Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
ISSN: 2086-6135 E-ISSN: 2541-612x

Volume 15 No. 3. September 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

PREDICTION OF WATER INFILTRATION CONDITIONS DUE TO LAND COVER CHANGE IN THE BOLON RIVER WATERSHED

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ARTICLE HISTORY
Received : 23-07-2026
Revised : 20-08-2026
Accepted : 21-09-2026

KEYWORDS
Land cover change
water infiltration
condition CA-MC
WMCA-AHP
ANN

ABSTRACT
Land cover changes over the past two decades have resulted in a significant decline in water infiltration capacity, particularly in regions experiencing high development pressure such as the Bolon Watershed in North Sumatra. This decline is closely associated with the conversion of natural vegetation to residential areas and built-up land. This study aims to predict water infiltration conditions in the Bolon Watershed over the next ten years using an integrated spatial-temporal approach. Three methodologies were employed: Cellular Automata-Markov Chain (CA-MC) for projecting land cover changes, Weighted Multi-Criteria Analysis (WMCA) based on Analytic Hierarchy Process (AHP) for multi-parameter assessment, and Artificial Neural Network (ANN) to capture nonlinear relationships among environmental variables. The results indicate that although areas with high infiltration capacity remain dominant, their extent tends to decrease. Conversely, areas with very low infiltration capacity show an increasing trend, reflecting the continuous pressure of urbanization. The most influential variables affecting land infiltration capacity are land cover, soil texture, slope gradient, and precipitation, with expert assessment results demonstrating acceptable consistency. This study emphasizes the importance of integrating predictive spatial methods in spatial planning to identify priority conservation areas. Through this approach, data-driven policy formulation becomes more accurate in preventing the degradation of ecological functions in water infiltration areas.

INTRODUCTION

Land cover plays a crucial role in regulating the balance of hydrological systems, particularly in supporting the function of water infiltration areas. Areas that remain covered by natural vegetation such as forests, shrublands, and grasslands possess high capacity for absorbing rainwater into the soil through infiltration processes (Mahapatra et al., 2020). This vegetation also helps to slow surface runoff and maintain soil structure stability. Conversely, land use conversion to residential areas, roads, or intensive agriculture causes a decline in soil absorption capacity and increases the risk of surface water runoff (Rauf & Rahmawaty, 2024). The dynamics of land use change in recent decades have exerted significant pressure on the sustainability of water infiltration areas. Population growth rates, residential expansion, and infrastructure development have resulted in the conversion of vegetated land into impervious surfaces that drastically

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reduce infiltration capacity. Activities such as land clearing for settlements and agriculture have transformed landscapes that originally possessed high absorption capacity into impervious surfaces, such as concrete and asphalt, which accelerate surface runoff and reduce infiltration. Consequently, degradation of water infiltration quality and quantity occurs, directly impacting the hydrological cycle and ecosystem stability (Asri, 2024; Lupián-Machuca et al., 2024). From 2002 to 2024, North Sumatra lost 390 thousand hectares of humid primary forest, contributing 25% of the total tree cover loss during the same period. The total area of humid primary forest in North Sumatra decreased by 19% within this timeframe (*Indonesia Deforestation Rate & Statistic*, 2024). The diminishing land cover will also impact water infiltration in the Bolon Watershed. This decline in infiltration capacity is further exacerbated by illegal activities such as tree logging and unregulated C-type mining operations that are not optimally monitored. Changes in land designation also accelerate land conversion, resulting in the reduction of buffer zones along the Bolon Watershed river system. Massive land cover changes over the past two decades have become one of the primary causes of declining quality and extent of water infiltration areas. This condition directly impacts the reduction of clean water availability and increases the risk of environmental disasters such as flash floods, seasonal droughts, and river sedimentation that exacerbates aquatic ecosystem degradation (Santosa et al., 2021). However, conservation efforts and identification of water infiltration areas are still constrained by data limitations, resources, as well as spatial analysis approaches that have not been responsive to land use change dynamics. Most previous studies have only employed static scoring methods that depict current (existing) conditions, without considering long-term change patterns or causal relationships with their driving factors. This is evident in research conducted in the Cikeruh Sub-watershed, Tangerang City, and Pringsewu Regency, spatial-temporal predictive aspects and the interconnection of causal variables have not been fully integrated (Asri, 2024; Septory et al., 2023a; Simanjuntak et al., 2022). In this context, a predictive approach based on spatial-temporal dynamic models becomes highly relevant. This research aims to predict the conditions of water infiltration areas in the Bolon Watershed over the next 10 years through an integrative approach based on Cellular Automata-Markov Chains (CA-MC) models, Weighted Multi-Criteria Analysis (WMCA) combined with Analytic Hierarchy Process (AHP), and Artificial Neural Network (ANN) (Pengelolaan Sumber Daya Air Wilayah Sungai Bah Bolon Tahun 2023, 2023).

METHOD

This research was conducted in the Bolon Watershed, which administratively encompasses the areas of Pematang Siantar City, Simalungun Regency, and Batu Bara Regency in North Sumatra Province, with a total area of 1,956.38 km². The selection of this location was based on the significant level of land cover change and the considerable pressure on water infiltration areas. The map of the Bolon Watershed can be seen in **Figure 1**.

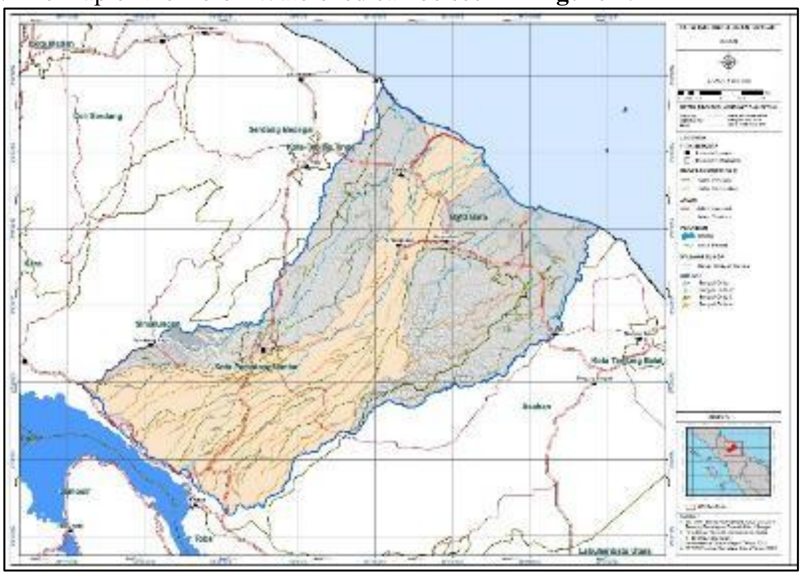

Figure 1. Map of Bolon Watershed

The data used in this research consists of primary and secondary data. Primary data were obtained through expert judgment questionnaires from 5 experts, which were used for weighting in Weighted Multi-Criteria Analysis (WMCA) based on Analytic Hierarchy Process (AHP). Meanwhile, secondary data included land cover data (2017, 2021, 2024), rainfall, slope, soil texture, and proximity to infrastructure (roads, residential, and public facilities) obtained from various agencies such as the Geospatial Information Agency, BPS (Statistics Indonesia), ESRI, and previous research.

The analytical approach was divided into three main stages. First, land cover change analysis was conducted using the MOLUSCE plugin in QGIS, utilizing the integration of Artificial Neural Network (ANN) algorithms and Cellular Automata-Markov Chain (CA-MC) models to project spatial dynamics of land cover based on historical patterns. Second, water infiltration factor analysis was performed by classifying and weighting each spatial variable using AHP. The weighting results were validated through consistency testing (CR < 0.1). Third, prediction of water infiltration area conditions was conducted by integrating classified maps in the WMCA plugin. The weighted raster overlay process generated predictive maps of water infiltration areas for 2029 and 2033

RESULT AND DISCUSSIONS

This research utilized land cover data from ESRI for 2017 and 2021, with validation using ESRI 2024 data classified according to SNI 7645:2010 standards. Subsequently, the land cover data were overlaid with forest maps from the Forest Area Consolidation Agency (BPKH) and rice field maps sourced from the Sustainable Wetland Data of the Ministry of ATR/BPN (Agrarian Affairs and Spatial Planning/National Land Agency).

Table 1 Data Tutupan Lahan 2017 dan 2021

No.	Type of Land Cover	2017(km^2)	2021(km^2)	Δ	2017%	2021%	Δ %
1	Forests	183.55	85.87	-97.68	9.525	4.46	-5%
2	Paddy fields	236.26	339.34	103.08	12.261	17.61	5%
3	Agricultural land	1364.28	1346.64	-17.64	70.801	69.88	-1%
4	Grasslands	84.27	26.16	-58.12	4.373	1.36	-3%
5	Water bodies	0.07	2.87	2.81	0.003	0.15	0%
6	Residential	58.51	126.06	67.55	3.037	6.54	4%
Total		1926.94	1926.94	0	100	100	0

Analysis of **Table 1** shows that plantations constitute the dominant land cover in the Bolon Watershed with high consistency throughout the 2017-2021 observation period. In 2017, plantations covered 1,364.28 km² (70.80% of the total watershed area), then experienced a relatively small decrease to 1,346.64 km² (69.88%) in 2021. Despite experiencing an absolute decrease of 17.64 km² (-1.29%), plantations maintained their position as the dominant land cover with a stable proportion above 69%.

However, significant dynamics of change occurred in other land covers during the 2017-2021 period. Residential experienced the most significant growth with an absolute increase of 67.55 km² or 115.47%. This residential expansion was highly dramatic: from 58.51 km² (3.04%) in 2017, it more than doubled to 126.06 km² (6.54%) in 2021. This exponential settlement growth reflects high urbanization pressure in the Bolon Watershed area within a four-year period, likely triggered by population growth, infrastructure development, and increased economic activities.

The research results reveal complex land cover change dynamics in the Bolon Watershed. Residential growth reaching 159.24% during the 2017-2024 period reflects high urbanization pressure, consistent with findings from Asif et al. (2023) this pattern of change reflects the complexity of LULC dynamics involving conversion between various types of land use and stems from complex interactions between human activities and the natural environment with significant implications for ecosystem sustainability and spatial planning. The prediction process was conducted by considering several main driving factors that influence land change dynamics in the Bolon Watershed with reference to previous research, including: proximity to residential, regional morphology (slope), proximity to main roads, and proximity to public facilities. These factors were inputted into the WMCA (Weighted Multi-Criteria Analysis) plugin in raster format as supporting layers for analysis.

Table 2 Driving Factors of Land Cover Change

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Driving Factors	Classification	Source
Proximity to public facilities	0 - 250 m	
	250 - 500 m	
	500 - 750 m	(Somantri, 2022)
	750 - 1.000 m	
	>1.000 m	
Proximity to road	0 - 25 m	
	25 - 50 m	
	50 - 100 m	(Septory et al., 2023b)
	100 - 1.000 m	
	>1.000 m	
Proximity to residential	0 - 100 m	
	100 - 300 m	
	300 - 800 m	(Septory et al., 2023b)
	800 - 1.500 m	
	>1.500 m	
Morphology (slope)	0 - 3 %	
	3 - 15 %	
	15 - 20 %	(Rakuasa et al., 2022)
	20 - 40 %	
	>40 %	

Table 2 shows the classification of driving factors that influence changes in land cover. The closer a land is to public facilities, roads and settlements, the greater the influence on land change. This is due to the ease of access and proximity to activity centers that encourage land conversion into more productive or high economic value functions.

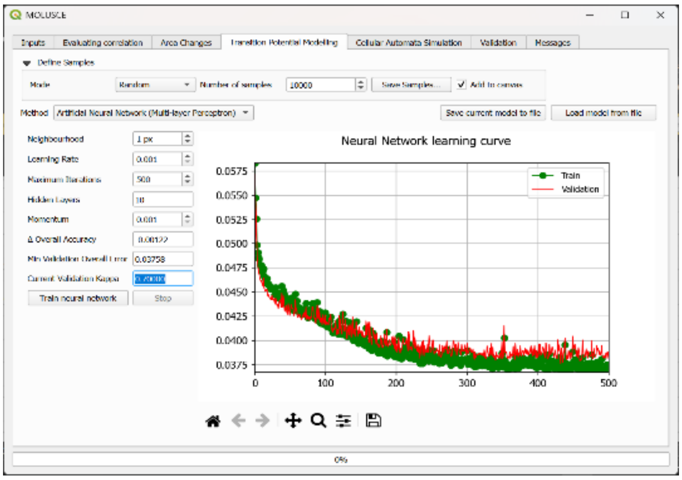

Figure 1 Artificial Neural Network (ANN) Model Training

In **Figure 2**, the training results of the Artificial Neural Network (ANN) model show excellent performance based on the learning curve that shows a consistent trend of decreasing error in the training (green line) and validation (red line) data until it reaches stability. This convergence pattern indicates an optimal learning process without overfitting, in line

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with the finding that ANN is a good method for solving problems with nonlinear relationships in the context of complex land cover modeling.

The minimum validation overall error value of 0.03758 (3.758%) indicates an accuracy level of 96.242% in predicting land cover changes. This accuracy level is consistent with previous studies that emphasize the importance of accurately classifying land use/land cover for environmental monitoring. The model's reliability is reinforced by a kappa validation value of 0.70000, which falls into the "substantial agreement" category according to Landis & Koch classification. Previous research confirms that a kappa coefficient approaching 1 indicates perfect agreement, while approaching 0 is only slightly better than random prediction.

With performance proven through various evaluation indicators, the ANN model is deemed suitable for integration in Cellular Automata simulation. The integration approach of ANN with Cellular Automata Markov Chain has been proven effective in previous studies for creating accurate simulations of future land change, provides a strong scientific foundation for subsequent simulation stages (Gharaibeh et al., 2020; Tashayo et al., 2020).

Table 3 Prediction of Land Cover Change

No.	IDLC	Type of Land Cover	2025 (km^2)	2029(km^2)	2033(km^2)
1	1	Forests	68.16	63.73	60.17
2	5	Paddy fields	323.82	307.54	294.43
3	6	Agricultural land	1352.91	1324.67	1307.23
4	9	Grasslands	14.01	12.68	12.03
5	11	Water bodies	1.15	0.91	0.79
6	12	Residential	167.05	217.57	252.47
Total			1927.10	1927.10	1927.10

The Celullar Automata process in **Table 3** was conducted in 3 iterations that resulted in predictions of land cover for 2025, 2029, and 2033. Table 3 is the result of the Celullar Automata analysis in the Bolon watershed, showing that forest cover consistently decreased from 68.16 km² (2025) to 60.17 km² (2033), indicating a deforestation rate of about 11.7% in an 10-year period. A similar pattern occurred for paddy fields which decreased from 323.82 km² to 294.43 km², indicating intensive conversion of agricultural land. In contrast, the residential category showed a significant expansion from 167.05 km² to 252.47 km², reflecting the expansion of built-up area indicating rapid urbanization as has been observed in many similar studies (Mujiono et al., 2017; Srivastava et al., 2020).

Agricultural land fluctuates with a decrease from 1352.91 km² (2025) to 1307.23 km² (2033), while grasslands and water bodies show a consistent downward trend. Forest areas are projected to experience a significant decline with a loss of about 6,000 hectares, equivalent to a 30% reduction over the projection period which is consistent with the findings of this study. This pattern of change reflects the high development pressure on natural land resources. Findings predict a 30% urban expansion with a 17% decrease in green cover, indicating a significant trade-off between development and environmental conservation (Mohamad et al., 2023). The CA-MC model used has been shown to have an overall accuracy of more than 87% in producing LULC maps, giving high confidence in the predictive results obtained for sustainable spatial planning (Kasahun & Legesse, 2024). Visualization of the results of the Celullar Automata prediction simulation in the Bolon watershed can be seen in **Figure 3**.

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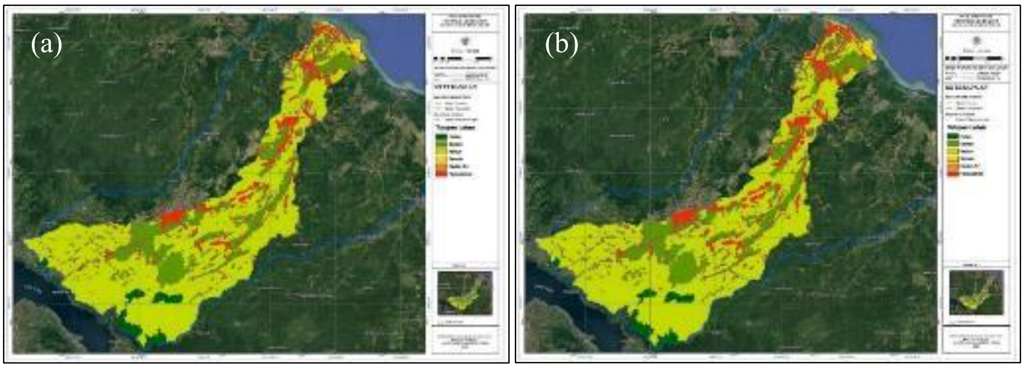

Figure 2 (a) Bolon Watershed Land Cover Prediction 2029 (b) Bolon Watershed Land Cover Prediction 2033

Determining the level of water infiltration capability is done through the classification of four main indicators, namely land cover, slope, soil texture and rainfall. Each indicator has several parameters that are scored based on their contribution to the water infiltration process. This scoring is based on literature review and previous research results and the Ministry of Environment and Forestry Regulation No. 10 of 2022 on the preparation of the General Plan for Forest and Land Rehabilitation of Watersheds and the Annual Plan for Forest and Land Rehabilitation. Classification and classification weights can be seen in **Table 4**.

Table 4 Influence Factor Of Infiltration Conditions

Indicator	Parameter	Infiltration Level	Score	Influence on Infiltration
	Forest	Very High	5	
	Shrubland	High	4	
Land Cover	Mixed field-plantation	Moderate	3	Areas with forest land cover will have higher water infiltration capacity compared to areas with residential land cover.
	Rice field, pond, swamp	Low	2	
	Residential	Very Low	1	
	0 - 8%	Very High	5	
	8 - 15%	High	4	
Slope	15 - 25%	Moderate	3	Areas with flat terrain (<8%) will have higher water infiltration capacity compared to areas with steep slopes.
	25 - 45%	Low	2	
	> 45%	Very Low	1	
	Sand	Very High	5	
	Sandy Loam	High	4	
Soil Texture	Clay Loam	Moderate	3	Areas with sandy soil texture will have higher water infiltration capacity compared to areas with clay soil texture.
	Fine Clay Loam	Low	2	
	Clay	Very Low	1	
	> 3000 mm/year	Very High	5	
Rainfall	2000 - 3000 mm/year	High	4	Areas with high precipitation (>3000mm/year) will have higher water infiltration potential compared to areas with low precipitation (<500mm/year).
	1000 - 2000 mm/year	Moderate	3	

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500 - 1000 mm/year	Low	2
<500 mm/year	Very Low	1

The results of the expert questionnaire were taken from agencies related to the study topic and study area, namely the Public Works and Spatial Planning Office of North Sumatra Province, the Sumatra II River Basin Center, the Natural Resources Conservation Center and Lecturers at the University of North Sumatra.

Table 5 AHP Weighting Results

Indicator	Percentage
Land Cover	48%
Slope	19%
Rainfall	5%
Soil Texture	28%

In **Table 5**, the weighting of variables using the AHP method shows that land cover is the most dominant factor in determining the ability of water catchment areas, with a weight of 48%. Followed by soil texture (28%), slope (19%), and rainfall (5%). This finding is in line with research by Simanjuntak et al. (2022) which states that land cover is the most dominant factor that can affect the condition of water infiltration.

Table 6 Consistency Test

Consistency Indeks	0.09
Random Indeks	1.12
Consistency Ratio	0.08

The consistency test results in **Table 6** show that the CR value of 0.08 means that the inconsistency level is only 8% of the inconsistency of the random matrix, and this is still below the tolerance limit of 0.1 (10%) recommended by Thomas L. Saaty. This means that the comparison results are considered consistent and acceptable.

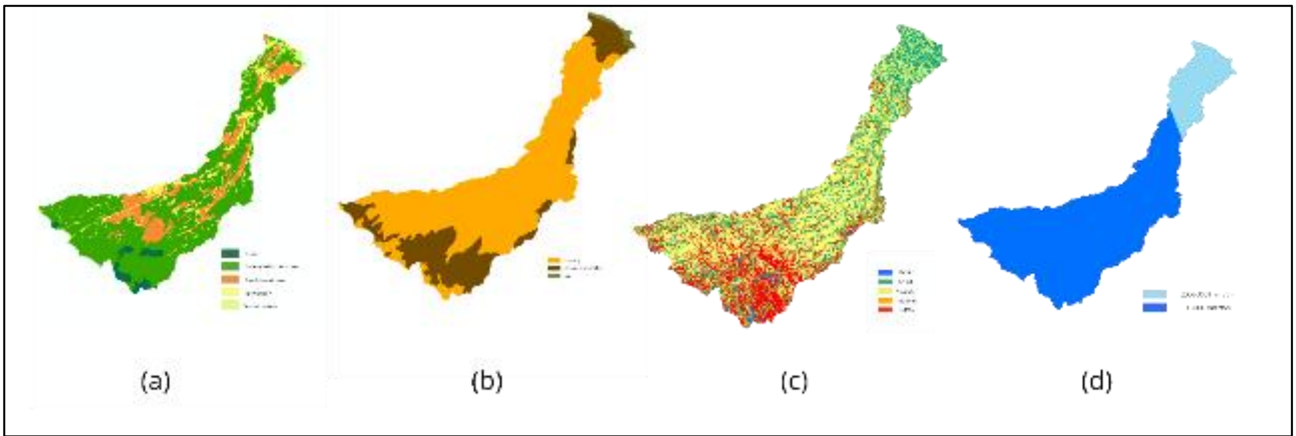

Figure 3 (a) Land Cover (b) Soil Texture (c) Slope (d) Rainfall

The maps resulting from the classification and scoring of each variable in **Figure 4** (a) (b) (c) (d) will be entered into the WMCA (Weighted Multi Criteria Analysis) plugin for spatial analysis. The importance weight of each variable is obtained from the results of processing the expert questionnaire using the Analytic Hierarchy Process (AHP) method. The WMCA (Weighted Multi Criteria Analysis) plugin process will be carried out twice with different land cover, namely land cover 2029 and land cover 2033 so as to produce the condition of the water catchment area as shown in **Figure 5** (a) and **Figure 5** (b).

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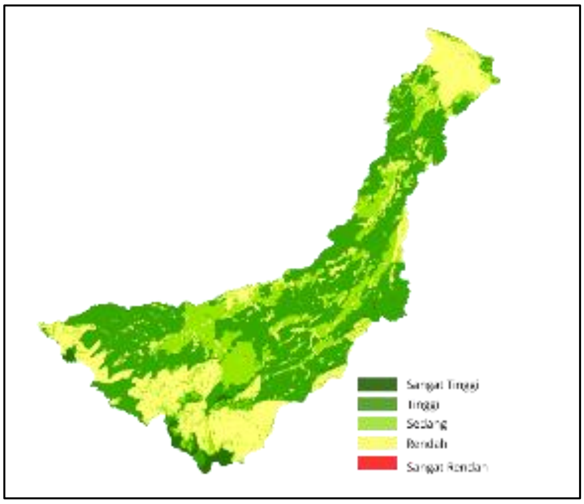

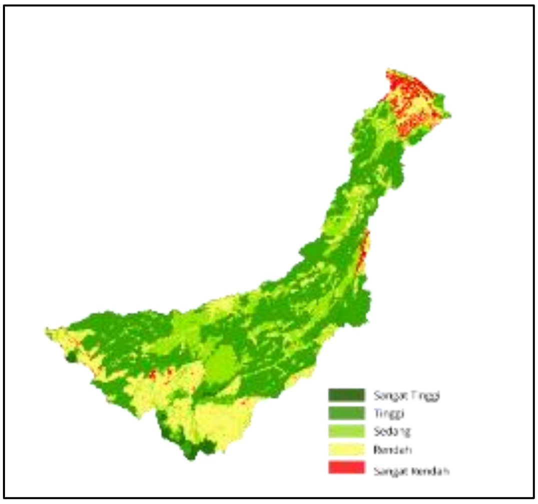

Figure 4 (a) Predicted Water Infiltration Condition 2029 (b) Predicted Water Infiltration Condition 2033

Table 7 Change in Water Infiltration Condition 2029 and 2033

Infiltration Level	Land area 2029 (km^2)	Precentage 2029	Land area 2033 (km^2)	Precentage 2033
Very Low	0.07	0.0%	59.68	3.1%
Low	540.30	28.2%	503.07	26.2%
Medium	390.60	20.4%	387.76	20.2%
High	953.48	49.7%	935.26	48.7%
Very High	34.65	1.8%	33.65	1.8%

The results of the spatial analysis in **Table 7** show a change in the distribution of water infiltration capacity in the Bolon watershed between 2029 and 2033. The high infiltration category remained dominant although its area decreased from 953.48 km² (49.7%) to 935.26 km² (48.7%). The medium infiltration class remained relatively stable, while the low infiltration class decreased from 540.30 km² (28.2%) to 503.07 km² (26.2%). In contrast, the very low infiltration class increased significantly from 0.07 km² to 59.68 km² (3.1%). This change indicates a degradation of infiltration function, most likely due to urbanization and land use change, in line with the findings of the study Simanjuntak et al. (2022) Pringsewu Regency.

CONCLUSION

Based on ESRI land cover data (2017-2021), there has been significant land use change in the Bolon watershed covering an area of 67.55 km², mainly from agriculture and paddy fields to residential areas, which has an impact on reducing water infiltration functions. AHP analysis showed that land cover is the dominant factor (48%) in determining infiltration ability, with valid weighting results (CR 0.08). WMCA modelling for the period 2029-2033 reinforced these findings, where although the high infiltration class was still dominant, there was a decrease in area and a significant spike in the very low class, indicating the degradation of infiltration function due to urbanization pressure.

REFERENSI

Asif, M., Kazmi, J. H., Tariq, A., Zhao, N., Guluzade, R., Soufan, W., Almutairi, K. F., Sabagh, A. El, & Aslam, M. (2023). Modelling of Land Use and Land Cover Changes and Prediction Using CA-Markov and Random Forest. *Geocarto International*, *38*(1). https://doi.org/10.1080/10106049.2023.2210532

Asri, R. (2024). Analisis Kondisi dan Distribusi Spasial Kawasan Resapan Air di Kota Tangerang Menggunakan Sistem Informasi Geografis. *Geodika: Jurnal Kajian Ilmu Dan Pendidikan Geografi*, *8*(1), 53–64. https://doi.org/10.29408/geodika.v8i1.25730

Gharaibeh, A., Shaamala, A., Obeidat, R., & Al-Kofahi, S. (2020). Improving Land-Use Change Modeling by Integrating ANN with Cellular Automata-Markov Chain Model. *Heliyon*, *6*(9), e05092. https://doi.org/10.1016/j.heliyon.2020.e05092

Indonesia Deforestation Rate & Statistic. (2024). Global Forest Watch.

Kasahun, M., & Legesse, A. (2024). Machine Learning for Urban Land Use/ Cover Mapping: Comparison of Artificial Neural Network, Random Forest and Support Vector Machine, a Case Study of Dilla Town. *Heliyon*, *10*(20), e39146. https://doi.org/10.1016/j.heliyon.2024.e39146

Lupián-Machuca, M. R., Cruz-Cárdenas, G., Flores-Magallón, R., Silva-García, J. T., Ochoa-Estrada, S., & Martínez-Trinidad, S. (2024). Prediction of Water Infiltration of Three Types of Soil with Machine Learning in the Sahuayo River Basin. *Applied and Environmental Soil Science*, *2024*(1). https://doi.org/10.1155/2024/5555105

Mahapatra, S., Jha, M. K., Biswal, S., & Senapati, D. (2020). Assessing Variability of Infiltration Characteristics and Reliability of Infiltration Models in a Tropical Sub-humid Region of India. *Scientific Reports*, *10*(1), 1515. https://doi.org/10.1038/s41598-020-58333-8

Mohamad, S., Ash'aari, Z. H., Ramli, M. F., Abdullah, R., & Mohamed Rehan, B. (2023). Application of a Hybrid Cellular Automaton-Markov Model in Land Use Change Detection and Prediction in Flood-Prone Area, Johor, Malaysia. *Planning Malaysia*, *21*. https://doi.org/10.21837/pm.v21i30.1394

Mujiono, Indra, T. L., Harmantyo, D., Rukmana, I. P., & Nadia, Z. (2017). *Simulation of Land Use Change and Effect on Potential Deforestation Using Markov Chain - Cellular Automata*. 030177. https://doi.org/10.1063/1.4991281

Pengelolaan Sumber Daya Air Wilayah Sungai Bah Bolon Tahun 2023. (2023).

Rakuasa, H., Salakory, M., & Latue, P. C. (2022). Analisis Dan Prediksi Perubahan Tutupan Lahan Menggunakan Model Celular Automata-Markov Chain Di Das Wae Ruhu Kota Ambon. *Jurnal Tanah Dan Sumberdaya Lahan*, *9*(2), 285–295. https://doi.org/10.21776/ub.jtsl.2022.009.2.9

Rauf, A., & Rahmawaty. (2024). *Pedoman Teknis Mendukung Keberlanjutan Sumber Daya Lahan di Sumatera Utara*. Universitas Sumatera Utara.

Santosa, S. S., Suryadi, E., & Kendarto, D. R. (2021). Analisis Kekritisan Daerah Resapan Air Menggunakan Metode Skoring di Sub DAS Cikeruh. *Jurnal Keteknikan Pertanian Tropis Dan Biosistem*, *9*(1), 79–89. https://doi.org/10.21776/ub.jkptb.2021.009.01.09

Septory, J. S. I., Latue, P. C., & Rakuasa, H. (2023a). Model Dinamika Spasial Perubahan Tutupan Lahan dan Daya Dukung Lahan Permukiman Kota Ambon Tahun 2031. *Geographia: Jurnal Pendidikan Dan Penelitian Geografi*, *4*(1), 51–62. https://doi.org/10.53682/gjppg.v4i1.5801

Septory, J. S. I., Latue, P. C., & Rakuasa, H. (2023b). Model Dinamika Spasial Perubahan Tutupan Lahan dan Daya Dukung Lahan Permukiman Kota Ambon Tahun 2031. *GEOGRAPHIA : Jurnal Pendidikan Dan Penelitian Geografi*, *4*(1), 51–62. https://doi.org/10.53682/gjppg.v4i1.5801

Simanjuntak, D. N., Rahmadi, E., & Dewi, C. (2022). Analisis Potensi Daerah Resapan Air di Kabupaten Pringsewu - Propinsi Lampung. *Rekayasa: Jurnal Ilmiah Fakultas Teknik Universitas Lampung*, *26*(1), 1–4. https://doi.org/10.23960/rekrjits.v26i1.52

Somantri, L. (2022). Model Prediksi Perubahan Penutup Lahan di Kabupaten Majalengka Menggunakan Metode Cellular Automata Markov Chain. *Majalah Geografi Indonesia*, *36*(2), 95. https://doi.org/10.22146/mgi.70636

Srivastava, A., Kumari, N., & Maza, M. (2020). Hydrological Response to Agricultural Land Use Heterogeneity Using Variable Infiltration Capacity Model. *Water Resources Management*, *34*(12), 3779–3794. https://doi.org/10.1007/s11269-020-02630-4

Tashayo, B., Honarbakhsh, A., Akbari, M., & Ostovari, Y. (2020). Digital Mapping of Philip Model Parameters for Prediction of Water Infiltration at The Watershed Scale in a Semi-Arid Region of Iran. *Geoderma Regional*, *22*, e00301. https://doi.org/10.1016/j.geodrs.2020.e00301