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Ability of CA-Markov Model to Predict the Expansion of Growth Rate of Ambon City, Indonesia and Gaza Strip, Palestine

Heinrich Rakuasa[1], Stewart Pertuack[2], Philia Christi Latue[3]
[1] National Research Tomsk State University, Russian Federation, [2] Tomsk State University of Architecture and Construction, Russian Federation,[3] Irkutsk State University, , Russian Federation
heinrichrakuasa02@gmail.com

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Abstract
This study aims to explore the ability of Cellular Automata-Markov (CA-Markov) model in predicting the expansion of urban growth rate in Ambon, Indonesia, and Gaza Strip, Palestine. Using a literature study approach, this research collected and analyzed secondary data on land use change, population growth, and factors affecting urbanization in both regions. The results of the analysis show that the CA-Markov model has high accuracy in predicting land use change, and is able to describe the spatial dynamics of built-up land growth. This research emphasizes the importance of integrating environmental aspects in land use planning to achieve sustainable development. The findings are expected to provide useful recommendations for policy makers in managing urban growth, as well as enrich the literature on the application of the CA-Markov model in different contexts.

Abstrak
Abstrak: Penelitian ini bertujuan untuk mengeksplorasi kemampuan model Cellular Automata-Markov (CA-Markov) dalam memprediksi ekspansi laju pertumbuhan kota di Ambon, Indonesia, dan Gaza Strip, Palestina. Dengan menggunakan pendekatan studi literatur, penelitian ini mengumpulkan dan menganalisis data sekunder mengenai perubahan penggunaan lahan, pertumbuhan populasi, dan faktor-faktor yang mempengaruhi urbanisasi di kedua wilayah. Hasil analisis menunjukkan bahwa model CA-Markov memiliki akurasi tinggi dalam memprediksi perubahan penggunaan lahan, serta mampu menggambarkan dinamika spasial pertumbuhan lahan terbangun. Penelitian ini menekankan pentingnya integrasi aspek lingkungan dalam perencanaan penggunaan lahan untuk mencapai pembangunan yang berkelanjutan. Temuan ini diharapkan dapat memberikan rekomendasi yang berguna bagi pengambil kebijakan dalam mengelola pertumbuhan kota, serta memperkaya literatur mengenai penerapan model CA-Markov dalam konteks yang berbeda.

Kata Kunci : Ambon, CA-Markov Model, Gaza Strip, Pertumbuhan Kota, Penggunaan Lahan

INTRODUCTION

Rapid urban growth is one of the main challenges for many countries, including Indonesia and Palestine (Attaallah 2018 & Rakuasa 2023). Ambon, as the capital city of Maluku Province, is experiencing significant population growth, which has resulted in an increasing demand for land (BPS 2023; Latue et al., 2023). According to data from the Central Bureau of Statistics (BPS) in 2020, Ambon was the most populous city in Maluku with 25.50% of the total population of the province. On the other hand, Gaza Strip is also facing similar challenges, where rapid population growth and urbanization are putting pressure on limited land resources (Attaallah, 2018). In this context, it is important to understand the dynamics of land use change and urban expansion. Cellular Automata-Markov (CA-Markov) models have proven effective in predicting land use change and urban expansion. This model combines the strengths of cellular automata that are able to capture spatial interactions with Markov processes that capture uncertainty in land change (Supriatna et al. 2022; Sugandhi.,2022). By using this model, researchers can analyze and predict urban growth patterns more accurately.

Ambon and the Gaza Strip have different geographic and demographic characteristics, but both face similar challenges in terms of land management. In Ambon, rapid economic growth and urbanization led to the need for more residential land (Rakuasa & Latue 2023), while in the Gaza Strip, conflict and restricted access to land exacerbated the situation (B. Abuelaish 2018). Therefore, this study aims to explore the ability of the CA-Markov model to predict the expansion of urban growth rates in both regions. One important aspect of this research is the analysis of land capacity. Limited land capacity

can lead to a mismatch between land demand and land availability, which in turn can trigger social and environmental problems (Salakory & Rakuasa 2022). By using the CA-Markov model, researchers can identify potential areas for development and plan for more sustainable land use. In addition, this research will also address the impact of urban growth on the environment. Unplanned urbanization can cause environmental damage, such as soil degradation, pollution, and biodiversity loss (Kisamba and Li 2022; Achmadi et al., 2023). Therefore, it is important to integrate environmental aspects in land use planning to achieve sustainable development (Rahnama 2021; Rakuasa & Pakniany 2022).

Figure 1. Research location

In a policy context, the results of this study are expected to provide useful recommendations for local governments in planning and managing urban growth. By understanding growth patterns and land capacity, governments can make better decisions in resource management and spatial planning (He et al. 2018). This is crucial to ensure that urban growth can take place without compromising the quality of life of people and the environment (Fahad et al. 2021; Rakuasa and Pertuack 2023). This research is expected to contribute to the existing literature on the use of CA-Markov models in the context of urban growth. By comparing two different locations, namely Ambon and Gaza Strip, this research will add insight into how this model can be applied in various geographical and social contexts. Based on this background, this study aims to explore and analyze the ability of the CA-Markov model in predicting the expansion of the growth rate of the cities of Ambon and Gaza Strip, and its implications for sustainable land use planning.

METHOD

This research method uses a literature study approach to explore the ability of the Cellular Automata-Markov (CA-Markov) model to predict the expansion of the growth rate of the cities of Ambon, Indonesia, and Gaza Strip, Palestine (Figure 1). The process began with the collection and analysis of secondary data from various sources, including journal articles, research reports, and relevant policy documents. The data collected included information on land use change, population growth, and factors affecting urbanization in both regions. Furthermore, the analysis was conducted by comparing the application of the CA-Markov model in different contexts, as well as evaluating the prediction results produced by the model. This research also reviewed the existing literature on the effectiveness of CA-Markov models in spatial planning and land resource management, with the aim of providing evidence-based recommendations for policy makers in both locations.

RESULT

Historical Data Analysis

1. Land Use Change in Ambon City

The analysis shows that Ambon City experienced significant changes in land use from 2010 to 2020. The data shows an increase in built-up land area, especially for residential land use, which increased along with rapid population growth. In 2020, the built-up land area is predicted to reach 7,299.17 ha, with a projected population of 2,445,961 people in 2031. This indicates a high pressure on land availability, which can lead to an imbalance between land demand and existing land availability. The CA-Markov model successfully predicted this trend with high accuracy, showing that it is effective in forecasting land use change in Ambon, as well as providing insights for sustainable spatial planning in the future (Septory et al., 2023). Land Use Change in Ambon, Indonesia can be seen in Figure 2.

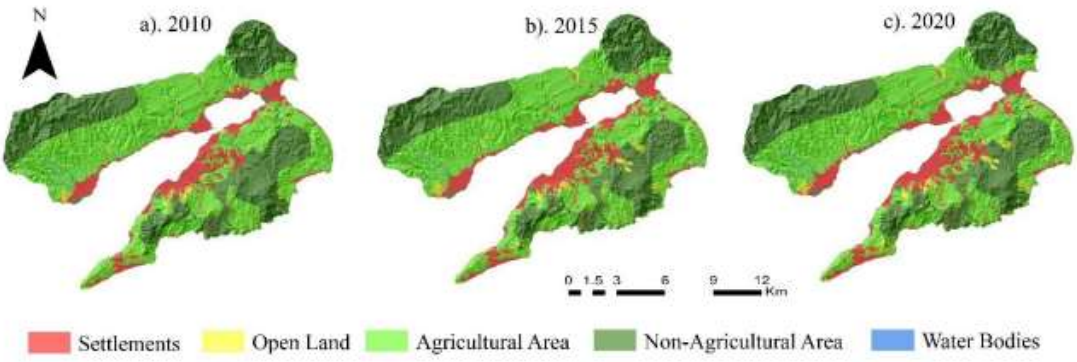

Figure 2. Land Cover Change in Ambon, Indonesia (Salakory, & Rakuasa 2022)

2. Land Use Change in the Gaza Strip

In the Gaza Strip, analysis of historical data shows a similar pattern of land use change, albeit in a different context. Land use for settlements and infrastructure increased, while agricultural land decreased. This is due to high population growth and space constraints due to complex geopolitical conditions. A CA-Markov model was used to predict land use in the Gaza Strip until 2036, with results showing that built-up land will continue to increase, while open and agricultural land will decrease. These results highlight the challenges faced in land management in the Gaza Strip, where the need for land for settlement must be balanced with the need to maintain agricultural land and open space. The CA-Markov model proved to be effective in providing a clear picture of land use dynamics in the Gaza Strip, which can help in decision-making related to spatial planning and resource management (B. Abuelaish 2018). Land Use Change in Gaza Strip, Palestine can be seen in Figure 3.

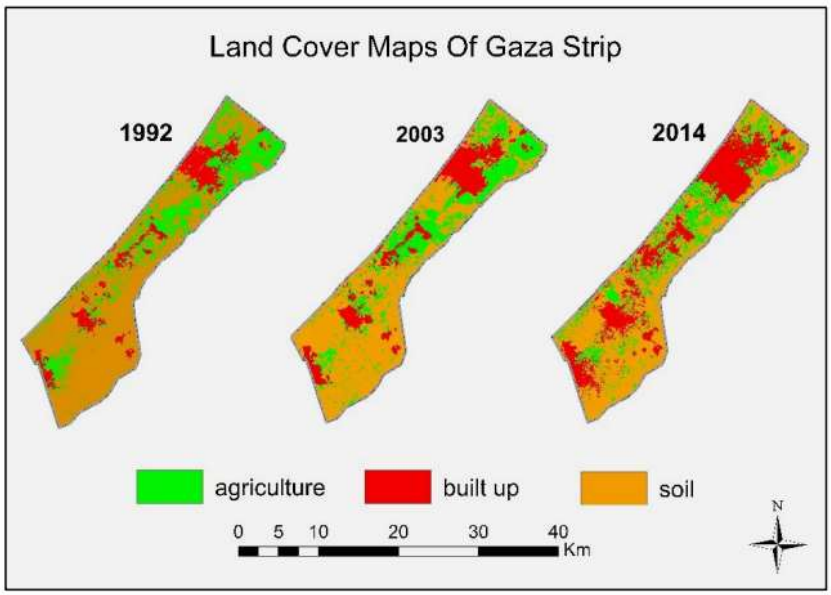

Figure 3. Land Cover Change in Gaza Strip, Palestine (Attaallah 2018)

Implementation of CA-Markov Model

1. Model Calibration for Ambon City

Calibration of the CA-Markov model for Ambon City was conducted using historical land use data from 2010 to 2020. The calibration process involved adjusting the model parameters to reflect the real conditions in the field. The data used included satellite images and classified land use maps. Calibration results show that the model can reproduce land use change patterns with high accuracy, with kappa values indicating good agreement between predicted and actual data. The model successfully predicted an increase in built-up land area, reflecting the rapid population growth and urbanization in Ambon. With proper calibration, the CA-Markov model provides reliable results for forecasting future land use change, as well as assisting in more effective and sustainable spatial planning (Girma et al., 2022).

2. Model Calibration for Gaza Strip

In the Gaza Strip, calibration of the CA-Markov model was carried out using a similar approach, using historical data from 1992 to 2014. This process involved analyzing satellite imagery and previously collected land use data. The calibration results show that the model can capture the dynamics of land use change due to population growth and urbanization pressure. Despite the challenges faced due to complex geopolitical conditions, the CA-Markov model successfully predicted the trend of increasing built-up land and decreasing agricultural land. The kappa values obtained indicate that the model has good accuracy in predicting land use change in the Gaza Strip (Attaallah 2018). With effective calibration, the model can provide valuable insights for decision makers in planning for sustainable land use in this densely populated region.

Predicted Urban Growth Rate Expansion

1. Growth Projection of Ambon City

Based on the results of the analysis using the CA-Markov model, the projected growth of Ambon City shows a significant trend in the expansion of built-up land until 2031. The model predicts that the area of built-up land will increase substantially, along with the population growth which is estimated to reach 2,445,961 people. This increase reflects the growing need for land for housing, infrastructure and public services. The projection results show that built-up land could reach approximately 7,299.17 ha by 2031, which represents a significant increase compared to the 2020 data (Figure 4). These projections highlight the importance of sustainable spatial planning to manage rapid growth and ensure that community needs can be met without compromising environmental quality.

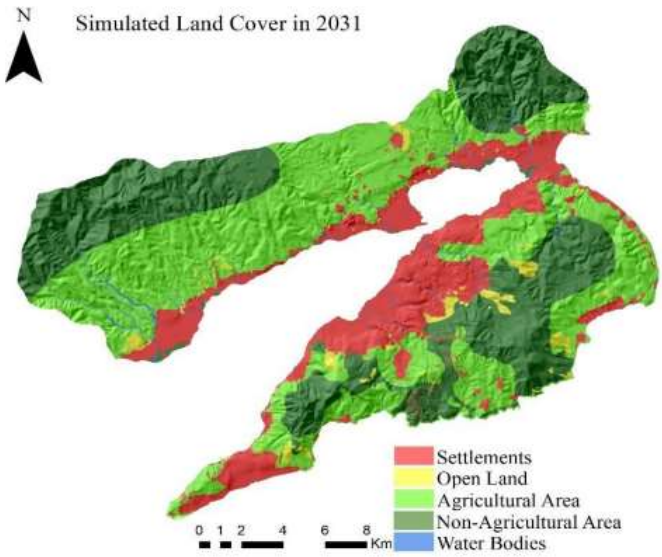

Figure 4. Results of land use predictions for Ambon City in 2031 (Salakory, & Rakuasa 2022)

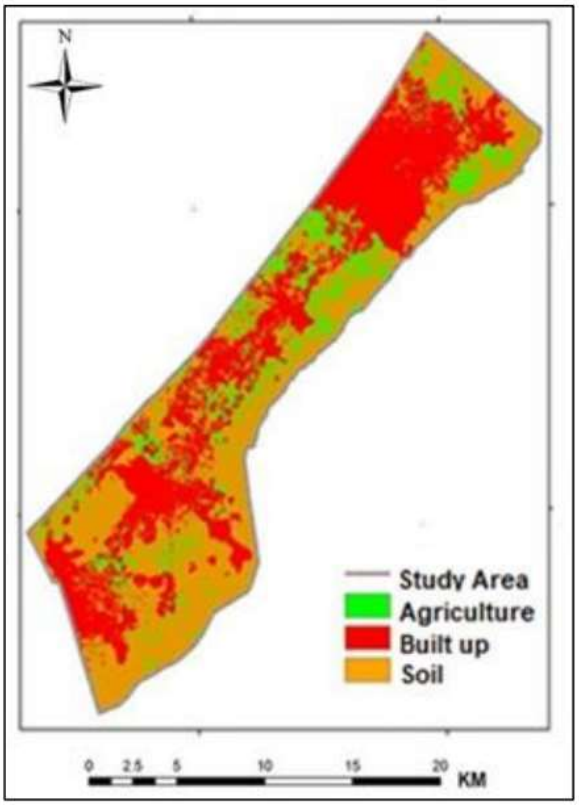

Figure 5. Results of land use predictions for the Gaza Strip in 2036 (Attaallah 2018)

2. Gaza Strip Growth Projections

In the Gaza Strip, the CA-Markov model also provides striking projections of built-up land growth up to 2036 (Figure 5). The analysis shows that if the current growth trend continues, built-up land in the Gaza Strip could reach 45.3% of the total area, which means a significant transformation from agricultural and open land to built-up land (Attaallah 2018). This projection reflects the high pressure on land resources due to rapid population growth and urgent housing needs. As the population continues to increase, the challenges of land management become more complex, and the projections highlight the need for better planning strategies to address the negative impacts of rapid urbanization.

DISCUSSION

Comparison of Urban Growth Patterns

1. Expansion Characteristics of Ambon City vs Gaza Strip

The growth pattern of built-up land in Ambon City and Gaza Strip shows different characteristics although both are experiencing significant expansion. Built-up land expansion in Ambon tends to be focused around the city center and developed areas (Somae et al., 2023). This growth is driven by rapid urbanization, where demand for housing and infrastructure increases along with population growth (Rakuasa & Somae 2022). The CA-Markov model suggests that built-up land in Ambon could increase substantially, with more planned and directed development, although it still faces challenges in terms of adequate infrastructure and public services (Hehanussa and Rakuasa 2024). On the other hand, the expansion of built-up land in the Gaza Strip has been more reactive and unplanned, often occurring in areas that were previously agricultural or open land. This growth is fueled by high demographic pressure and complex geopolitical conditions, which limit planned infrastructure development (Attaallah 2018). Projections suggest that built-up land in the Gaza Strip could reach 45.3% of the total area, with much of the agricultural land significantly reduced.

1. Factors Affecting the Differences in Growth Patterns

Several factors influence the difference in growth patterns between Ambon City and the Gaza Strip:

a) Geopolitical Conditions: Gaza Strip is in a prolonged conflict situation, which affects infrastructure planning and development. Political uncertainty and restricted access to

resources make the growth of built-up land more unplanned and often informal (Abuelaish and Olmedo 2016). In contrast, Ambon, despite its challenges, operates in a more stable context, allowing for better planning

b) Population Growth: Rapid population growth in the Gaza Strip, which reached a very high population density, drove the urgent need for housing (Abuelaish 2018). This has led to the rapid conversion of agricultural land to built-up land. In Ambon, while population growth is also significant, there is more room for planned development, which allows for better management of land expansion (Rakuasa & Pakniany 2022)

c) Resource Availability: Resource availability, including land and infrastructure, also plays a role in growth patterns. In the Gaza Strip, limited resources and conflict-damaged infrastructure hinder planned development (Attaallah 2018). Meanwhile, Ambon has better access to resources and infrastructure support, although it still needs to be improved to meet the needs of rapid growth (Pakniany, and Rakuasa 2024). Overall, a comparison of growth patterns between Ambon City and the Gaza Strip shows that while both locations are experiencing built-up land expansion, the characteristics and factors influencing such growth are very different. Understanding these differences is important for formulating appropriate and sustainable planning strategies in each region.

Performance Evaluation of CA-Markov Model

1. Advantages and Limitations of the Model in Predicting the Growth of Ambon City

Advantages:

a) Prediction Accuracy: The CA-Markov Model showed high accuracy in predicting land use change in Ambon City. The model successfully integrates spatial and temporal data, thus providing a more realistic projection of built-up land expansion (Ajeeb et al. 2020).

b) Ability to Capture Spatial Dynamics: The model is able to capture the spatial dynamics of built-up land growth well, thanks to the use of a combination of Markov and Cellular Automata models. This allows for a more in-depth analysis of how built-up land expands around existing areas (Weslati, Bouaziz, and Sarbeji 2023).

c) Flexibility: The CA-Markov Model can be customized with various scenarios and parameters, so it can be used to forecast various growth possibilities based on different planning policies (Wang et al. 2020).

Limitations:

a) Dependence on Historical Data: This model relies heavily on accurate historical data. If the data used is not representative or there are errors in data collection, then the prediction results may be less accurate (Mustafa et al. 2021).

b) Simple Assumptions: The CA-Markov Model often makes assumptions that may not reflect the real complexity of the urban growth process. For example, the model may not fully consider the social, economic and environmental factors that can influence growth (Zhou et al. 2020).

2.Advantages and Limitations of the Model in Predicting Gaza Strip Growth

Advantages:

a) Ability to Identify Trends: The CA-Markov Model is effective in identifying trends in built-up land growth in the Gaza Strip, albeit in a more complex and unplanned context. The model can provide insights into how agricultural and open land is diminishing as housing demand increases.

b) Visualization of Spatial Change: The model allows for clear visualization of land use change, which is particularly useful for planning and decision-making in areas under high growth pressure such as the Gaza Strip.

Limitations:

a) Unstable Geopolitical Conditions: The main limitation in using the CA-Markov Model for the Gaza Strip is the uncertainty caused by geopolitical conditions. Conflict situations and access restrictions may change the growth pattern which cannot be predicted by the model (Attaallah 2018).

b) Data Limitations: In Gaza Strip, the availability of accurate and up-to-date data is often a challenge. Incomplete or inaccurate data can affect the prediction results, reducing the reliability of the model (Abuelaish 2018).
c) Complex Social and Economic Factors: The model may not fully capture the social and economic factors that affect growth in the Gaza Strip, such as migration, government policies, and fluctuating economic conditions (Basheer Abuelaish and Olmedo 2016).

Overall, the CA-Markov Model has advantages and limitations in predicting the growth of built-up land in Ambon City and Gaza Strip. While the model provides a useful tool for analysis and planning, it is important to consider the local context and factors that may affect the prediction results. The use of this model should be accompanied by an in-depth understanding of the social, economic, and environmental dynamics that exist in each region.

Implications of Prediction Results

1. Potential Impacts of Expansion on the Environment and Infrastructure in Ambon City
   a) Environmental Impacts: Environmental Quality Degradation: The expansion of built-up land in Ambon City may lead to a decline in environmental quality, including loss of green open spaces and agricultural land. This may result in reduced biodiversity and increased pollution Changes in Drainage Patterns: With increased infrastructure development, natural drainage patterns may be disrupted, potentially leading to flooding and water management issues. This is of particular concern in areas vulnerable to climate change (Somae and Rakuasa 2024).
   b) Impact on Infrastructure: Traffic Density: Population growth and expansion of built-up land can increase traffic density, potentially causing congestion and increasing travel times. This requires better transportation planning to address these issues. Basic Infrastructure Needs: Rapid expansion will increase the need for basic infrastructure such as clean water, sanitation, and electricity. If not properly anticipated, this can cause pressure on existing systems and reduce service quality (Kushwaha et al. 2021).
2. Potential Impacts of Expansion on the Environment and Infrastructure in the Gaza Strip
   a) Environmental Impacts: Environmental Degradation: The expansion of built-up land in the Gaza Strip could lead to significant environmental degradation, including loss of agricultural land and open space. This could exacerbate food security issues and reduce the ability of ecosystems to support life. Pollution: Unplanned development can lead to soil and water pollution, especially if construction waste and domestic waste are not properly managed. This can have a negative impact on public health and quality of life (Han and Jia 2017).
   b) Impact on Infrastructure: Infrastructure Limitations: The Gaza Strip already faces significant infrastructure challenges. Rapid expansion could exacerbate these conditions, with increased needs for housing, roads, and other public services that may not be able to be met (Yin et al. 2008).
   c) Resource Conflicts: With increased demand for infrastructure and services, there is potential for resource conflicts, both between different communities and between individuals and the government. This can exacerbate already existing social tensions.

Prediction results from the CA-Markov Model show that the expansion of built-up land in Ambon City and Gaza Strip has significant potential impacts on the environment and infrastructure. In Ambon City, challenges such as environmental degradation and basic infrastructure needs are the main concerns. Meanwhile, in Gaza Strip, environmental degradation and limited infrastructure are critical issues that need to be addressed. Therefore, it is important to integrate the results of these predictions into sustainable planning and management to minimize negative impacts and maximize the benefits of growth.

City Planning Recommendations

1. Growth Management Strategy for Ambon City
   a) Integrated Land Use Planning: Develop a spatial plan that integrates land use for residential, commercial, and green open spaces. This is important to maintain a balance between

development and environmental preservation. Prioritize the development of existing areas over expanding into new land, to reduce negative impacts on agricultural land and local ecosystems (He et al. 2018).

b) Sustainable Infrastructure Improvement: Invest in sustainable infrastructure, such as efficient and environmentally friendly public transportation systems, to reduce congestion and pollution. Establish effective water and waste management systems to address pollution problems and ensure access to clean water for all residents (Kushwaha et al. 2021).
c) Community Participation: Involving the community in the planning process to ensure that their needs and aspirations are taken into account. This can be done through community forums and public consultations. Encourage local initiatives for open space and environmental management, such as greening and park maintenance programs (Rakuasa et al., 2024).

2. Urban Growth Management Strategy for Gaza Strip

a) Crisis Responsive Planning: Develop contingency plans to address the challenges facing the Gaza Strip, including conflict and resource constraints. This plan should be flexible and adaptable to changing circumstances. Prioritize basic infrastructure development that supports immediate needs, such as housing, sanitation, and access to clean water (Al-Hameedi et al. 2021).
b) Sustainable Management of Natural Resources: Implement sustainable agricultural practices to protect remaining agricultural land and improve food security. This includes the use of efficient and environmentally friendly farming techniques. Develop policies to protect open spaces and green lands, which are important for community well-being and environmental health (Kushwaha et al. 2021).
c) International and Local Collaboration: Build partnerships with international organizations and non-governmental agencies to gain support for infrastructure development and social programs. This can help overcome existing resource limitations. Encourage collaboration between local governments and communities to create solutions that fit the local context and specific needs of the population (Latue & Rakuasa 2023).

The urban planning recommendations for Ambon City and Gaza Strip emphasize the importance of an integrated and sustainable approach to managing growth. In Ambon City, a focus on integrated land use planning and sustainable infrastructure improvements is essential. Meanwhile, the Gaza Strip requires crisis-responsive strategies and sustainable natural resource management. By implementing these strategies, both regions can address growth challenges and minimize negative impacts on the environment and society.

CONCLUSION

This research shows that the CA-Markov model is effective in predicting land expansion and urban growth in Ambon and the Gaza Strip, with results that provide important insights for sustainable land use planning. With an in-depth analysis of land use change and factors affecting urbanization, this study emphasizes the need for integration of environmental aspects in urban planning policies. The results are expected to serve as recommendations for local governments to better manage urban growth, thereby reducing negative impacts on people's quality of life and the environment. In addition, this study also contributes to the existing literature on the application of CA-Markov models in different contexts, enriching the understanding of challenges and solutions in land resource management in diverse regions.

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