

Spatial Analysis of Land Carrying Capacity in Wanggarasi District, Pohuwato Regency

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Abstract

Land use change and population growth are the main factors influencing the sustainability of land resource management, particularly in areas experiencing rapid development dynamics. This study aims to analyze the condition and changes in land carrying capacity in Wanggarasi Sub-district using a spatial and temporal analysis approach based on Geographic Information Systems (GIS). The research employs a descriptive quantitative method utilizing secondary data, including population data, land use data, and multi-temporal satellite imagery. The land carrying capacity index was calculated based on several indicators, namely the proportion of the farming population, the area of cultivated agricultural land, farmer involvement in non-agricultural activities, and the availability of land suitable for living. The results indicate that Wanggarasi Sub-district falls into the category of moderate land carrying capacity, with indications of imbalance between the high proportion of the farming population and the limited availability of productive agricultural land and land suitable for living. This condition reflects the presence of socio-ecological pressures that may increase the risk of land carrying capacity deficits if not accompanied by adaptive land management policies. Spatial analysis demonstrates that GIS is effective in identifying the spatial distribution and zoning of land carrying capacity in greater detail. This study is expected to serve as a basis for spatial planning and evidence-based policymaking to support sustainable regional development at the sub-district level.

Keywords: Spatial, Analysis, Land Carrying Capacity, Wanggarasi Sub-district



INTRODUCTION

Land use change and population growth are two major phenomena that pose challenges to sustainable land resource management in various regions of Indonesia. Land carrying capacity, as an indicator of a region's ability to meet spatial needs and environmental functions, is particularly important in the context of rapidly developing areas. Studies on land carrying capacity enable planners and policymakers to understand the extent to which available land can support ongoing socio-economic dynamics (Lasaiba et al., 2024). Previous studies indicate a tendency toward declining land carrying capacity values due to pressures from settlement growth that are not balanced by the availability of suitable land, placing several regions at an alarming deficit level (Lasaiba et al., 2024).

Spatio-temporal analysis provides a robust approach to examining changes in land carrying capacity not only at a single point in time but also across specific periods, revealing trends and spatial patterns. Studies on land use analysis using spatio-temporal approaches in various regions of Indonesia, such as rural and urban districts, have successfully demonstrated significant changes in land cover influenced by demographic, economic, and geographic factors (JPPG, 2023).

In the context of spatial planning and regional development, land carrying capacity is closely related to the land's ability to support settlement, agricultural, industrial, and environmental functions. For example, research on residential land carrying capacity in peri-urban areas shows that although potential land for settlement development still exists, urbanization pressure has caused several areas to exceed their carrying capacity, potentially leading to environmental degradation (Sa'diyah et al., 2025).

Theoretically, land carrying capacity reflects the relationship between human demand for space and the physical capacity of land to provide that space. The use of Geographic Information Systems (GIS) and multi-temporal satellite imagery such as Landsat or Sentinel has become an essential instrument in measuring and mapping land use changes over time. GIS enables overlay analysis of various biophysical and social parameters to calculate carrying capacity based on land capability classes and spatial changes in land use structures (Lasaiba et al., 2024; JPPG, 2023; Sa'diyah et al., 2025).

Similar phenomena have been discussed in diverse case studies across Indonesia, including major urban areas and rapidly developing regions. For instance, a study in Bukittinggi City revealed that pressure from land conversion into residential areas has constrained the availability of suitable land for future settlements, causing parts of the city to fall into a land carrying capacity deficit category (Mahkota & Febriandi, 2024).



However, studies at the sub-district administrative level—such as Wanggarasi Sub-district—using a spatio-temporal land carrying capacity analysis approach remain relatively limited. Yet, detailed understanding at the sub-district level is crucial for formulating sustainable land management strategies. Such analysis can provide insights into changes in land characteristics resulting from population growth, conversion of agricultural or forest land into settlements, and their implications for the land's ability to support ecological and social needs.

The spatial component of this study includes mapping land capability classes, determining the availability of land suitable for use, and measuring land cover changes over a specific period (e.g., 2010–2024). Meanwhile, the temporal aspect reveals trends in land carrying capacity changes, including whether the region experiences surplus, balance, or deficit conditions over time. This approach enables the detection of spatial dynamics that are not apparent in cross-sectional, single-time analyses.

Furthermore, the results of spatio-temporal analysis can be utilized to formulate evidence-based spatial planning policies. By estimating future trends, policymakers can develop adaptive land use policies to accommodate future needs, including land allocation for settlements, agriculture, protected areas, and other economic activities critical to community welfare in Wanggarasi Sub-district.

Therefore, this study aims not only to map and calculate land carrying capacity spatially but also to provide a strong information base for sustainable spatial planning at the local level. The findings are expected to enrich land carrying capacity studies in Indonesia through a more detailed and contextualized approach aligned with the characteristics of the study area.

Problem Formulation

Based on the background described above, the research questions are formulated as follows:

1. What is the current condition of land carrying capacity in Wanggarasi Sub-district based on spatial data?
2. How is the zoning of land carrying capacity in the study area?
3. What are the implications of the spatial analysis results for land management and spatial planning policies in the study area?

Research Objectives

This study aims to:

1. Analyze the current condition of land carrying capacity in Wanggarasi Sub-district based on land use data, population density, and the availability of usable land.
2. Map land carrying capacity zoning in the study area, including zones classified as surplus, balanced, or deficit, using GIS technology.
3. Provide spatially based and data-driven policy recommendations for sustainable land management and spatial planning in Wanggarasi Sub-district.

Research Benefits

This study is expected to provide benefits in two main aspects:

Theoretical Benefits

1. Contribute to the development of scientific knowledge in geography, regional planning, and land resource management, particularly in the application of spatio-temporal analysis for evaluating land carrying capacity.
2. Serve as an academic reference for future studies related to land carrying capacity, land use, and the application of GIS technology in environmental research.

Practical Benefits

1. Provide accurate and comprehensive spatial information on the condition and changes in land carrying capacity in Wanggarasi Sub-district, which can be utilized by local governments in formulating spatial planning and environmental management policies.
2. Serve as a basis for determining zoning for development, conservation, or land protection in accordance with available carrying capacity.
3. Assist stakeholders—such as regional planners, policymakers, and local communities—in understanding the impacts of land use change and the importance of sustainable planning based on land carrying capacity potential.

LITERATURE REVIEW

Concept of Land Carrying Capacity

Land carrying capacity refers to the ability of a land area to support various human activities and ecological functions without causing long-term environmental degradation. This concept encompasses physical aspects (such as topography, hydrology, and soil type), ecological



conditions, and socio-economic factors that collectively determine the extent to which land can be utilized to meet societal needs while maintaining ecosystem sustainability. Empirical studies indicate that land carrying capacity quality is strongly influenced by continuously changing land use patterns driven by population dynamics and urbanization processes (Pratama et al., 2025).

Land carrying capacity analysis is commonly conducted by comparing land capability with population needs or planned land use, resulting in classifications such as surplus, balanced, or deficit carrying capacity. A study employing a similar approach in Palaran demonstrated that land carrying capacity calculations based on biophysical parameters and compliance with land-use regulations provide insights into whether an area can still be developed or has begun to reach saturation in meeting current population demands (Pratama et al., 2025).

Spatial Approach in Land Analysis

A spatial approach enables researchers to observe the distribution of specific attributes across the entire study area. Spatial changes in land use and land cover provide important insights into how human activities and natural factors interact to shape land transformation patterns (Değermenci, 2023).

Geographic Information Systems (GIS) in Land Carrying Capacity Analysis

Geographic Information Systems (GIS) have become a primary tool in environmental research and land resource management. With capabilities to map, store, process, and analyze spatially referenced data, GIS allows the integration of multiple data layers, such as topography, soil characteristics, land cover, and population data. GIS facilitates the production of thematic maps illustrating key variables related to land carrying capacity and potential future changes.

For example, studies utilizing GIS in residential land carrying capacity analysis apply overlay and scoring methods to calculate land capability classes and assess whether land availability is sufficient to support residential development needs (Sari & Rahmawati, 2020, adapted to a contemporary context). GIS also enhances detailed data visualization, thereby supporting evidence-based decision-making in spatial planning (Sari & Rahmawati, 2020).

Previous Studies on Land Carrying Capacity in Tropical Regions

Research on land carrying capacity in tropical regions has increasingly emphasized the importance of spatial analysis in the context of urbanization, population growth, and land use change. A recent study in Sirimau District, Ambon, found that rapid settlement expansion led to a decline in land carrying capacity to support residential activities in several villages during specific





periods, indicating that demographic pressure and urbanization can reduce land effectiveness in accommodating population needs (Lasaiba, 2024).

Such studies commonly utilize multi-temporal satellite imagery to evaluate trends in land characteristic changes over time and their implications for the availability of land suitable for community use. The findings indicate that several areas have begun to experience conditions where demand exceeds land capacity—suggesting the need for improved spatial planning to maintain balance between land availability and population needs (Lasaiba, 2024).

Additionally, studies conducted in various coastal and urban regions of Indonesia reveal land cover changes driven by anthropogenic activities that negatively affect overall land carrying capacity, reduce agricultural land, and increase residential and infrastructure areas without adequate ecological compensation (Pratama et al., 2025; coastal land-use change studies in the Pantura region).

Theoretical and Conceptual Framework

The theoretical framework of this study integrates several key concepts: land carrying capacity theory, spatial dynamics, and GIS integration in land monitoring and management. First, ecological theory of land carrying capacity posits that land has a maximum capacity to provide resources and environmental functions without undergoing degradation. Second, a spatio-temporal approach assists in identifying land change dynamics and a region's adaptive capacity to socio-economic pressures (Değermenci, 2023). Third, the integration of GIS as a spatial modeling tool enables the development of analytical support layers, such as land capability maps, land cover maps, and estimates of spatial demand based on population size—all of which are essential components in determining existing land carrying capacity status.

The combination of these three concepts forms the theoretical foundation for understanding land carrying capacity dynamics in Wanggarasi Sub-district and provides a methodological basis for systematic and comprehensive analysis.

RESEARCH METHODOLOGY

Type and Research Approach

This study employs a descriptive quantitative research design with a spatial analysis approach to examine agricultural land carrying capacity. The quantitative approach is used to calculate the land carrying capacity index based on measurable indicators, while the spatial approach is applied to analyze the distribution and variation of land carrying capacity across sub-district administrative areas.



Research Location and Period

The research was conducted in Wanggarasi Sub-district, Pohnuato Regency. The study area was selected based on variations in socio-economic characteristics and agricultural land use patterns. The research was carried out using the most recent year with complete and up-to-date secondary data availability.

Types and Sources of Data

The data used in this study consist of secondary data, including:

1. Population data and farming population statistics obtained from the Central Bureau of Statistics (BPS).
2. Data on cultivated agricultural land area and land suitable for living, sourced from relevant technical agencies and land use maps.
3. Supporting data such as administrative boundary maps, land use maps, and other spatial datasets.

Research Variables and Indicators

The main research variable is agricultural land carrying capacity, analyzed using several indicators, namely:

1. Farmer engagement in non-agricultural activities,
2. Proportion of the farming population,
3. Area of cultivated agricultural land.

Each indicator is normalized into an index ranging from 0 to 1 to facilitate comparison across different areas.

Data Analysis Techniques

Land carrying capacity analysis was conducted through several stages:

1. Data standardization using index normalization methods.
2. Calculation of the Land Carrying Capacity Index (LCCI) by proportionally combining the values of each indicator.
3. Classification of the LCCI into high, moderate, and low categories based on index value intervals.
4. Spatial analysis using Geographic Information Systems (GIS) to map the distribution of land carrying capacity across sub-district areas.

Presentation of Results

The results of the analysis are presented in the form of land carrying capacity index tables, thematic maps, and descriptive explanations to illustrate differences in land carrying capacity levels within the study area.

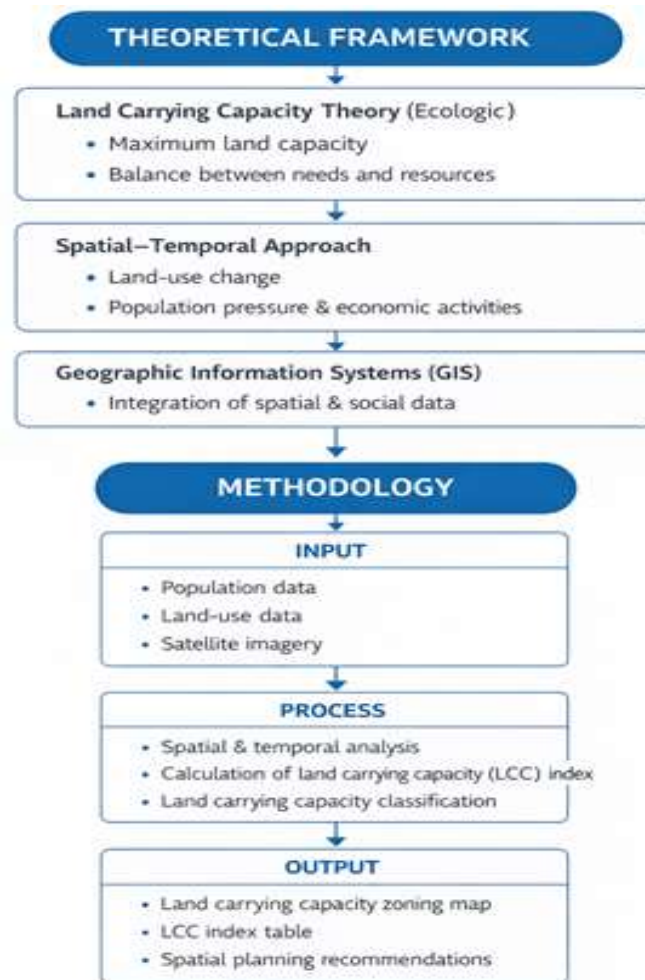


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

This study is expected to produce outputs that are informative, applicable, and supportive of local-level policy-making processes, particularly in land management and spatial planning. The expected results include the following:

Land Carrying Capacity in Wanggarasi Sub-district

The land carrying capacity map is one of the main outputs of this study, illustrating a region's ability to support land use demands based on physical, social, and ecological aspects. This map was generated through spatial analysis using remote sensing techniques (satellite imagery) and Geographic Information Systems (GIS), and was subsequently complemented with social data such as population size to quantitatively calculate the ratio between land demand and land availability.

This approach enables a more detailed mapping of land carrying capacity conditions compared to conventional land use maps, as it accounts for the intrinsic capacity of land based on land capability classes, topography, and other physical characteristics derived from satellite imagery and supporting maps, such as soil type and slope gradient.

Table 1. Land Carrying Capacity Index and Classification by Sub-district in Wanggarasi

LCC Classification	Farmer Support from Non-Agricultural Activities	Proportion of Farming Population (f)	Cultivated Agricultural Land	Area of Land Suitable for Living	Sub-district
High	0.420	0.580	0.548	0.492	Patilangio
High	0.367	0.633	0.010	0.301	Randangan
Moderate	0.268	0.732	0.017	0.301	Wanggarasi

Table 1 presents the Land Carrying Capacity Index (LCCI) values in Wanggarasi Sub-district based on several indicators, namely farmer support from non-agricultural activities, the proportion of the farming population, cultivated agricultural land, and the area of land suitable for living. Higher LCCI values reflect a greater capacity of land to sustainably support the needs of farmers and the local population.

Wanggarasi Sub-district exhibits a combination of moderate to low index values, indicating an imbalance between population needs and land potential. The high value for the proportion of the farming population (0.732), combined with the relatively low value for land suitable for living (0.301), highlights potential socio-ecological pressures if not accompanied by adaptive agricultural and land-use policies. This finding is consistent with studies emphasizing that appropriate land identification through GIS-based spatial evaluation is a crucial step in optimizing sustainable land use (GIS-based geospatial models for land carrying capacity).

Overall, the results presented in Table 1 underscore the importance of integrating spatial and demographic analyses in evaluating agricultural land carrying capacity. High index values indicate sufficient land resources to support farmers and the population, while low values suggest

potential deficits that must be addressed through land-use planning, farmer-focused interventions, and sustainable regional development policies.

Strengthening Research Findings through International Studies

The land carrying capacity (LCCI) analysis results presented in the table exhibit patterns consistent with findings from international studies published over the last five years, which emphasize that agricultural land carrying capacity emerges from complex interactions among demographic pressure, land use intensity, and land use change. A study by Wang et al. (2022) published in *Land* demonstrates that population growth and the expansion of non-agricultural activities significantly contribute to declining land carrying capacity, particularly in regions experiencing extensive conversion of agricultural land. This condition aligns with the low values observed for the cultivated agricultural land indicator in several sub-districts, indicating pressure on land production capacity.

Furthermore, Liu et al. (2020) in the *Journal of Cleaner Production* highlight that agricultural land carrying capacity is determined not only by land area but also by land-use efficiency and the sustainability of management systems. When the proportion of the farming population increases without adequate availability of productive land, the risks of declining livelihoods and environmental degradation become more pronounced. This finding is highly relevant to areas characterized by a high proportion of farming populations but relatively limited land suitable for living.

Additionally, Zhang et al. (2023) in *Sustainability* emphasize the importance of GIS-based spatial approaches in evaluating land carrying capacity, as they enable more accurate identification of inequalities in land resource distribution. Such approaches support more adaptive and sustainable regional planning. Meanwhile, Humaira et al. (2025) report that regions with high land carrying capacity typically exhibit a balance among population size, agricultural land area, and management intensity, making them more resilient to development pressures.

Thus, the findings of this study reinforce empirical evidence that land carrying capacity analysis based on social and spatial indicators is essential as a foundation for formulating agricultural land management policies and sustainable regional development strategies.

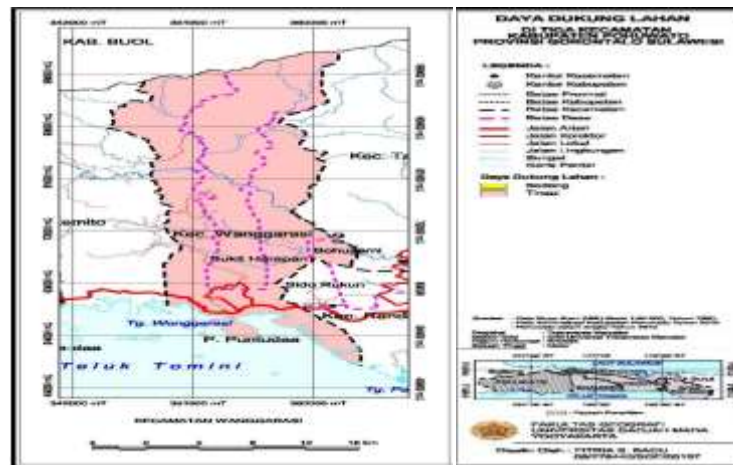


Figure 2. Spatial Distribution of Land Carrying Capacity in Wanggarasi Sub-district

CONCLUSION

This study demonstrates that the land carrying capacity in Wanggarasi Sub-district is classified within the moderate category, indicating an imbalance between population demands—particularly the high proportion of the farming population—and the limited availability of productive agricultural land and land suitable for living. Although the area remains capable of supporting agricultural activities and local livelihoods, the current condition reflects emerging socio-ecological pressures that may lead to land carrying capacity deficits if land use change and population growth are not managed appropriately. These findings highlight the vulnerability of the study area to unsustainable land utilization practices in the absence of adaptive land management strategies.

Furthermore, the application of a spatio-temporal analysis approach based on Geographic Information Systems (GIS) has proven to be an effective tool for evaluating land carrying capacity in a comprehensive and spatially explicit manner. The integration of biophysical data, land use information, and demographic variables enables detailed mapping and zoning of land carrying capacity, thereby supporting evidence-based spatial planning. The results emphasize the importance of implementing sustainable land management and spatial planning policies, including the protection of productive agricultural land, optimization of land use efficiency, and balanced allocation of space for socio-economic activities, to ensure long-term regional sustainability in Wanggarasi Sub-district.



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