JOURNAL OF APPLIED GEOSPATIAL INFORMATION

Vol 7 No 1 2023

http://jurnal.polibatam.ac.id/index.php/JAGI
ISSN Online: 2579-3608

Analysis of Land Cover Change Due to Urban Growth in Central Ternate District, Ternate City using Cellular Automata-Markov Chain

Philia Christi Latue[1*], Heinrich Rakuasa[2]

[1]Department of Biology, Faculty of Biology, Herzen University, Russia
[2]Department of Geography, Faculty of Mathematics and Natural Sciences, University of Indonesia, Indonesia

Corresponding Author e-mail: [1]philialatue04@gmail.com , [2]heinrichrakuasa14@gmail.com

Received: October 01, 2022
Accepted: January 17, 2023
Published: January 17, 2023

Abstract

The increase in population and the increasing flow of urbanization in Central Ternate District make the need for land to live also increase as a result of which there will be inconsistencies or inequalities between land needs and available land, a decrease in environmental carrying capacity and environmental damage in the future. This study aims to analyze changes in land cover due to urban growth in Central Ternate District, Ternate City using The Automata- Markov Chain. Cellular Automata- Markov Chain is used to analyze and predict land cover changes in 2002, 2012, 2022 and 2031. The results showed that residential land will continue to experience an increase in area along with population growth and the high demand for land to settle. The results of this study are expected to be input in policy making related to the arrangement and utilization of space in The Central Ternate District in the future.

Keywords: celular automata, markov chain, land cover,ternate

1. Introduction

According to Kisamba and Li, (2022) the phenomenon of urban growth has become an important issue that affects the land use system and land cover in a region for several reasons such as population growth and the economy. Almdhun et al., (2018) argue that one of the important factors that encourage urban growth is urbanization. Urbanization has become one of the main environmental issues lately because it has had a devastating impact on urban ecosystems (Wang & Wang, 2017; Alimuddin, et al., 2022)

Geographically, the location of The Central Ternate District which is in the center of Ternate City and is also the City Area Section (BWK) II which makes this district the most populous district and is the destination of urbanization in North Maluku Province. Based on data from BPS Ternate City in 2021, Ternate Tengah District is one of the districts that has the highest population growth rate in Ternate City with a total population in 2021 reaching 53,643 people (BPS, 2021).

Based on previous research conducted by Umanailo et al., (2017), there are two factors that are considered to greatly affect changes in land cover in Central Ternate District, namely population factors and economic factors, therefore, it can be concluded that the increasing population of Central Ternate District makes the need for land to settle also increase as a result of which there will be inconsistencies or inequalities between land needs and available land, the occurrence of a decrease in environmental carrying capacity and environmental damage in the future (Salakory & Rakuasa, 2022; Sugandhi et al., 2022).

The geographical condition of the Central Ternate District which is in the active volcanic area, namely Mount Gamalama, has an impact on the availability of land for settlement in the future, therefore, predictions of urban development and growth or urban growth need to be carried out which later the information can be used as a basis and foothold in policy making related to the arrangement and use of sustainable space and as a first step in efforts to mitigate natural disasters in the future.

According to Ajeeb et al., (2020) there are many GIS and remote sensing models and methods to predict urban growth patterns such as detection of land use changes and landscape matrices in the range of which are the Cellular Automata (CA) model, Land Transformation Model (LTM), and Logistics Regression (LR). Utilization of Geographic Information System (GIS) and remote sensing data can be used to develop a sustainable urban planning system in the future (Mohamed & Worku, 2020)

Dynamic spatial modeling plays an important role in urban planning, namely predicting urban growth patterns (Han and Jia, 2017; Akbar and Supriatna, 2019; Rakuasa et al., (2022), therefore dynamic spatial modeling is highly recommended for use in simulation and prediction of urban trends.

Dynamic spatial modeling using the CA-Markov method or Celular Automata- Markov Chain has become one of the main dynamic models used by most researchers in recent years in the fields of geography, environmental science and urban and regional planning (Rakuasa et al., 2022; Getu and Bhat, 2022)

According to Kushwaha et al., (2021) The CA-Markov model is a commonly used model in the last five years due to its simplicity and can be easily integrated with other models. Xu et al., (2022) add that the CA-Markov model greatly provides ease of use and simplicity of implementation, as well as its expansion and the ability to add influencing variables in the simulation process. There are several types of influencing variables that can be added, for example statistics such as population and economic variables and dynamic variables such as height and slope. Entering variables of this type produces results that are not only more realistic but also much more accurate (Hegazy & Kaloop, 2015).

In this study, Central Ternate Subdistrict was chosen as a case study area because this area has experienced extensive urban development in recent years due to several reasons such as the pace of urbanization, economic growth and population, which led to a decrease in green areas in Central Ternate District. Previous research on land cover changes in Central Ternate District has been carried out by Umanailo et al., (2017), but this study only analyzes land cover changes that occurred in 2000, 2005, 2010, and 2015 in 2020. Sarihi et al., (2020) in 2019 also researched land use analysis on Ternate Island, these two studies analyzed land cover changes without predicting future changes. This research offers something new, namely that this research not only analyzes land cover changes in 2002, 2012, and 2032 but also predicts land cover in 2031.

In this study, the Celular Automata- Markov Chain model was selected to predict urban growth trends and patterns in Central Ternate District using ArcGIS and IDRISI Selva software. This model is widely used in this field of study for several reasons such as its simplicity and accuracy. To the author's knowledge, no such research has ever been conducted in this area before, therefore this study aims to analyze land cover changes due to urban growth in Central Ternate District, Ternate City using Celular Automata- Markov Chain.

2. Methods

This research was conducted in Ternate District, Ternate City, North Maluku Province, which has an area of 1,407.17 ha. To analyze land cover changes due to urban growth in Central Ternate District, Ternate City using Celular Automata-Markov Chain

The software used for data processing and analysis in this study consists of Arc GIS 10.8 software for the process of processing land cover data and driving factors, IDRISI Selva software for processing the 2032 land cover model, Microsoft Office 365 software used for the process of analyzing the area of land cover development.

The processing of multi-temporal imagery data, namely Landsat imagery in 2002, 2012 and 2022 which has been downloaded from the USGS, is then carried out a radiometric correction process with the aim of making the pixels in the imagery in good condition to be able to be interpreted the type of land cover (Sukojo et al., 2017) and geometric correction is carried out to minimize geometric errors in the image during wave recording (Sukojo et al, 2017). Then the image was cut based on the administrative boundaries of the Central Ternate District. After the three images were carried out a combination of bands to facilitate the interpertation and digitization process, for Landsat 5 imagery using a combination of band 321 and Landsat 8 using band 432, after that the digitization process was carried out in the Arc GIS 10.8 software with reference to (SNI 7465: 2010 (Badan Standarisasi Nasional, 2010), namely settlements, open land, agricultural areas, non-agricultural areas, and waters.

The process of processing multitemporal land cover data and data processing of driving factors in this study using Arc GIS 10.8 software and the process of making a land cover prediction model in 20432 using IDRISI Selva 17.0 software. Each driving factor has a different influence on each type of land cover change so that weighting is carried out. (Table 1), to calculate the strength of the driving factor.

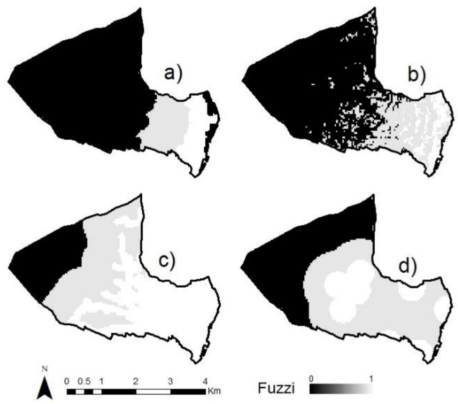

Fig 1. Driving Factors; a) elevation, b) slope, c) Distance from the road, d) distance from POI

Table 1. Driving Factor Classification

Parameter	Class	Score
Land Elevation	0-7 m dpl	1
	8-25 m dpl	3
	26-100 m dpl	2
	>100 m dpl	1
Slope	0-3 %	3
	4-15 %	2
	>15 %	1
Distance from the Road	0-100 m	3
	101-1000 m	2
	> 1000 m	1
Distance from POI	<400 m	3
	401-1000 m	2
	>1000 m	1

Source: Sugandhi et al., (2022)

The processing of push factor data is carried out using the Arc Map 10.8 application using the fuzzy overlay technique and produces output in the form of a push factor (Figure 2). Fuzzy is a logic system that aims to formulate an appraisal estimate reflected in the form of a level of importance that has a range of values of 0-1 (Boolean).

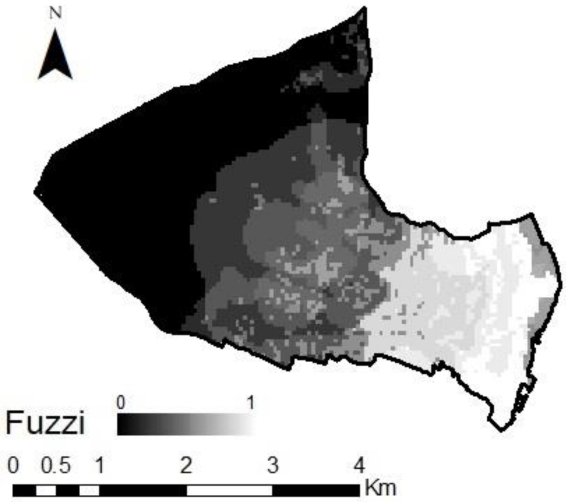

Fig 2. Overlay Results of Factors Driving the Development of Settlements

According to Ghosh et al., (2017), fuzzy logic is an excellent method for defining data obtained continuously, effectively and efficiently, which is a great process for performing celular automata-based modeling considering that using parallel computing consists of interconnected cells and has continuous values, so that in this study the author processed the driving factor data by applying the concept of fuzzy logic The fuzzy logic value is displayed with a black and white gradation, where the resulting white color gradation is the higher the value, referring to the higher the development of settlements in the area. The five variables that have been carried out fuzzy membership are then overlaid with fuzzy gamma logic in the Arc Map 10.8 application (Figure 3), then a combination of the suitability of all the driving factor variables can be produced.

Land cover modeling in 2032 was carried out using LCM (Land Change Modeller), Markov, CA Markov, and Validate tools in the IDRISI Selva software. The method used to create a land cover model in 2032, the Cellular Automata Markov Chain method, is a hybrid model that is commonly used to predict land cover changes based on geographic information systems. Cellular Automata Markov Chain combines two different methods namely Markov Chain, which is an empirical/statistical model, while Cellular Automata is a dynamic model that is included in the GIS platform (Marko et al., 2016). After the model is generated, the accuracy of the model is tested using the K-standard calculation (Kappa Coefficient) using the Validate tool in the IDRISI Selva software. If the simulation accuracy result is reached > 75%, there is no need to repeat the accuracy process, and can proceed to the next modeling process Sugandhi et al., (2022). The complete research workflow can be seen in Figure 4

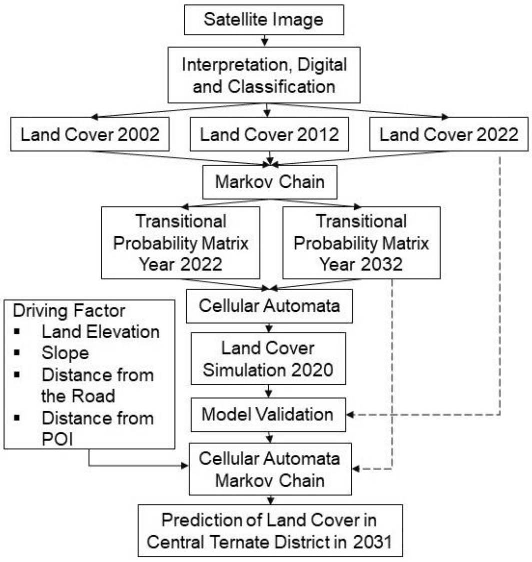

Figure 3. Research Workflow

3. Results and Discussion

3.1. Land Use and Land Cover (LULC) in 2002, 2012 and 2022

Land Use and Land Cover (LULC) in Ternate Tengah Subdistrict has undergone significant changes from 2002, 2012 and 2022, especially in the type of residential and open land cover that continues to increase in area, in contrast to the type of land cover of agricultural areas and land cover of non-agricultural areas that continue to decrease in area due to uncontrolled urban growth. According to Sugandhi et al., (2022), this is influenced by the continued increase in the number of residents living in Central Ternate District which makes the need for built/settlement land higher which has an impact on the conversion of other functions into residential land which continues to increase from year to year.

Spatially, the Land Use and Land Cover (LULC) of Central Ternate District in 2002, 2012 and 2022 can be seen in Figure 5 and the area of each land cover class can be seen in Table 2.

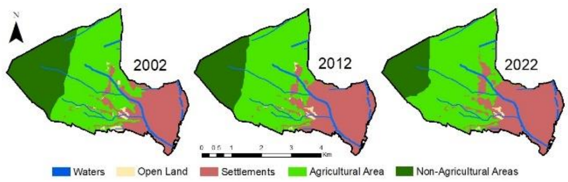

Fig 4. Land Use and Land Cover, Central Ternate District

Based on Figure 4 and Table 1, it can be seen that the Land Use and Land Cover (LULC) of Ternate Tengah District in 2002, 2012 and 2022 experienced an increase in residential land cover and open land cover, while the land cover that decreased was the land cover of agricultural areas and land cover not agricultural areas. Then the land cover that does not undergo changes is only the water land cover.

Table 2. Land Use and Land Cover Area of Central Ternate District

Land Use and Land Cover (LULC)	2002		2012		2022	
	Ha	%	Ha	%	Ha	%
Settlements	385.08	27.37	441.91	31.40	459.01	32.62
Open Land	18.21	1.29	10.40	0.74	8.38	0.60
Agricultural Area	648.75	46.10	695.24	49.41	732.49	52.05
Non-Agricultural Area	354.33	25.18	258.83	18.39	206.5	14.67
Waters	0.79	0.06	0.79	0.06	0.79	0.06
Total	1407.17	100.00	1407.17	100.00	1407.17	100.00

Figure 4 shows that the settlements development pattern is heading eastward. The rate of population growth that continues to increase in line with development in all fields has resulted in the emergence of new problems, namely the increasing need for residential land as a demand for living needs in addition to clothing and food needs (Salakory & Rakuasa, 2022). Central Ternate subdistrict which is the center of ternate City as well as the center of education, economy, and government makes the flow of urbanization that is getting higher every year, the movement of residents from rural to urban. This is certainly one of the factors that trigger changes in cover in Central Ternate District.

Ajeeb et al., (2020) argue that population movement from rural to urban, brings substantial and diverse changes to urban land, both in land use and land cover. Rakuasa et al., (2022b) also added that the increase in the number of people is in line with the increase in human activities in various sectors, especially the economic sector, making the need for land resources will also continue to increase.

3.2. Land Cover Simulation in 2022

Simulations were carried out using CA-Markov using previously created driving factors. The probability of a change occurring or not is known from the Markovian value (Markov Chains Value) or the Transition Probability Matrix (TPM). The amount from the Markovian value (Markov Chains Value) or the Transition Probability Matrix (TPM). The amount of TPM in the 2022 simulation is shown in Table 3an driving factors that have been made previously.

Ambon City land cover modeling in 2021 was carried out using Markov Chains and driving factors data that had been prepared. The magnitude of the possibility of land cover change is called the Transition Probability Matrix (TPM) while the figures contained in the SDGs table show the magnitude of the possibility of land cover that has changed into other land cover.

Table 3. Transition Probability Matrix (TPM) from 2012 - 2022

LU/LC	Settlements	Open Land	Agricultural Area	Non-Agricultural Area	Waters
Settlements	0.8500	0.0375	0.0375	0.0375	0
Open Land	0.5121	0.4879	0	0	0
Agricultural Area	0.2142	0	0.7858	0	0
Non-Agricultural Area	-	0	0.3789	0.6211	0
Waters	0	0	0	0	1

The magnitude of the Transition Probability Matrix (TPM) value in the range of 0-1. The number 0 indicates that there is no change in land cover in one area to another. Meanwhile, the number 1 indicates that the land cover will be fixed and will not change to other land cover. From table 3, it can be seen that open land has a higher probability of turning into Settlements with a TPM value of 0.5121.

After the 2022 land cover simulation is generated, an accuracy test is then carried out on the model to find out whether the model can be used to create a second model. The accuracy test was carried out by comparing the existing land cover data (in 2022) as a ground truth image using idrisi selva software where the kappa (Kstandard) value is 0.8960 or 89.60% which shows that this accuracy value is said to be very good and can be continued to model the land cover of The Central Ternate District in 2032. More details of the kappa test can be seen in Figure 5.

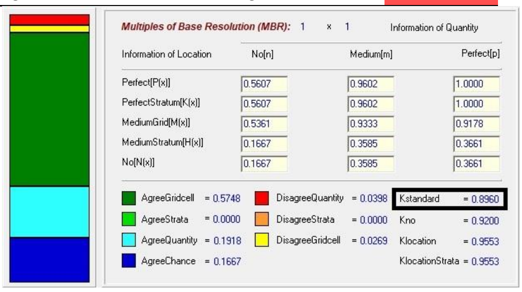

Fig 5. Validate 2022 Models with Kappa Test

Based on the results of land cover simulations in 2022, significant changes in land cover are found in residential land cover whose area has increased. This significant increase in the area of settlements occurred in the central and northern parts of Pariaman City. Meanwhile, land cover that has decreased occurs in agricultural land cover. For more details can be seen in Figures 6 and 7.

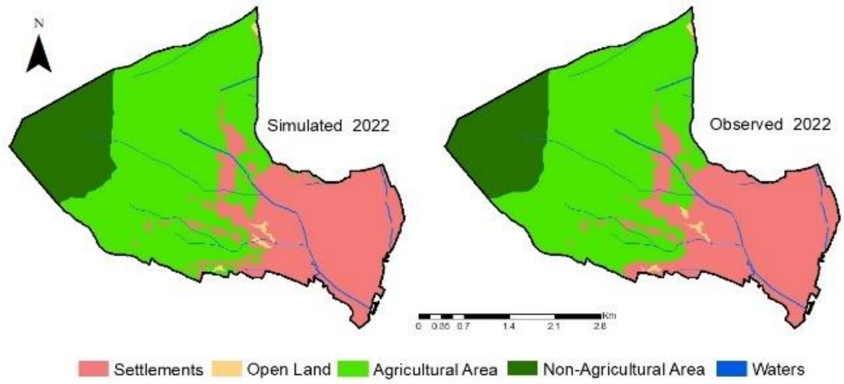

Fig 6. Comparison of simulated and observed land cover results in 2022

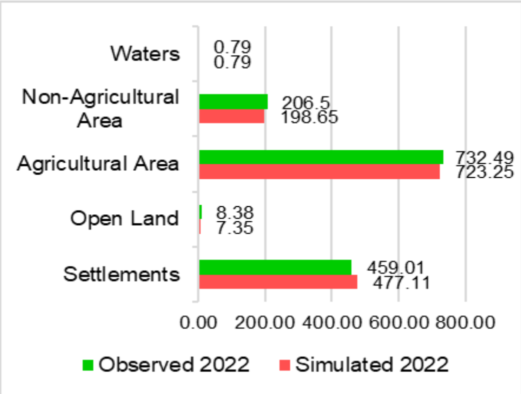

Fig 7. Comparison of land cover area in 2022 resulting from simulated and observed results

From the five land cover, it can be seen that Open Land has the greatest probability value to turn into residential land with a TPM value of 0.4680, followed by the type of Agricultural Area cover which has a TPM value of 0.1495. water land cover has a TPM value of 0 which means it will not change to other types of land cover. Based on the results of processing land cover simulations in Central Ternate District in 2032 using CA-MC in Figure 9, it is known that the type of residential land cover has an area of 503.91 ha, open land has an area of 7.35 ha, agricultural areas have an area of 696.46 ha, non-agricultural areas have an area of 198.65 and types of aquatic land cover have an area of 0.79 ha. The results of land cover analysis in 2012, 2017, 2022 and the 2031

Table 4. Transition Probability Matrix (TPM) from 2022 - 2032

LU/LC	Settlements	Open Land	Agricultural Area	Non-Agricultural Area	Waters
Settlements	0.8500	0.0375	0.0375	0.0375	0
Open Land	0.4680	0.5320	0	0	0
Agricultural Area	0.1495	0.0191	0.8314	0	0
Non-Agricultural Area	-	0	0.3231	0.6769	0
Waters	0	0	0	0	1

3.3. Land cover simulation in 2032

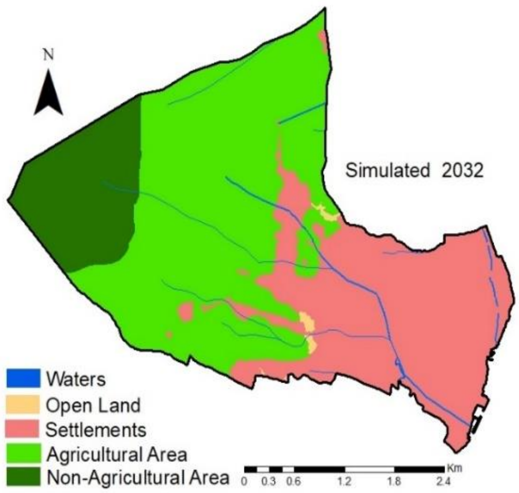

Fig 8. Results of land cover simulation in 2032

The 2032 land cover simulation in Central Ternate District is the second simulation, in this stage using the same driving factors and potential transition accuracy as in the first simulation, but using different macrovian values (Table 4), so that it will produce the 2032 model year (Figure 8).

Urban growth in Central Ternate District greatly affects changes in Land Use and Land Cover (LULC), this can be seen from the development of built-up land from 2002, 2012, 2022 and based on the results of modeling in 2031 the area of residential land will continue to experience an increase in area of 503.91 ha. The results of the land cover simulation of The Central Ternate District in 2032 can be used as information in evaluating the Ternate City RTRW in 2012-2032 and also as a basis for policy making related to the arrangement and utilization of space in the future, considering the geographical conditions of the Central Ternate District which is in the active volcano area, namely Mount Gamalama (Figure 9).

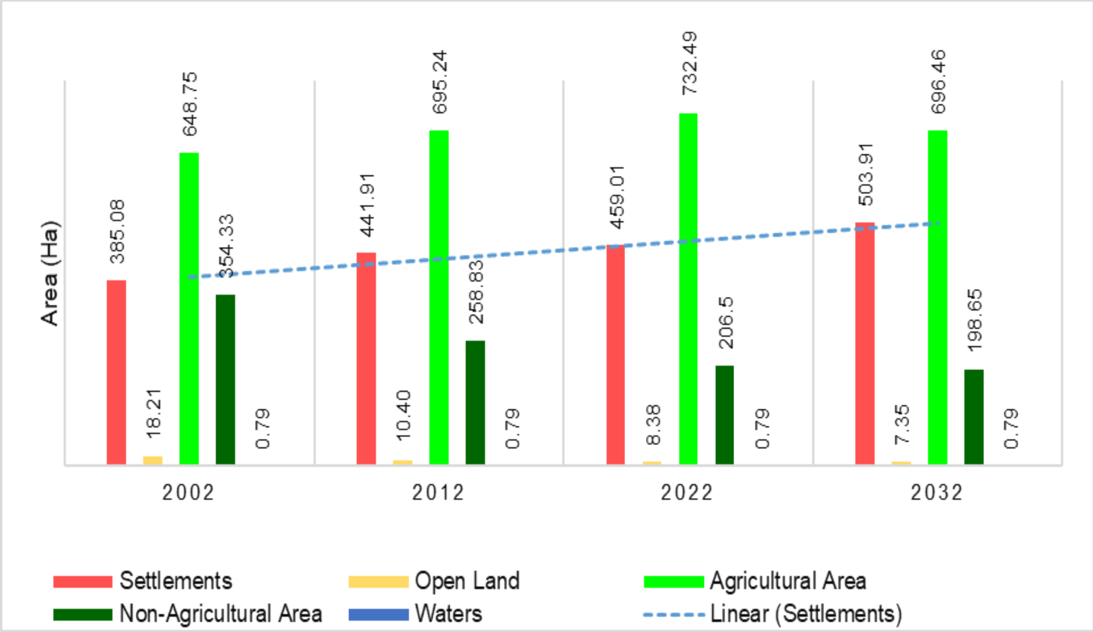

Fig 9. Development of Land Use and Land Cover in Central Ternate District

4. Conclusion

Over the last 15 years from 2012, 2017, 2022 and the results of the Celullar Automata Markov Chain model predictions in 2032 land cover in Central Ternate District continues to experience an increase in area. Land cover that has consistently increased in area is found in residential and open land cover. Land cover that has decreased in area is found in the land cover of agricultural areas and non-agricultural areas. Residential land will continue to experience an increase in area in line with population growth and high demand for land in Central Ternate District. Therefore, the results of this study are expected to be input in policy making related to the arrangement and utilization of disaster mitigation-based space in Central Ternate District in the future.

References

Ajeeb, R., Aburas, M. M., Baba, F., Ali, A., & Alazaiza, M. Y. D. (2020). The Prediction of Urban Growth Trends and Patterns using Spatio-temporal CA-MC Model in Seremban Basin. *IOP Conference Series: Earth and Environmental Science*, *540*(1), 012028. https://doi.org/10.1088/1755-1315/540/1/012028

Akbar, F., & Supriatna. (2019). Land cover modelling of Pelabuhanratu City in 2032 using celullar automata-markov chain method. *IOP Conference Series: Earth and Environmental Science*, *311*, 012071. https://doi.org/10.1088/1755-1315/311/1/012071

Alimuddin, A., Hariati, F., Fachruddin, F., Lutfi, M., & Rizki, M. (2022). Analysis of Land Cover Changes On Rainwater Runoff In Ciapus Sub-Watershed. *Journal of Applied Geospatial Information*, *6*(2), 620–625. https://doi.org/https://doi.org/10.30871/jagi.v6i2.4188

Almdhun, H. M., Mallak, S. K., Aburas, M. M., Md Said, M. A., & Ghadiri, S. M. (2018). Measuring and predicting urban growth patterns and trends in Putrajaya, Malaysia. *IOP Conference Series: Earth and Environmental Science*, *169*, 012114. https://doi.org/10.1088/1755-1315/169/1/012114

Badan Standarisasi Nasional. (2010). *SNI 7645-2010 tentang klasifikasi penutup lahan*.

BPS. (2021). *Kota Ternate Dalam Angka Tahun 2021* (BPS Kota Ternate (ed.)). BPS Kota Ternate.

Getu, K., & Bhat, H. G. (2022). Dynamic simulation of urban growth and land use change using an integrated cellular automata and markov chain models: a case of Bahir Dar city, Ethiopia. *Arabian Journal of Geosciences*, *15*(11), 1049. https://doi.org/10.1007/s12517-022-10304-1

Ghosh, P., Mukhopadhyay, A., Chanda, A., Mondal, P., Akhand, A., Mukherjee, S., Nayak, S. K., Ghosh, S., Mitra, D., Ghosh, T., & Hazra, S. (2017). Application of Cellular automata and Markov-chain model in geospatial environmental modeling- A review. *Remote Sensing Applications: Society and Environment*, *5*, 64–77. https://doi.org/https://doi.org/10.1016/j.rsase.2017.01.005

Han, Y., & Jia, H. (2017). Simulating the spatial dynamics of urban growth with an integrated modeling approach: A case study of Foshan, China. *Ecological Modelling*, *353*, 107–116. https://doi.org/10.1016/j.ecolmodel.2016.04.005

Hegazy, I. R., & Kaloop, M. R. (2015). Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt. *International Journal of Sustainable Built Environment*, *4*(1), 117–124. https://doi.org/10.1016/j.ijsbe.2015.02.005

Kisamba, F. C., & Li, F. (2022). Analysis and modelling urban growth of Dodoma urban district in Tanzania using an integrated CA–Markov model. *GeoJournal*. https://doi.org/10.1007/s10708-022-10617-4

Kushwaha, K., Singh, M. M., Singh, S. K., & Patel, A. (2021). Urban growth modeling using earth observation datasets, Cellular Automata-Markov Chain model and urban metrics to measure urban footprints. *Remote Sensing Applications: Society and Environment*, *22*, 100479. https://doi.org/10.1016/j.rsase.2021.100479

Marko, K., Zulkarnain, F., & Kusratmoko, E. (2016). Coupling of Markov chains and cellular automata spatial models to predict land cover changes (case study: upper Ci Leungsi catchment area). *IOP Conference Series: Earth and Environmental Science*, *47*, 012032. https://doi.org/10.1088/1755-1315/47/1/012032

Mohamed, A., & Worku, H. (2020). Simulating urban land use and cover dynamics using cellular automata and Markov chain approach in Addis Ababa and the surrounding. *Urban Climate*, *31*, 100545. https://doi.org/https://doi.org/10.1016/j.uclim.2019.100545

Rakuasa, H., Sihasale, D. A., & Latue, P. C. (2022). Model Tutupan Lahan di Daerah Aliran Sungai Kota Ambon Tahun 2031: Studi Kasus DAS Wai Batu Gantung, Wai Batu Gajah, Wai Tomu, Wai Batu Merah Dan Wai Ruhu. *Jurnal Tanah Dan Sumberdaya Lahan*, *9*(2), 473–486. https://doi.org/10.21776/ub.jtsl.2022.009.2.29

Rakuasa, H., Supriatna, S., Karsidi, A., Rifai, A., Tambunan, M. ., & Poniman K, A. (2022). Spatial Dynamics Model of Earthquake Prone Area in Ambon City. *IOP Conference Series: Earth and Environmental Science*, *1039*(1), 012057. https://doi.org/10.1088/1755-1315/1039/1/012057

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

Sarihi, Y. R., Tilaar, S., & Rengkung, M. M. (2020). Analisis penggunaan lahan di Pulau Ternate. *Spasial*, *7*(3), 259–268.

Sugandhi, N., Supriatna, S., Kusratmoko, E., & Rakuasa, H. (2022). Prediksi Perubahan Tutupan Lahan di Kecamatan Sirimau, Kota Ambon Menggunakan Celular Automata-Markov Chain. *JPG (Jurnal Pendidikan Geografi)*, *9*(2), 104–118. https://doi.org/http://dx.doi.org/10.20527/jpg.v9i2.13880

Sukojo, B.M ., Hidayat.M., & Santoso, R. (2017). Analisis Ketelitian Horizontal Orthorektifikasi Citra Pleiades Untuk Pembuatan Peta Dasar Rdtr Pesisir (Studi Kasus : Kecamatan Semampir, Kota Surabaya). *GEOID*, *12*(2), 136–142. https://doi.org/http://dx.doi.org/10.12962/j24423998.v12i2.3585

Umanailo, H. A., Franklin, P. J., & Waani, J. O. (2017). Perkembangan Pusat Kota Ternate (Studi Kasus: Kecamatan Ternate Tengah). *Spasial*, *4*(3), 222–233.

Wang, C., & Wang, Z. (2017). Projecting population growth as a dynamic measure of regional urban warming. *Sustainable Cities and Society*, *32*(February), 357–365. https://doi.org/10.1016/j.scs.2017.04.010

Xu, T., Zhou, D., & Li, Y. (2022). Integrating ANNs and Cellular Automata–Markov Chain to Simulate Urban Expansion with Annual Land Use Data. *Land*, *11*(7), 1074. https://doi.org/10.3390/land11071074