ISSN: 3021-7636
International Journal of Science Technology and Health

Research Article
Vol. 4 (1), 2026, page 32-40
DOI: https://doi.org/10.69930/ijsth.v4i1.60

Prediction of Settlement Distribution Patterns Based on Population Density in Ambon City for 2031

Rizky Ahmad Laitupa [1,*], Ahmat Rifai [2], Halim [3], Philia Christi Latue [4], Heinrich Rakuasa [5]

1 Department of Regional and Rural Development Planning, IPB University, Indonesia.
2 School of Environmental Science, University of Indonesia, Indonesia
3 Coastal and Marine Resources Management Study Program, IPB University, Indonesia
4 Biology Education Study Program, Faculty of Teacher Training and Science, Pattimura University, Indonesia
5 Department of Geography, National Research Tomsk State University, Russian Federation

* Correspondence: rizkylaitupa10@gmail.com

Received : 3 December 2025	Accepted: 29 January 2026	Published: 31 January 2026

Abstract: Rapid urbanization in Ambon City is driving population growth and demanding more extensive settlements. Low population density is increasing with growth and centralization in the city center, shaping new settlement distribution patterns. This study predicts settlement distribution patterns based on population density in Ambon City for 2031 using the Cellular Automata-Markov Chain model integrated with the Ambon RTRW 2011-2031 and statistical calculations. Analysis shows the highest densities in Sirimau Sub-district (1,713.42 people/km²) and Teluk Ambon Baguala (1,527.57 people/km²), with settlements concentrated in coastal and central zones, while hilly areas offer expansion potential. The Land Settlement Carrying Capacity Index (DDPm) of 1.27 indicates high capacity to accommodate projected population growth of 2,445,961 people in 2031, aligned with the national per capita space standard of 16 m²/person per Minister of Housing Regulation No. 11/Per-MenM/2008, supporting SDG 11 for sustainable cities.

Keywords: Ambon, Density, Distribution, Population, Settlement

1. Introduction

Urban development in Indonesia, particularly in Ambon City as the capital of Maluku Province, exhibits settlement expansion patterns influenced by physical and social factors. In this area, spatial change often follows the coast because there isn't much flat land, which leads to mostly linear patterns of settlement distribution (Malerba et al., 2022). In Ambon City, high settlement concentration patterns are evident in the city center, particularly coastal areas, due to population growth and economic activities (Zhang et al., 2022). These dynamics require spatial prediction methodologies to foresee forthcoming alterations.

Physical factors such as topography and road accessibility influence the direction of settlement development in Ambon, with initial expansion hindered by past social conflicts (Rakuasa & Budnikov, 2024). Post-conflict, government policies have driven shifts toward hilly areas, where population dynamics and urban utilities serve as primary drivers of spatial distribution patterns (Rifai et al., 2025). These shifts are crucial for understanding how urban growth can be effectively managed and planned in response to the unique challenges posed by the terrain and previous conflicts. Prediction of settlement distribution patterns frequently utilizes spatial models such as cellular automata Markov chains to project land cover changes, considering population density as a key variable (Cherigui et al., 2025). Integration of historical data with such methods provides better accuracy for long-term projections (Choudhary et al., 2025).

Although previous studies have examined settlement patterns in Ambon using historical data or short-term projections (Rakuasa et al., 2023), this research provides the first integrated analysis that combines CA-Markov modeling with the Ambon City Spatial Plan (RTRW) 2011-2031 to generate 2031 projections. This approach offers a novel framework for assessing land carrying capacity against national space standards by integrating historical satellite data with RTRW zoning. Previous studies in Eastern Indonesia's island regions have not included this contribution. Predictions of settlement distribution based on population density are necessary for managing density pressures in Ambon, which include land limitations and rising infrastructure needs (Liu et al., 2025).

This research aligns with SDG 11: Sustainable Cities and Communities, particularly Target 11.3 (enhancing inclusive and sustainable urbanization through integrated settlement planning), Target 11. a (positive economic-social-environmental links between Ambon's urban-rural areas and Central Maluku), Target 11.6 (reducing urban environmental impacts), and Target 11.b (disaster resilience). The projections support the land consumption to population growth ratio, contributing to efficient city management (Shafik, 2025). Based on the background above, this research aims to determine predictions for settlement distribution patterns based on population density for Ambon City in 2031, along with sustainable spatial planning recommendations.

2. Methods

This research was conducted in Ambon City, Maluku Province, Indonesia. Administratively, Ambon City consists of five sub-districts: Sirimau, Nusaniwe, Teluk Ambon, Teluk Ambon Baguala, and Leitimur Selatan. The research data comprise Ambon City's population data for 2025 obtained from the Central Bureau of Statistics, the Ambon City Spatial Planning Plan (RTRW) 2011-2031 acquired from the Ambon City Development Agency, and map data from previous settlement predictions for Ambon City in 2031.

This study applies spatial analysis through overlay techniques on spatial data to form new mapping units as the basis for analysis. Overlay techniques are utilized to determine land grading or categorization. Furthermore, this analysis adopts sustainable development principles as an effort to meet present needs. The realization of these principles is achieved through regional development aligned with environmental carrying capacity, namely the maximum population capacity that can be supported without causing ecosystem damage.

The primary focus of the carrying capacity analysis is to evaluate the land area in Ambon City's sub-districts capable of accommodating housing needs amid population growth dynamics. The formula for carrying capacity analysis calculation and district capacity determination is explained in Equation 1 with certain adjustments (Pratami et al., 2019).

$$n = \frac{P\%(B\% \times L) \times L}{100} \quad (1)$$

Information:
n: Maximum population capacity per sub-district (persons)

P%: Settlement land allocation ratio (50%)
B%: Effective land utilization rate (50% of sub-district area)
L: Total sub-district area (km²)
k: Average household size (3 persons/family)
100: Minimum land requirement per household (m²)

Settlement land carrying capacity analysis aims to evaluate the adequacy of suitable land for settlements against spatial needs standards per capita, ensuring sustainable urban development in Ambon City amid population growth pressures. The calculation employs the regional carrying capacity formula for settlements (Equation 2), which integrates available land area with per capita spatial norms to determine maximum population capacity without compromising environmental sustainability (Fitri et al., 2021). This approach facilitates identification of land sufficiency across sub-districts, supporting strategic spatial planning aligned with RTRW Ambon 2011-2031 and promoting balanced housing provision that respects ecological limits:

$$DDPM = \frac{LPm/JP}{\alpha} \tag{2}$$

Information:
DDPm = Settlement Land Carrying Capacity Index
Lpm = Settlement Land Area
JP = Total Population
α = Space Requirement Coefficient per Capita

The interpretation of the Settlement Land Carrying Capacity Index (DDPm) reflects the region's ability to sustainably accommodate population, where DDPm > 1 indicates high settlement carrying capacity allowing land to support additional residents for adequate housing development, DDPm = 1 signifies optimal conditions with perfect balance between resident population and available land area, and DDPm < 1 denotes low carrying capacity where land can no longer adequately accommodate residents for habitation, thus requiring spatial planning interventions to prevent ecosystem pressure.

3. Results and Discussion

3.1. The Population Density of Ambon City in 2025

The carrying capacity of a region is primarily determined by the characteristics and potential of its local ecosystem (Salakory & Rakuasa, 2022). The concept of settlement land carrying capacity refers to a region's ability to provide adequate housing space to accommodate a specific population, enabling sustainable and decent living from both environmental and social perspectives (Sejati et al., 2025). This understanding serves as the primary foundation for urban spatial planning, particularly in island regions like Ambon, which face limitations in flat land due to dominant mountainous topography and coastlines (Hidalgo-Arellano & Fernández-Avilés, 2025).

Population density, as the main spatial indicator, is calculated through the ratio of total population to land area in persons per hectare (persons/ha), enabling accurate identification of urban pressure zones (see Figure 1). This approach visualizes uneven population distribution, where coastal areas tend to experience high concentrations while hilly regions retain development potential. Population density analysis becomes a crucial tool for detecting spatial imbalances that may trigger environmental and social issues (Bole et al., 2025).

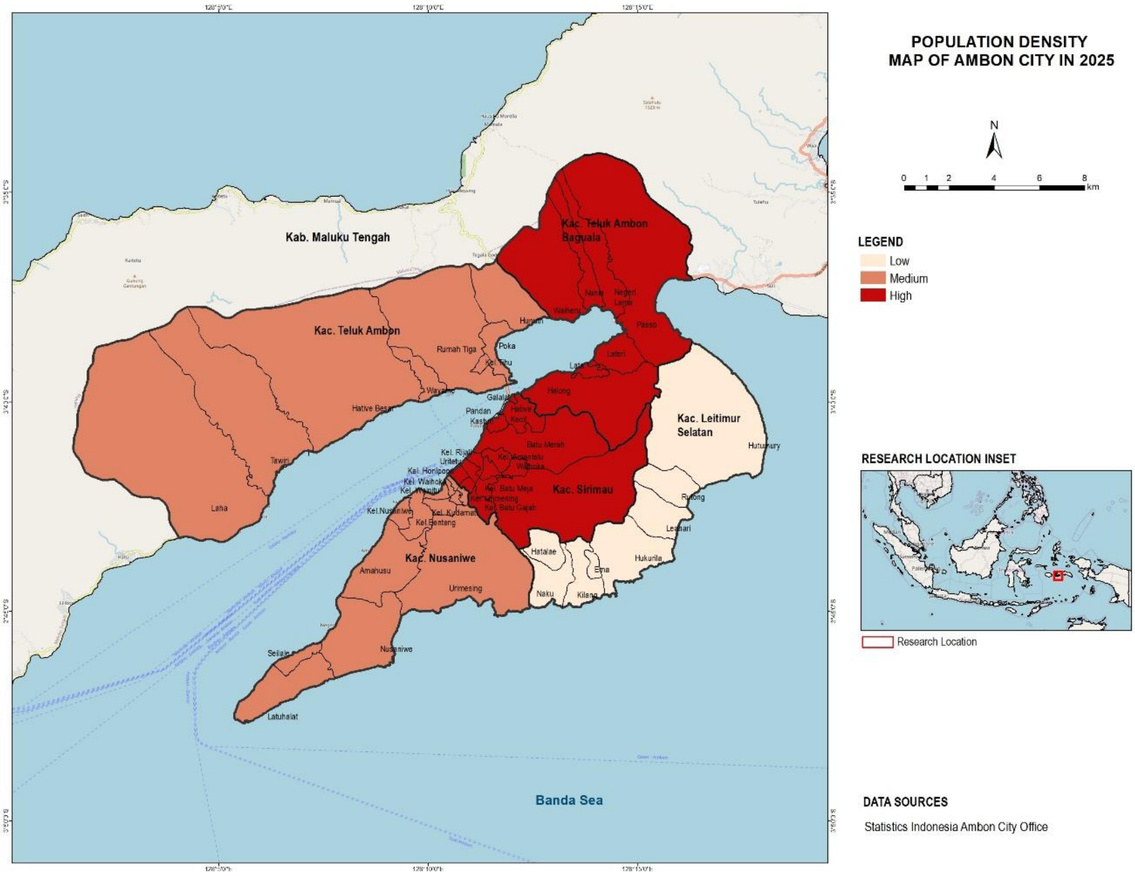

Figure 1. Population Density Map of Ambon City in 2025
Source: Statistical data analysis results from BPS 2025

Table 1. Classification of Population Density of Ambon City

Sub District	Area (Km²)	Percentage (%)	Population Density in 2025	Classification
Sirimau	86.81	41.63	1.713.42	High
Nusaniwe	88.35	25.63	1.036.61	Medium
Teluk Ambon	93.68	12.73	485.64	Medium
Teluk Ambon Baguala	40.11	17.15	1.527.57	High
Leitimur Selatan	50.50	2.86	202.12	Low

Source: (BPS, 2025)

This conceptual understanding forms the basis for carrying capacity analysis to prevent land overutilization and housing quality degradation. By integrating population density data with per capita space norms, planners can establish maximum population limits per sub-district aligned with Ambon City's Spatial Planning Plan (RTRW) 2011-2031 (Dinas Perumahan Rakyat dan Kawasan Permukiman Kota Ambon, 2012). This approach not only supports sustainable land management but also ensures equitable access to decent housing for all city residents.

Table 2. Population Density Classification (people/km²)

Population Density Classification (people/km²)	
Low	<300 people/km²
Medium	300-1.500 people/km²
High	1,500 people/km²

Source: (BPS, 2025)

Table 1 and 2 illustrates the varying population densities across Ambon City's five sub-districts, revealing uneven spatial distribution patterns. Sirimau Sub-district, with the largest area (86.81 km² or 41.63% of the total city area), experiences the highest population density at 1,713.42 persons/km², classifying it as high density, while Leitimur Selatan Sub-district has the lowest density at 202.12 persons/km² despite its relatively small area (50.50 km² or 2.86%), falling into the low density category. Nusaniwe and Teluk Ambon Sub-districts occupy medium density positions with 1,036.61 and 485.64 persons/km² respectively despite their large areas, whereas Teluk Ambon Baguala maintains high density (1,527.57 persons/km²) despite its smaller area (40.11 km² or 17.15%). This pattern reflects concentrated settlements in central and coastal areas driven by economic activities, while peripheral hilly regions retain greater development potential to balance overall population density pressures in Ambon City.

5.2. Land Support Capacity of Settlements

5.2.1. Modeling Cellular Automata for Land Support Capacity

Ambon City Settlement Land Cover based on RTRW 2011-2031 has a total area of 6,583.35 ha or 65,833,460 m². Meanwhile, Cellular Automata-Markov Chain modeling by Salakory & Rakuasa (2024) projects that settlement land area in Ambon City for 2031 will reach 4,958.33 hectares or equivalent to 49,583,268 m², reflecting significant spatial expansion due to ongoing urbanization dynamics. The per capita space requirement coefficient refers to Minister of State for People's Housing Regulation No. 11/PERMEN/M/2008 concerning Guidelines for Housing and Settlement Area Compatibility (Peraturan Menteri Negara Perumahan Rakyat, 2008), which sets a standard of 16 m²/capita for the City Center Zone to ensure adequate and sustainable housing space. Meanwhile, the population projection for Ambon City in 2031, calculated using the geometric method, yields an estimate of 2,445,961 persons, serving as a critical basis for evaluating settlement land adequacy against future demographic pressures (Table 3). The integration of these three parameters enables comprehensive analysis of land carrying capacity suitability with spatial needs, aligned with sustainable spatial planning principles.

Table 3. The Capacity of Ambon City Subdistrict in 2025

Sub District	Population in 2025	Capacity	Difference
Sirimau	148.742	543,195	-394,453
Nusaniwe	91.574	552,138	-460,564
Teluk Ambon	45.495	586,125	-540,630
Teluk Ambon Baguala	61.271	250,694	-189,423
Leitimur Selatan	10.207	315,625	-305,418

Source: Results of BPS statistical data analysis

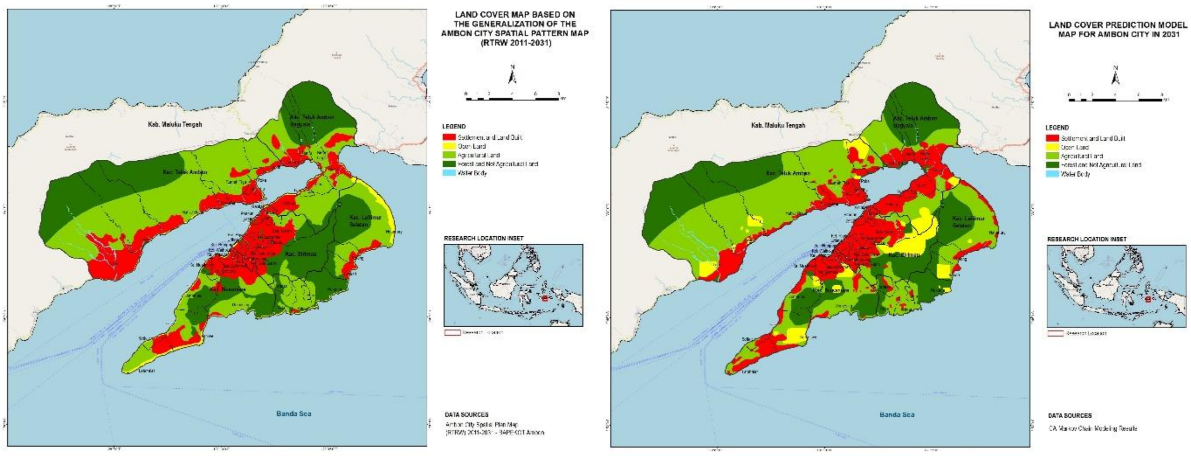

Figure 2. Map of Comparison of Land Cover Predictions for Year 2031 and RTRW
Source: (Dinas Perumahan Rakyat dan Kawasan Permukiman Kota Ambon, 2012; Salakory & Rakuasa, 2022)

5.2.2. Settlement Land Carrying Capacity Based on Ambon City RTRW

LPm (suitable land area for settlement in Ambon City) is derived from the RTRW Ambon City 2011-2031 allocation of 6,583.35 ha (65,833,460 m²) minus the 2031 projected settlement area from the Cellular Automata-Markov Chain model by Salakory & Rakuasa (2024) at 4,958.33 ha (49,583,268 m²), yielding an effective LPm of 1,625.02 ha or 16,250,192 m² available for sustainable residential development. The 2031 population projection using the geometric method estimates 2,445,961 persons, serving as the primary demographic parameter for assessing regional carrying capacity against future urbanization pressures. The per capita space requirement coefficient of 16 m²/person follows City Center Zone standards per Minister of State for People's Housing Regulation No. 11/PERMEN/M/2008, ensuring adequate housing space compliant with national norms.

Table 4. Calculation Results of Ambon City Space Needs

LPm	Large (ha)	Large (m2)	Space Needs	Meter/Soul
RTRW Ambon –Prediction 2031	1,625.0	16,250.19	122.52	1.27
Conformity - Prediction 2031	2,150.0	21,500.00	162.4	2.15

Source: Results of RTRW and Rakuasa & Salakory (2022) data analysis.

The 2031 Settlement Land Carrying Capacity Index (DDPm) calculation yields a value of 1.27, falling within the DDPm > 1 category, indicating high settlement land carrying capacity capable of accommodating additional population for adequate housing development. This value reflects a surplus capacity of 1.27 times the minimum space requirement standard, signifying that Ambon City maintains sufficient land reserves to support population growth without experiencing spatial deficits in the medium term (Table 4). This condition provides strategic flexibility for spatial planners in directing settlement expansion toward potential zones such as optimally capacitated hilly areas.

These findings carry significant implications for Ambon City's spatial management, particularly in supporting RTRW 2011-2031 implementation and SDG 11 achievement for sustainable cities. With high land carrying capacity classification, local government can prioritize supporting infrastructure development such as clean water networks, drainage systems, and mass transit in surplus land areas while preventing excessive conversion of protected lands. This integrated approach ensures adequate housing availability for residents while maintaining ecological balance in the climate-vulnerable island city ecosystem. The Map of Comparison between 2031 Land Cover Predictions and RTRW can be seen in Figure 2.

5.2.3. Carrying Capacity of Residential Land based on Land Suitability

Analysis of residential land carrying capacity reveals that Ambon City maintains adequate land capacity to support sustainable settlement growth, as indicated by an index falling within the high category. This condition signifies that land remains capable of accommodating additional population without experiencing excessive spatial pressure, with reserves aligned with national space requirement standards for city center zones (Abdelatif & Djiar, 2025). Applied spatial modeling confirms the presence of surplus capacity, providing strategic flexibility in regional spatial management.

This carrying capacity surplus reflects equilibrium between long-term spatial plan land allocations and predicted land conversion due to urbanization dynamics, enabling housing development in potential zones such as hilly areas with optimal capacity. The approach aligns with national regulations on per capita space norms, ensuring settlement expansion does not exceed the ecological limits of island regions (Amiruddin et al., 2026). Integration of demographic projections with land suitability mapping strengthens effective decision-making.

These findings provide a strong foundation for city spatial plan implementation and achievement of sustainable development goals related to resilient cities. Local government can prioritize supporting infrastructure development such as clean water systems, drainage, and transportation in surplus land areas while protecting protected lands from unnecessary conversion. This integrated approach maintains ecological balance in the vulnerable island city ecosystem, ensuring adequate housing availability alongside resilience to climate change and natural disasters

Conclusions

Prediction of settlement distribution patterns based on population density in Ambon City for 2031 demonstrates that the city maintains high residential land carrying capacity through integration of Cellular Automata-Markov Chain modeling with RTRW 2011-2031 land suitability analysis, yielding adequate surplus capacity to accommodate sustainable population growth without significant spatial deficits. Findings confirm concentrated settlement patterns in central and coastal zones alongside expansion potential toward hilly areas, aligning with national per capita space standards while supporting SDG 11 through ecosystem-oriented spatial planning for the island city.

Acknowledgments

We researchers express our gratitude to all parties who have assisted in this study.

Conflicts of Interest

The authors declare no conflict of interest.

References

Abdelatif, I., & Djiar, K. A. (2025). Developing indicators for water-energy-food nexus based on urban carrying capacity: Implications for algiers resource management. *Journal of Cleaner Production*, *513*, 145736. https://doi.org/10.1016/j.jclepro.2025.145736

Amiruddin, H. B., Arif, S., & Sakka, S. (2026). Geospatial analysis of land degradation and settlement in Barru Regency: Implications for sustainable land management. *Journal of Degraded and Mining Lands Management*, *13*(1), 9081–9094. https://doi.org/10.15243/jdmlm.2026.131.9081

Bole, Y., Rina, S., Guga, S., Na, M., Fan, S., & Zhang, J. (2025). Evaluation of resources, environment, and ecological carrying capacity from the perspective of "production-living-ecology" spaces: A case study of western Jilin Province, China. *Journal of Cleaner Production*, *491*, 144770. https://doi.org/10.1016/j.jclepro.2025.144770

BPS. (2025). *Kota Ambon Dalam Angka 2025* (BPS Kota Ambon (ed.)). BPS Kota Ambon.

Cherigui, A., Talia, A., Benstaali, I., Blissag, B., Zerouali, B., & Meddi, M. (2025). Urban expansion and its environmental impacts in northwestern Algeria using cellular automata-Markov-chain modeling. *Modeling Earth Systems and Environment*, *11*(3), 159. https://doi.org/10.1007/s40808-025-02309-y

Choudhary, P., Devatha, C. P., & Azhoni, A. (2025). Integration of multi-layer perceptron neural network and cellular Automata-Markov chain approach for the prediction of land use land cover in land change modeler. *Ecological Modelling*, *506*, 111162. https://doi.org/10.1016/j.ecolmodel.2025.111162

Dinas Perumahan Rakyat dan Kawasan Permukiman Kota Ambon. (2012). *Peraturan Daerah Kota Ambon Nomor 24 Tahun 2012 Tentang Rencana Tata Ruang Wilayah (RTRW) Kota Ambon Tahun 2011 Sampai Dengan Tahun 2031*. Dinas Perumahan Rakyat dan Kawasan Permukiman Kota Ambon.

Fitri, N. I., Damayanti, A., Indra, T. L. L., & Dimyati, M. (2021). Cellular Automata and Markov Chain Spatial Modeling for Residential Area Carrying Capacity in Samarinda City, East Kalimantan Province. *IOP Conference Series: Earth and Environmental Science*, *673*(1), 12051. https://doi.org/10.1088/1755-1315/673/1/012051

Hidalgo-Arellano, I., & Fernández-Avilés, G. (2025). Spatial depopulation risk assessment through spatial principal component analysis and indicator kriging in Castilla-La Mancha (Spain). *Journal of Rural Studies*, *119*, 103771. https://doi.org/10.1016/j.jrurstud.2025.103771

Liu, Y., Ou, C., Liu, Y., Cao, Z., Robinson, G. M., & Li, X. (2025). Unequal impacts of global urban–rural settlement construction on cropland and production over the past three decades. *Science Bulletin*, *70*(10), 1699–1709. https://doi.org/10.1016/j.scib.2024.12.054

Malerba, A., Castro Noblejas, H., Sortino Barrionuevo, J. F., & Mérida Rodríguez, M. (2022). Urban Transformation of the Coastline from a Landscape Perspective. Analysis of Cases on the Costa del Sol (Spain). In F. Calabrò, L. Della Spina, & M. J. Piñeira Mantiñán (Eds.), *New Metropolitan Perspectives* (pp. 1671–1682). Springer International Publishing.

Peraturan Menteri Negara Perumahan Rakyat. (2008). *Peraturan Menteri Negara Perumahan Rakyat Nomor: 11/PERMEN/M/2008 tetang Pedoman Keserasian Kawasan Perumahan Dan Permukiman*.

Pratami, M., Susiloningtyas, D., & Supriatna. (2019). Modelling cellular automata for the development of settlement area Bengkulu City. *IOP Conference Series: Earth and Environmental Science*, *311*(1), 12073. https://doi.org/10.1088/1755-1315/311/1/012073

Rakuasa, H., & Budnikov, V. V. (2024). Assessing Settlement Suitability Using Road Network Analysis for Sustainable Urban Planning in Ambon City, Indonesia. *Applied Engineering, Innovation, and Technology*, *1*(2), 68–74. https://doi.org/10.62777/aeit.v1i2.39

Rakuasa, H., Sihasale, D. A., Somae, G., & Latue, P. C. (2023). Prediction of Land Cover Model for Central Ambon City in 2041 Using the Cellular Automata Markov Chains Method. *Jurnal Geosains Dan Remote Sensing*, *4*(1), 1–10. https://doi.org/10.23960/jgrs.2023.v4i1.85

Rifai, A., Rakuasa, H., Halim, Latue, P. C., Sarfan, R., & Tehupelasury, S. (2025). Spatial Transformation of Physical Change of Built-up Land in Ambon City Center, Indonesia, Period 1940-2025. *Asian Journal of Environmental Research*, *2*(1), 67–81. https://doi.org/10.69930/ajer.v2i1.319

Salakory, M., Rakuasa, H. (2022). Modeling of Cellular Automata Markov Chain for predicting the carrying capacity of Ambon City. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (JPSL)*, *12*(2), 372–387. https://doi.org/https://doi.org/10.29244/jpsl.12.2.372-387

Sejati, A. W., Putri, S. N. A. K., Tyas, W. P., Buchori, I., Handayani, W., Basuki, Y., Barbarossa, G., & Husna, I. N. (2025). Predicting urban carrying capacity to support sustainable tourism using GIS. *Journal of Policy Research in Tourism, Leisure and Events*, *17*(3), 632–655. https://doi.org/10.1080/19407963.2023.2279065

Shafik, W. (2025). *SDG 11: Sustainable Cities and Communities—Smart Cities and Urban Sustainability BT - Factoring Technology in Global Sustainability: A Focus on the Sustainable Development Goals* (W. Shafik (ed.); pp. 333–363). Springer Nature Singapore. https://doi.org/10.1007/978-981-96-7299-8_12

Zhang, D., Zhou, C., Zhou, Y., & Zikirya, B. (2022). Spatiotemporal relationship characteristic of climate comfort of urban human settlement environment and population density in China. *Frontiers in Ecology and Evolution*, *10*. https://doi.org/10.3389/fevo.2022.953725