying capacity is low, with a DDLP value of 0.83. At the village level, the results show spatial variations in both indicators, with villages having higher population pressure generally tending to have lower agricultural land carrying capacity. These findings confirm the study objective that the spatial relationship between population pressure and agricultural land carrying capacity in the Slawi District can be identified at the village level.

The study also shows that the distribution of land support capacity is not uniform across the district, indicating that some villages face greater pressure on agricultural resources than others. Therefore, the main contribution of this study is providing village-level spatial evidence that can support more targeted land-use planning and agricultural land protection. Because this study used a descriptive quantitative design, the findings should be interpreted as showing spatial patterns and associations rather than direct causal relationships.

This study was limited to one district and one period of analysis. Future studies are recommended to incorporate temporal data, direct land-use change variables, and broader socioeconomic indicators to better explain the dynamics of population pressure and agricultural land carrying capacity over time.

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