

## SPATIAL ANALYSIS OF LAND USE CHANGE IN SLAWI SUBDISTRICT, TEGAL REGENCY, 2014 - 2024 USING HIGH RESOLUTION SATELLITE IMAGERY DATA

Heinrich Rakuasa<sup>1\*</sup>, Panji Nurul Achmadi

<sup>1</sup>National Research Tomsk State University, Russian Federation

<sup>2</sup>Universitas Indonesia, Indonesia

[heinrichrakuasa01@gmail.com](mailto:heinrichrakuasa01@gmail.com)<sup>1</sup>

Received: 12-04-2024

Revised: 21-04-2024

Approved: 30-04-2024

### ABSTRACT

*This research aims to analyze land use change in Slawi Sub-district, Tegal Regency, from 2014 to 2024 using high-resolution satellite image data. This study used Worldview-2 high resolution satellite image data in 2014 and Geoeye-1 in 2024. This study was classified into 14 land use classes consisting of rivers, roads, railways, agriculture, green open space, other vegetation, industry, housing, government, public service facilities, trade services, transportation, defense and security and open land. The spatial analysis method was used to map changes in land area based on the main use classes such as agriculture, housing, and infrastructure. The results showed a significant decrease in agricultural land area as well as an increase in residential land area and infrastructure, reflecting the changing pattern of regional growth and development. In conclusion, an in-depth understanding of land use dynamics in Slawi Sub-district is important to support environmental management policies, natural resource conservation, and sustainable regional development in the future.*

**Keywords:** Satellite Imagery, Land Use, Slawi

### INTRODUCTION

Land use refers to the modifications made by humans to the living environment, such as fields, agriculture, and settlements [1],[2]. Land use also includes the land cover of the earth's surface and the use of that land cover in an area [3], [4]. Land use information is different from land cover information that can be recognized directly from remote sensing satellite images [5], [6]. Land use is the result of human activities in a land or land use or land function, so it cannot always be assessed directly from remote sensing images, but can be indirectly recognized from the association of land cover [7], [8]. Land use has adverse side effects such as deforestation, erosion, soil degradation, desert formation, and increased soil salinity [9], [10]. Land use can be related to land use planning, which is planning in the utilization and use of land in an area so that it has its own function [11], [12]. Thus, land use is an important aspect in environmental management and spatial planning.

Land use change is the process by which an area or region undergoes a change in the type of land use over time [13],[14]. This change can involve a shift from one type of land use to another, such as a change from agricultural land to residential land, forest land to industrial land, and so on [15],[16]. Land use change can be influenced by various factors, including population growth, urbanization, government policies, and socio-economic changes [17], [18].

This research is based on the need for a deeper understanding of the dynamics of land use in the region over the past decade. Slawi Sub-district, located in Tegal Regency, Indonesia, is an area that experienced significant growth and development during this

period [19]. Population growth, urbanization, and economic activities are the main factors influencing changes in land use patterns [20]. Slawi sub-district is geographically and economically important in the context of Tegal regency. As an administrative, commercial, and educational center, changes in land use here can have a major impact on surrounding social, economic, and environmental developments [21].

In addition, global climate change and rapid urbanization have significantly altered the landscape of Slawi Sub-district during the period under investigation. These changes include conversion of agricultural land to housing or infrastructure, deforestation for commercial development, as well as an increase in built-up surface area. In the context of sustainable development, an in-depth understanding of land use change is crucial. Spatial analysis using high-resolution image data makes it possible to identify, map and analyze land change with a high level of detail, which in turn can support better decision-making in environmental planning and regional development. In addition, this study is also relevant in the context of natural resource and environmental conservation. Changes in land use often result in ecosystem damage, habitat loss and environmental degradation [22]. By understanding these change patterns, protection and restoration measures can be designed and implemented to maintain ecological balance and environmental sustainability [23]. In addition to environmental aspects, understanding land use change also has significant social and economic implications [24]. Changes in land use patterns can affect the livelihoods, access to resources and well-being of local communities. Therefore, this analysis can also provide insights into the social and economic impacts of such changes. In the context of development planning, an understanding of land use change is also very important [25]. This analysis can provide valuable information for the government and other stakeholders in designing sustainable and effective development policies, programs and projects. This research can also serve as a foundation for further, more in-depth studies on the dynamics of land use and its influencing factors in Slawi Sub-district, Tegal Regency, as well as the surrounding areas. With a better understanding of land use change, more effective measures can be taken to maintain environmental, economic and social sustainability in the future.

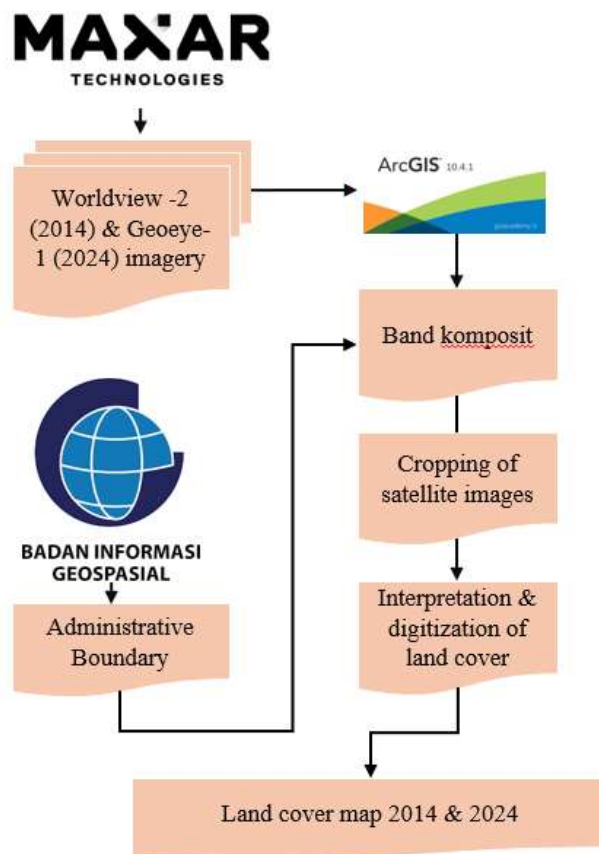
## **RESEARCH METHODS**

This research was conducted in Slawi Sub-district, Tegal Regency, Central Java Province, which has a high development of land cover, especially built-up areas, among other sub-districts in Central Java Province. This research began with a preparatory phase containing literature studies from books, journals, or from the internet. The literature study was conducted to understand the basic theories related to land use change. After the preparation stage, the next stage is data collection. The data collected consists of primary data and secondary data, where this research uses a lot of secondary data. The primary data used in this research, namely Worldview-2 high-resolution satellite image data in 2014 (50 cm resolution) and Geoeye-1 in 2024 (40 cm resolution), was obtained from Maxar Technologies, a space technology company headquartered in Westminster, Colorado, United States, and has a representative office in Singapore. The company specializes in the provision of communications, Earth observation, radar and orbiting satellites, satellite products and other services.

Worldview -2 Satellite Imagery Data is a commercial remote sensing satellite

launched by DigitalGlobe in 2009. It is equipped with a multispectral camera system that can produce imagery with a spatial resolution of up to 50 cm. GeoEye-1 is a remote sensing satellite launched by GeoEye in 2008. This satellite is equipped with a multispectral camera that can produce imagery with a spatial resolution of up to 41 cm. The research used administrative boundary data in Slawi Subdistrict, Tegal Regency, Central Java Province obtained from the Geospatial Information Agency (BIG). Worldview -2 satellite image data in 2014 and Geoeeye-1 in 2024 obtained from Maxar Technologies has been carried out an orthorectification correction process. and RGB band compositing has been carried out. The following are some of the data processing stages carried out including:

- 1) Digitization was carried out to create a land use map and view settlements in the study area, with visual image interpretation using the interpretation key. Digitization was done using ArcMap software. Digitization was conducted to obtain actual 2014 and 2024 land use area data and temporal land use fraction.
- 2) Interpretation of land use is done based on interpretation keys, namely hue or color, shape, size, texture, pattern, shadow, site, and association. In addition, interpretation is carried out based on land use classification referring to Permen Agraria/Head of BPN No. 14 of 2021 which consists of land use classes of rivers, roads, railways, agriculture, green open space, other vegetation, industry, housing, government, public service facilities, trade services, transportation, security defense and open land. The complete research workflow can be seen in Figure 1.

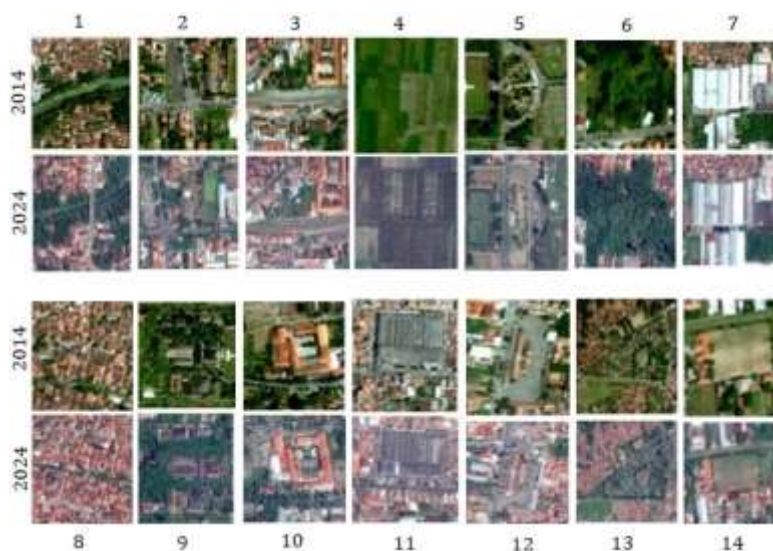


**Figure 1.** Workflow

**RESULTS AND DISCUSSION**

**Interpretation of High Resolution Satellite Imagery**

Land use data is obtained through interpretation of high-resolution satellite imagery, with the method used being visual interpretation. For urban areas with large-scale and high-resolution satellite image data, visual image interpretation produces better land use data in terms of data completeness and accuracy [26]. Land use interpretation is done with the interpretation key and local knowledge of the interpreter. Each land use has a different interpretation key for recognizing its objects on satellite imagery. In Figure 2 part (1) rivers can be identified by their linear pattern, texture, and color which are different from the surrounding environment. Rivers usually have a clear shape and direction of flow. The key to interpretation is to look at the flow pattern, the shape of the river, and the association with other elements such as bridges and riverbanks. In the image above part (2) the road is seen as a darker or lighter line pattern depending on the hue of the image, elongated in shape and cutting through land with certain characteristics. The interpretation keys used are the size of the road, its shape and direction, and association with roadside buildings. In Figure 2 part (3), it can be seen that the railway line is a straight line that is wider than the road. The interpretation keys used are the longitudinal pattern of the rail line and the association with the station. Agricultural land (Figure 2 part 3) has a regular pattern and can be distinguished by its dark or light green color with smooth texture and boxy shape. The interpretation keys used are green color/tone, pattern, shape, texture and size.



**Figure 2.** Comparison of 2014 and 2024 High Resolution satellite imagery of each of the 14 land use types in Slawi sub-district

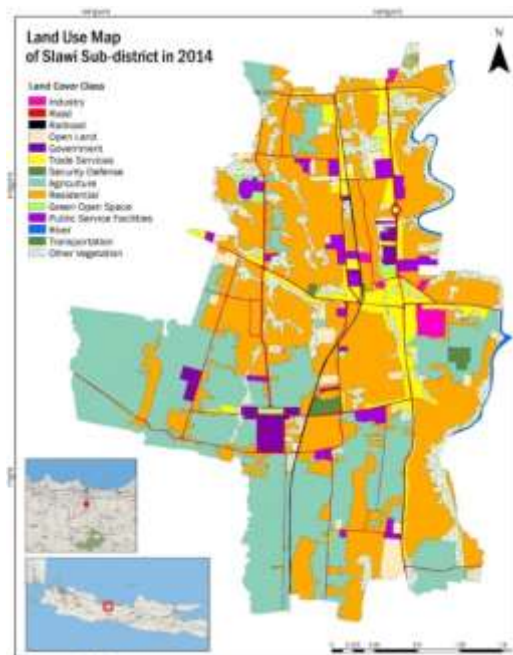
In Figure 2 part (5) it can be seen that green open spaces are characterized by regular and uniform vegetation with brighter colors compared to other land cover types. The interpretation keys used are hue pattern, bright green color, regular pattern, and association with government offices. Other vegetation includes forest, shrubs, or

overgrown land that is not categorized as agriculture or green open space. The interpretation keys used are density, dark green color, rough texture, and random pattern shown in Figure 2 part 6. In Figure 2 part 7, it can be seen that the industrial area has a dense pattern of buildings and structures, a larger size than other building objects, and has a roof with a bright hue and white color. The interpretation keys used are hue/color, pattern, and size. Housing can be recognized by the regular pattern of buildings, uniform size and located in urban or suburban areas as can be seen in figure 2 section 8. The key to interpretation uses size, pattern, and rough texture and association with roads.

Government areas include government buildings, such as administrative buildings, government offices, or other public institutions as can be seen in figure 2 section 9. The interpretation key takes into account the structure of the building and the association with public open spaces and roads. Public service facilities include hospitals, schools, and other important facilities that serve the community. The interpretation key notices the square shape, the size of the building is larger than residential, and the association with other public service facilities can be seen in Figure 2 section 10. The trade and service area includes shopping centers, markets, hotels, and the like. The interpretation key pays attention to the square shape, large size compared to housing, association with parking lots and arterial roads in Figure 2 section 11. The transportation area in Slawi Sub-district is a bus terminal. The key to interpretation used is the pattern of the terminal which has 2 access doors, an elongated shape, and association with bus parking lots (Figure 2 section 12). The security defense area includes military bases, defense facilities, and other restricted zones. The keys to interpretation are the regular pattern of buildings and roads, dark green roof hue and color, and association with a large field (Figure 2 section 13). Open fields are areas that do not have significant structures or vegetation. The key to interpretation is a brighter hue than the surrounding objects, no buildings or little vegetation on it, has a finer texture than vegetation or buildings can be seen in Figure 2 section 14.

#### **Land Use of Selawi Sub-district in 2014**

Land use in Selawi Subdistrict 2014 is classified into 14 classes, namely Industry, road, railroad, open land, government, trade services, security, defense, agriculture, residential, green open space, public service facilities, river, transportation and other vegetation. The industrial area has an area of 12.61 hectares with a percentage area of 0.82%. This shows that industry plays an important role in land use in Slawi Sub-district, covering a small portion of the total land area.



**Figure 3.** Land Use Map 2014

The road area is 37.17 hectares with a percentage area of 2.42%. Roads play an important role in the infrastructure of the sub-district, covering a small portion of the total land. Railroad area: The area is 5.92 hectares with a percentage area of 0.39%. Railways represent an important transportation infrastructure for the connectivity of the area. In Figure 3 the open land area has an area of 43.45 hectares with a percentage area of 2.83%. Open land includes open spaces that have not been developed or used for other purposes. The government area has an area of 26.26 hectares with a percentage area of 1.71%. This indicates an area used by the government for various administrative purposes. The trade service area has an area of 91.55 hectares with a percentage area of 5.96%. Trade services include areas used for trading activities, such as markets and shops. The defense and security area has an area of 10.84 hectares with a percentage area of 0.71%. This indicates that there are areas used for defense and security purposes. The agriculture area has an area of 490.50 hectares with a percentage area of 31.92%. Agriculture includes areas used for agricultural production, being the largest land use class.

Residential areas have an area of 605.60 hectares with a percentage area of 39.41%. Housing covers the area used for housing development, being the second largest land use class. The green open space area has an area of 8.29 hectares with a percentage area of 0.54%. Green open space includes areas used for recreation and nature conservation. The public service facility area has an area of 36.84 hectares with a percentage area of 2.40%. Public service facilities include areas used for health, education and other facilities. The river area has an area of 8.19 hectares with a percentage area of 0.53%. Rivers include areas used for irrigation and natural purposes. The transportation area has an area of 3.20 hectares with a percentage area of 0.21%. Transportation includes areas used for other transportation infrastructure. Other vegetated areas have an area of 156.37 hectares with an area percentage of 10.18%. Other vegetation includes areas used for other purposes such as forests and

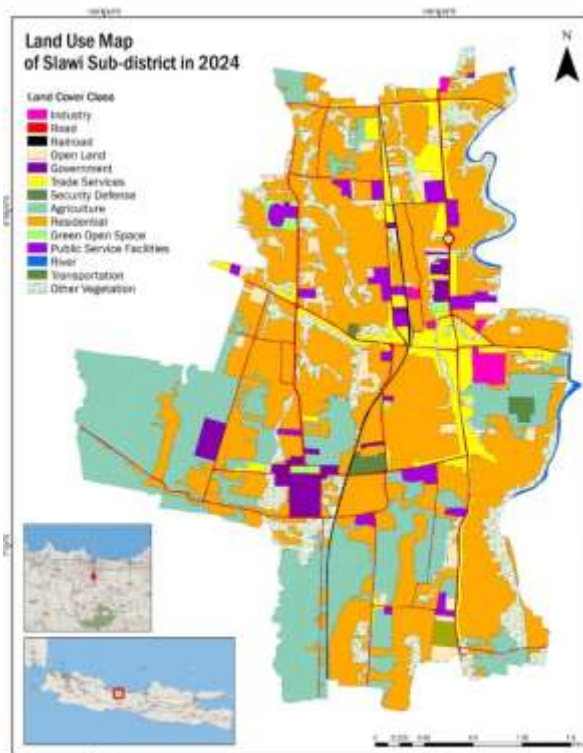
green fields. The results show that land use in Slawi Sub-district in 2014 was dominated by agriculture and housing, with significant percentages of area. This reflects the focus on sustainable economic and infrastructure development in the area.

#### **Land Use of Selawi Sub-district in 2024**

In 2024 the Industrial area in Slawi Sub-district has an area of 12.61 hectares with a percentage area of 0.77%. This shows that industry plays an important role in land use in Slawi Sub-district, covering a small portion of the total land. The Road land use type has an area of 37.17 hectares with a percentage area of 2.28%. Roads play an important role in the infrastructure of the sub-district, covering a small portion of the total land. Railroad area has an area of 5.92 hectares with a percentage area of 0.36%. Railways represent important transportation infrastructure for regional connectivity. The open land area has an area of 43.69 hectares with a percentage area of 2.67%. Open land includes open spaces that have not been developed or used for other purposes.

The results of digitization and interpretation show that the government area has an area of 31.21 hectares with a percentage area of 1.91%. This indicates an area used by the government for various administrative purposes. The trade services land use type has an area of 96.69 hectares with a percentage area of 5.92%. Trade services include areas used for trading activities, such as markets and shops. Defense and security area has an area of 10.84 hectares with a percentage area of 0.66%. This indicates that there are areas used for defense and security purposes. The agriculture area has an area of 374.04 hectares with a percentage area of 22.89%. Agriculture includes areas used for agricultural production, being the largest land use class. The residential land use type has an area of 794.38 hectares with a percentage area of 48.62%. Housing covers the area used for housing construction, being the second largest land use class.

The green open space area has an area of 8.29 hectares with a percentage area of 0.51%. Green open space includes areas used for recreation and nature conservation. The public service facility land use type has an area of 39.17 hectares with a percentage area of 2.40%. Public service facilities include areas used for health, education and other facilities. Rivers have an area of 8.19 hectares with a percentage area of 0.50%. Rivers include areas used for irrigation and natural purposes. The transportation land use type has an area of 5.21 hectares with a percentage area of 0.32%. Transportation includes areas used for other transportation infrastructure. The other vegetation land use type has an area of 166.53 hectares with an area percentage of 10.19%. Other vegetation includes areas used for other purposes such as forests and green fields. Overall, the results show that land use in Slawi Sub-district in 2024 is dominated by agriculture and housing, with significant percentages of area. This reflects the focus on sustainable economic and infrastructure development in the area. The spatial land use of Slawi Sub-district in 2024 can be seen in Figure 4.



**Figure 4.** Land Use Map 2024

The land use of Slawi Sub-district in 2014 and 2024 experienced no significant changes. The land area for industry, road and rail remained stable from 2014 to 2024, indicating that there were no significant changes in land use for these three classes over the period. Although there is a slight increase in the area of open land from 43.45 hectares in 2014 to 43.69 hectares in 2024, this change is relatively small and may not be statistically significant. The land area for government and public service facilities has increased from 2014 to 2024. Government land increased from 26.26 hectares to 31.21 hectares, while public service facilities increased from 36.84 hectares to 39.17 hectares. The land area for trade and services also experienced a significant increase from 91.55 hectares in 2014 to 96.69 hectares in 2024, indicating the growth of this sector in the ten-year period.

One of the most significant changes is the decrease in agricultural land from 490.50 hectares in 2014 to 374.04 hectares in 2024. This indicates the conversion of agricultural land to other land uses, possibly due to urbanization or industrial and residential development. Residential land area experienced a significant increase from 605.60 hectares in 2014 to 794.38 hectares in 2024. This indicates urban growth and increased housing development in the area. Land area for transportation also increased from 3.20 hectares in 2014 to 5.21 hectares in 2024, indicating a possible increase in transportation infrastructure such as roads or terminals. The land area for other vegetation also experienced a significant increase from 156.37 hectares in 2014 to 166.53 hectares in 2024. Thus, overall, land use change in Slawi Sub-district from 2014 to 2024 reflects changes in the pattern of growth and development of the area, with a significant decrease in the area of agricultural land and a significant increase in the area of residential land, trade, and public service infrastructure. Based on the results of field

validation in 2024, the change of use in Slawi Sub-district is dominated by agricultural land into housing. The housing land is in the form of middle-class housing and high-class housing. The characteristics of the housing location are close to collector roads and the city center.

Using high-resolution satellite image data to analyze land use change in Slawi Sub-district has several significant benefits:

- 1) **High Resolution Change Detection:** High-resolution satellite imagery enables the identification of land use change with a high level of detail [27]. This allows users to detect changes even on a relatively small scale, such as conversion of agricultural land to housing or infrastructure development.
- 2) **Periodic Monitoring:** High-resolution satellite image data can be used for periodic monitoring of land use change over time [28]. This allows stakeholders to understand long-term trends in land use, identify patterns of change, and plan for sustainable regional development.
- 3) **In-depth Spatial Analysis:** High-resolution satellite imagery provides rich and detailed spatial information on land use in Slawi Sub-district. This allows for more in-depth analysis of the spatial distribution of land use, identification of relationships between different land use classes, and mapping of potential land use conflicts.
- 4) **High Accuracy Change Mapping:** High-resolution satellite imagery enables mapping of land use change with high accuracy [29]. This allows stakeholders to precisely identify the location, type, and scale of change, thus providing a solid basis for decision-making.
- 5) **Integration with Other Data:** High-resolution satellite imagery data can be easily integrated with other data, such as spatial data, demographic data, or other environmental data [30]. This allows for a more holistic and comprehensive analysis of the factors that influence land use change in Slawi Sub-district.

Thus, using high-resolution satellite image data for land use change analysis in Slawi Sub-district can provide a better understanding of land use dynamics, support better decision-making, and assist in sustainable and effective regional development planning.

## **CONCLUSION**

The results of this study provide an in-depth understanding of the dynamics of land use change and its impact on social, economic and environmental development in Slawi Sub-district. Using high-resolution satellite image data, this research provides detailed information on land use change from 2014-2024, enabling high-accuracy change detection, periodic monitoring, in-depth spatial analysis, high-accuracy change mapping, and integration with other data. The results of this study are expected to support better decision-making in environmental planning, natural resource conservation, and sustainable regional development in Slawi Sub-district as well as the surrounding areas.

## **REFERENCES**

- [1] P. C. Manakane, S. E., Rakuasa, H., & Latue, 'Pemanfaatan Teknologi Penginderaan Jauh dan Sistem Informasi Geografis untuk Identifikasi Perubahan Tutupan Lahan

- di DAS Marikurubu, Kota Ternate', *Tabela J. Pertan. Berkelanjutan*, vol. 1, no. 2, pp. 51–60, 2023, doi: <https://jurnal.ilmubersama.com/index.php/tabela/article/view/301#:~:text=DOI%3A-,https%3A//doi.org/10.56211/tabela.v1i2.301,-Keywords%3A%20Marikurubu>.
- [2] S. Talukdar *et al.*, 'Land-Use Land-Cover Classification by Machine Learning Classifiers for Satellite Observations—A Review', *Remote Sens.*, vol. 12, no. 7, p. 1135, Apr. 2020, doi: 10.3390/rs12071135.
- [3] H. Rakuasa, D. A. Sihasale, G. Somae, and P. C. Latue, 'Prediction of Land Cover Model for Central Ambon City in 2041 Using the Cellular Automata Markov Chains Method', *J. Geosains dan Remote Sens.*, vol. 4, no. 1, pp. 1–10, May 2023, doi: 10.23960/jgrs.2023.v4i1.85.
- [4] Y. Rakuasa, H., & Pakniyany, 'Spatial Dynamics of Land Cover Change in Ternate Tengah District, Ternate City, Indonesia', *Forum Geogr.*, vol. 36, no. 2, pp. 126–135, 2022, doi: DOI: 10.23917/forgeo.v36i2.19978.
- [5] P. N. Achmadi, M. Dimiyati, M. D. M. Manesa, and H. Rakuasa, 'MODEL PERUBAHAN TUTUPAN LAHAN BERBASIS CA-MARKOV: STUDI KASUS KECAMATAN TERNATE UTARA, KOTA TERNATE', *J. Tanah dan Sumberd. Lahan*, vol. 10, no. 2, pp. 451–460, Jul. 2023, doi: 10.21776/ub.jtsl.2023.010.2.28.
- [6] H. Rakuasa, 'Analisis Spasial - Temporal Perubahan Tutupan Lahan di Kabupaten Maluku Barat Daya', *Geogr. J. Pendidik. dan Penelit. Geogr.*, vol. 3, no. 2, pp. 115–122, Dec. 2022, doi: 10.53682/gjppg.v3i2.5262.
- [7] H. Rakuasa, S. Supriatna, A. Karsidi, A. Rifai, M. . Tambunan, and A. Poniman K, 'Spatial Dynamics Model of Earthquake Prone Area in Ambon City', *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1039, no. 1, p. 012057, Sep. 2022, doi: 10.1088/1755-1315/1039/1/012057.
- [8] H. Rakuasa and P. C. Latue, 'ANALISIS SPASIAL DAERAH RAWAN BANJIR DI DAS WAE HERU, KOTA AMBON', *J. Tanah dan Sumberd. Lahan*, vol. 10, no. 1, pp. 75–82, Jan. 2023, doi: 10.21776/ub.jtsl.2023.010.1.8.
- [9] J. S. I. Septory, P. C. Latue, and H. Rakuasa, 'Model Dinamika Spasial Perubahan Tutupan Lahan dan Daya Dukung Lahan Permukiman Kota Ambon Tahun 2031', *Geogr. J. Pendidik. dan Penelit. Geogr.*, vol. 4, no. 1, pp. 51–62, Jun. 2023, doi: 10.53682/gjppg.v4i1.5801.
- [10] A. Senamaw, T. Gashaw, and M. A. Ehsan, 'Impacts of Land-Use/Land-Cover Changes on Water-Borne Soil Erosion Using Geospatial Technologies and RUSLE Model over Chimbel Watershed of Upper Blue Nile Basin in Ethiopia', *Earth Syst. Environ.*, vol. 6, no. 2, pp. 483–497, 2022, doi: 10.1007/s41748-021-00259-w.
- [11] K. Jafarpour Ghalehtemouri, A. Shamsoddini, M. N. Mousavi, F. Binti Che Ros, and A. Khedmatzadeh, 'Predicting spatial and decadal of land use and land cover change using integrated cellular automata Markov chain model based scenarios (2019–2049) Zarriné-Rūd River Basin in Iran', *Environ. Challenges*, vol. 6, p. 100399, 2022, doi: <https://doi.org/10.1016/j.envc.2021.100399>.
- [12] H. Rakuasa, D. A. Sihasale, and P. C. Latue, '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', *J. Tanah dan Sumberd. Lahan*, vol. 9, no. 2, pp. 473–486, Jul. 2022, doi: 10.21776/ub.jtsl.2022.009.2.29.
- [13] R. Yunita, S. F. Pratiwi, B. P. Pambudi, and H. Rakuasa, 'Evaluasi Kesesuaian Lahan

- untuk Budidaya Perikanan Tambak Terhadap Rencana Pola Ruang di Kabupaten Barru Provinsi Sulawesi Selatan', *J. Geogr. Media Inf. Pengemb. dan Profesi Kegeografian*, vol. 19, no. 1, pp. 10–17, Jun. 2022, doi: 10.15294/jg.v19i1.32201.
- [14] H. Latue, P. C., & Rakuasa, 'Analysis of Land Cover Change Due to Urban Growth in Central Ternate District, Ternate City using Cellular Automata-Markov Chain', *J. Appl. Geospatial Inf.*, vol. 7, no. 1, pp. 722–728, 2023, doi: <https://doi.org/10.30871/jagi.v7i1.4653>.
- [15] A. Rienow, J. Schweighöfer, T. Dedring, M. Goebel, and V. Graw, 'Detecting land use and land cover change on Barbuda before and after the Hurricane Irma with respect to potential land grabbing: A combined volunteered geographic information and multi sensor approach', *Int. J. Appl. Earth Obs. Geoinf.*, vol. 108, p. 102732, 2022, doi: <https://doi.org/10.1016/j.jag.2022.102732>.
- [16] S. W. Wang, L. Munkhnasan, and W.-K. Lee, 'Land use and land cover change detection and prediction in Bhutan's high altitude city of Thimphu, using cellular automata and Markov chain', *Environ. Challenges*, vol. 2, p. 100017, 2021, doi: <https://doi.org/10.1016/j.envc.2020.100017>.
- [17] A. R. Somae, G., Supriatna, S., Rakuasa, H., & Lubis, 'PEMODELAN SPASIAL PERUBAHAN TUTUPAN LAHAN DAN PREDIKSI TUTUPAN LAHAN KECAMATAN TELUK AMBON BAGUALA MENGGUNAKAN CA-MARKOV', *J. Sains Inf. Geogr. (J SIG)*, vol. 6, no. 1, pp. 10–19, 2023, doi: <http://dx.doi.org/10.31314/jsig.v6i1.1832>.
- [18] H. Latue, P. C., Septory, J. S. I., & Rakuasa, 'Perubahan Tutupan Lahan Kota Ambon Tahun 2015, 2019 dan 2023', *JPG (Jurnal Pendidik. Geogr.)*, vol. 10, no. 1, pp. 177–186, 2023, doi: <http://dx.doi.org/10.20527/jpg.v10i1.15472>.
- [19] M. Banowati, E., & Arifien, 'Pengaruh Pertambahan Penduduk Terhadap Perkembangan Permukiman Di Kecamatan Slawi Kabupaten Tegal Tahun 2000-2010', *Geo-Image J.*, vol. 1, no. 1, pp. 1–6, 2012, doi: <https://doi.org/10.15294/geoimage.v1i1.939>.
- [20] H. Latue, P. C., Manakane, S. E., & Rakuasa, 'Analisis Perkembangan Kepadatan Permukiman di Kota Ambon Tahun 2013 dan 2023 Menggunakan Metode Kernel Density', *Blend Sains J. Tek.*, vol. 2, no. 1, pp. 26–34, 2023, doi: <https://doi.org/10.56211/blendsains.v2i1.272>.
- [21] BPS, *Kecamatan Slawi Dalam Angka 2023*. BPS Kecamatan Slawi, 2023.
- [22] R. Girma, C. Fürst, and A. Moges, 'Land use land cover change modeling by integrating artificial neural network with cellular Automata-Markov chain model in Gidabo river basin, main Ethiopian rift', *Environ. Challenges*, vol. 6, p. 100419, 2022, doi: <https://doi.org/10.1016/j.envc.2021.100419>.
- [23] Y. P. Heinrich Rakuasa, Dzaka A Faris, Philia Christi Latue, 'Analysis of Indonesia's Foreign Policy in the Face of Climate Change: A Review from an International Relations Perspective', *J. Int. Multidiscip. Res.*, vol. 2, no. 4, pp. 41–48, 2024, doi: <https://doi.org/10.62504/bx9g2j06>.
- [24] H. Rakuasa and Y. Pakniany, 'Urbanization and Social Change in Ambon City: Challenges and Opportunities for Local Communities', *Pancasila Int. J. Appl. Soc. Sci.*, vol. 2, no. 01, pp. 12–18, Nov. 2023, doi: 10.59653/pancasila.v2i01.331.
- [25] G. S. Heinrich Rakuasa, 'Analisis Spasial Kesesuaian dan Evaluasi Lahan Permukiman di Kota Ambon', *J. Sains Inf. Geogr. (J SIG)*, vol. 5, no. 1, pp. 1–9, 2022, doi: DOI: <http://dx.doi.org/10.31314/j%20sig.v5i1.1432>.
- [26] M. Sapena and L. Á. Ruiz, 'Computers , Environment and Urban Systems Analysis of

- land use / land cover spatio-temporal metrics and population dynamics for urban growth characterization', *Comput. Environ. Urban Syst.*, vol. 73, no. August 2018, pp. 27–39, 2019, doi: <https://doi.org/10.1016/j.compenvurbsys.2018.08.001>.
- [27] P. Zhang, Y. Ke, Z. Zhang, M. Wang, P. Li, and S. Zhang, 'Urban Land Use and Land Cover Classification Using Novel Deep Learning Models Based on High Spatial Resolution Satellite Imagery', *Sensors*, vol. 18, no. 11, p. 3717, Nov. 2018, doi: [10.3390/s18113717](https://doi.org/10.3390/s18113717).
- [28] P. C. Latue and H. Rakuasa, 'ANALISIS SPASIAL PERUBAHAN TUTUPAN LAHAN DI DAS WAE BATUGANTONG, KOTA AMBON', *J. Tanah dan Sumberd. Lahan*, vol. 10, no. 1, pp. 149–155, Jan. 2023, doi: [10.21776/ub.jtsl.2023.010.1.17](https://doi.org/10.21776/ub.jtsl.2023.010.1.17).
- [29] H. R. Philia Christi Latue, 'Dinamika Spasial Wilayah Rawan Tsunami di Kecamatan Nusaniwe, Kota Ambon, Provinsi Maluku', *J. Geosains dan Remote Sens.*, vol. 3, no. 2, pp. 77–87, 2022, doi: <https://doi.org/10.23960/jgrs.2022.v3i2.98>.
- [30] D. E. Alexakis, G. D. Bathrellos, H. D. Skilodimou, and D. E. Gamvroula, 'Land Suitability Mapping Using Geochemical and Spatial Analysis Methods', *Appl. Sci.*, vol. 11, no. 12, p. 5404, Jun. 2021, doi: [10.3390/app11125404](https://doi.org/10.3390/app11125404).