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APPLICATION OF CA-MC FOR PREDICTION OF DEVELOPED LAND EXPANSION IN THE PERSPECTIVE OF KOLKATA CITY, INDIA AND MATARAM CITY, INDONESIA

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ABSTRACT

Abstrak: Saat ini, negara berkembang seperti India dan Indonesia mengalami peningkatan populasi penduduk di wilayah perkotaan sebagai dampak adanya urbanisasi. Peningkatan penduduk ini berkaitan erat dengan peningkatan lahan terbangun yang menjadi indikator adanya pertumbuhan perkotaan. Pertumbuhan perkotaan yang tidak terkendali dapat menyebabkan kerusakan pada ekosistem serta berbagai permasalahan keruangan. Oleh karena itu, diperlukan prediksi perubahan penggunaan lahan/tutupan lahan *(LU/LC)* sebagai masukan dalam kebijakan tata ruang yang berkelanjutan. Tujuan dari kajian ini adalah untuk melihat tren penelitian di India dan Indonesia serta melihat perbandingan pola perluasan lahan terbangun di Kota Kolkata, India dan Kota Mataram, Indonesia. Kajian ini dilakukan dengan metode studi literatur dan deskriptif komparatif prediksi perluasan lahan terbangun. Hasil dari penelitian ini adalah metode *CA-MC* dan *remote sensing* menjadi tren metode prediksi *LU/LC* di India dan Indonesia. Kota Kolkata, India dan Kota Mataram, Indonesia mengalami perluasan lahan terbangun yang polanya mengikuti pola pembangunan infrastruktur transportasi. Peningkatan luas lahan terbangun ini diimbangi dengan penurunan luas lahan pertanian.Harapannya penelitian ini dapat digunakan oleh pemangku kebijakan sebagai masukan perencanaan wilayah khususnya di Kota Mataram.

Kata Kunci: lahan terbangun; *LU/LC; CA-MC; remote sensing;* India; Indonesia

Abstract: Currently, developing countries such as India and Indonesia are experiencing an increase in population in urban areas as a result of urbanization. This increase in population is closely related to the increase in built-up land which is an indicator of urban growth. Uncontrolled urban growth can cause damage to ecosystems as well as various spatial problems. Therefore, it is necessary to predict changes in land use/land cover (LU/LC) as input for sustainable spatial planning policies. The purpose of this study is to look at research trends in India and Indonesia and to see a comparison of the expansion patterns of built-up land in the City of Kolkata, India and the City of Mataram, Indonesia. This study was carried out using the method of comparative descriptive and literature study in predicting the expansion of built-up land. The results of this study are that the CA-MC and remote sensing methods are becoming a trend in LU/LC prediction methods in India and Indonesia. The city of Kolkata, India and the city of Mataram, Indonesia experienced an expansion of built-up land whose pattern followed the pattern of transportation infrastructure development. The increase in built-up land area was offset by a decrease in agricultural land area. Hopefully, this research can be used by policy makers as input for regional planning, especially in Mataram City.

Keywords: built-up area; LU/LC; CA-MC; remote sensing; India; Indonesia

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A. INTRODUCTION

This spatial problem is closely related to regional growth, especially urban areas (Ridwana et al., 2021). The relatively high population movement from villages to cities as a sign of urbanization makes an urban area grow very quickly (Bose & Chowdhury, 2020; Hasnine & Rukhsana, 2023). An indicator of regional growth is an increase in built-up land. This built up land is an appearance of the earth's surface as a result of the intervention of human activities such as infrastructure, settlements and so on (Ridwana et al., 2021). Intensive urbanization and the dynamics of rapidly increasing built-up land will have a major impact on ecosystems (Derkzen et al. 2015; Wang et al. 2019; Das et al., 2022).To minimize spatial conflicts and control the growth of urban areas in order to preserve ecosystems, spatial planning strategies are needed that are spatially based and use the principles of sustainable development, one of which is predicting built-up land in urban areas.

In India, urbanization is dominant in middle-class urban areas (United Nations, 2015; Debnath et al., 2023). It is estimated that half of India's population will live in urban areas by 2050 (United Nations, 2018; Alam and Banerjee, 2023). Urban areas in India are regions with the fastest land use/land cover change dynamics in the world (Alam and Banerjee, 2023). To see changes in land use/land cover in India, several researchers conducted studies on predictions of changes in land use/land cover in urban areas in India. Das et al., (2022)predict land use/land cover change in Kolkata Urban Agglomeration for the purpose of improving the quality of urban ecosystems and sustainable management of Natural Resources. Debnath et al., (2023)perform predictions of land use/land cover change in the Koch Bihar Urban Agglomeration (Koch Bihar Urban Aglomeration) for the purpose of sustainable land use. The results of research on cities in India show an increase in built-up area.

In Indonesia, the population is increasing from year to year. Based on data from the Central Statistics Agency (BPS) the population in Indonesia in 2020 is 270,203,900 people and will increase by 5,569,900 people in 2022. This population is also accompanied by an increase in the area of built-up land in several big cities in Indonesia. Lisanyoto et al., (2019)conducted research on predictions of settlement expansion in Singkawang City in 2023. Ridwana et al., (2021)conducted research on predictions of built-up land in Tasikmalaya City in 2034. Agustina et al., (2022)conducted research on predictions of land cover in Cirebon City in 2031. The results of some of these studies indicate an increase in built-up land in Indonesia.

This study aims to look at research trends related to predictions of land use/land cover change in India and Indonesia and to compare predictions and patterns of expansion of built-up land using the Cellular Automata- Marcov Chain method in India and Indonesia. These two countries were chosen because they have something in common, namely they are developing countries. The study focused on the City of Kolkata, India (Hasnine & Rukhsana, 2023)and the City of Mataram, Indonesia (Putri et al., 2019). These two cities are major cities in the countries of India and Indonesia, but are not the capital of the country. Meanwhile,

the Cellular Automata-Marcov Chain (CA-MC) method was chosen because globally this method is widely used for modeling changes in land use/land cover.

B. RESEARCH METHODS

The method used in this study is a literature study with bibliometric analysis and a comparative study regarding predictions of the expansion of built-up land in India and Indonesia. Bibliometric analysis is a data analysis method that is carried out by mapping the development of a science and technology from a large number of diverse studies that can be used as a means of scientific evaluation and finding novelties for further research. Tupan et al., 2018)This study uses the Scopus database. Scopus is a database with literature. very complete globally with international quality literature reviews.On (Tupan et al., 2018)the other hand, comparative studies are a method of comparing two different things to then analyze the differences and similarities.

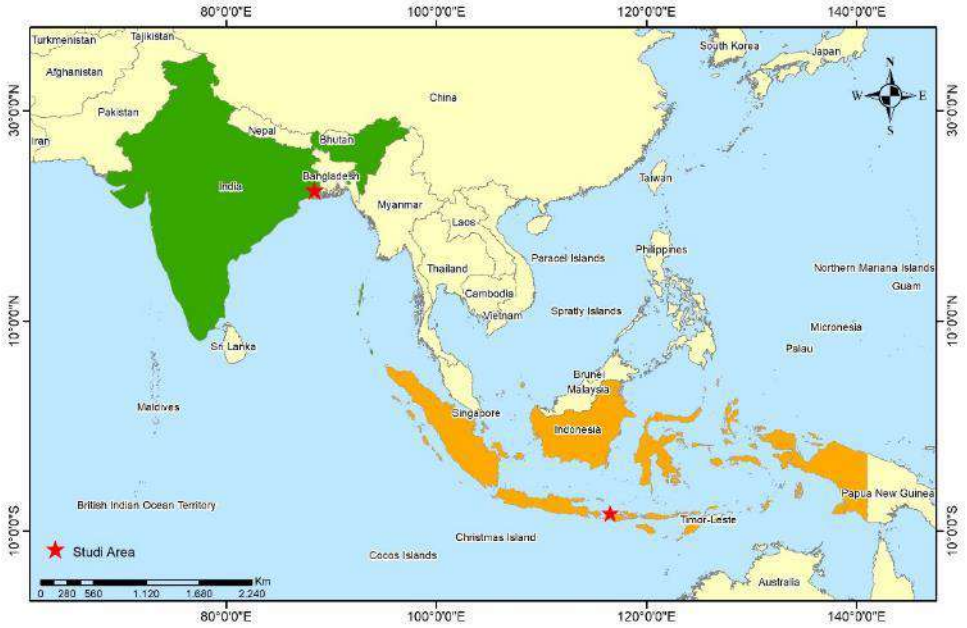


Figure 1. Study Location (Source : Data Analysis, 2023)

The data used in the literature study is data sourced from the Scopus database. Meanwhile , a comparative study of research related to the application of the Cellular Automata-Marcov Chain for predicting the expansion of built-up land in the City of Kolkata, India and the City of Mataram, Indonesia used a comparison of 2 studies, namely the results of research from Hasnine & Rukhsana (2023)and research results from Putri et al., (2019). The comparison focuses on data, software used, implementation methods, land cover classes and patterns of expansion of built-up land.

C. RESULTS AND DISCUSSION

1. Bibliographical Analysis of Research Trends Prediction of Global Land Use/Land Cover Change

To see research trends related to predictions of land use/land cover globally, it is necessary to search research data using keywords as in table 1.

Table 1. Keyword Search in the Scopus database regarding Global LU/LC Prediction

Keywords	Number of Articles
TITLE-ABS-KEY("Land Cover Change" OR "Land Use Change" AND "prediction") PUBYEAR > 2013 DOCTYPE("ar")	1,776

Furthermore, search data from the Scopus database are then presented in the VOS VIewer application to facilitate analysis. The visualization can be seen in Figure 2.

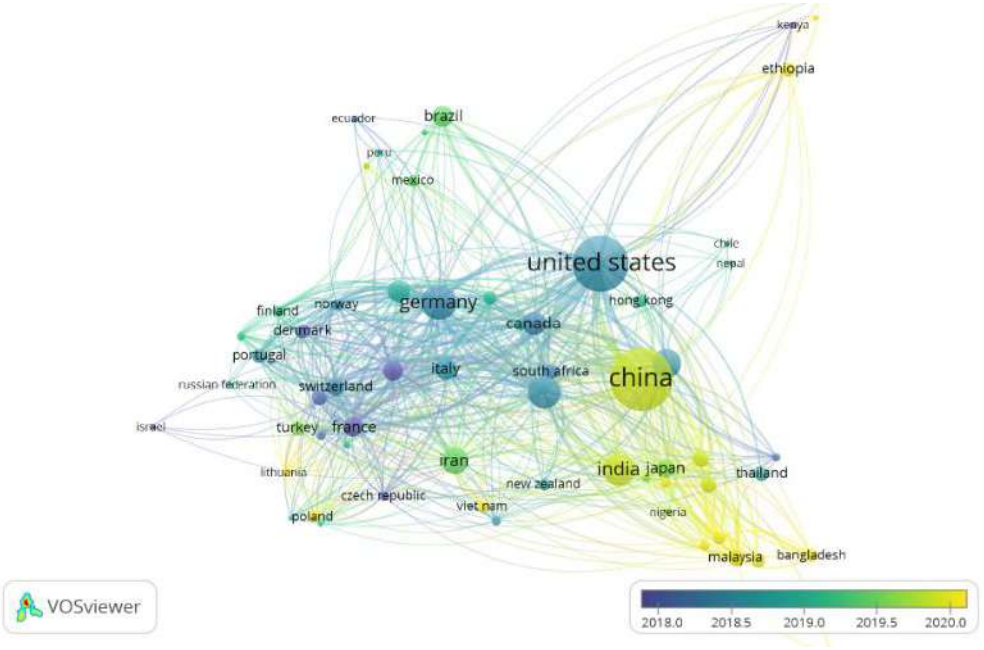


Figure 2. Bibliometric analysis based on author and country of origin and year of publication regarding LULCC Prediction globally (Source : Data Analysis, 2023)

Figure 2 explains that the most research publications related to predictions of land use and land cover globally are the United States, China, Germany, South Africa and India . However, recently, publications from Asia are the most recent. India is the second country that has quite a lot of publications and the latest in Asia after China with regard to predictions of global land use/land cover. On the other hand, India and Indonesia are developing countries where the population is increasing from year to year. Thus, a comparative study of predictions of changes in land use/land cover in India and Indonesia is quite relevant to do.

2. Bibliographical Analysis of Research Trends Prediction of Land Use/Land Cover Change in India and Indonesia

To find out research trends in predicting land use/land cover change in India and Indonesia, a search was carried out using keywords for each country. The keywords entered as searches in Scopus are seen in table 2.

Table2. Search Keyword on Scopus related to LU/LC Prediction in India and Indonesia

Country	Keywords	Number of Documents
India	TITLE-ABS-KEY("Land Cover Change" OR "Land Use Change" AND "Prediction") AFFILCOUNTRY("India") PUBYEAR > 2013	179
Indonesia	TITLE-ABS-KEY("Land Cover Change" OR "Land Use Change" AND "Prediction") AFFILCOUNTRY("Indonesia") PUBYEAR > 2013	78

(Source : Data Analysis, 2023)

The search results in the Scopus database are then entered into the VOS Viewer application . Analysis on VOS Viewer provides mapping related to keywords that frequently appear on the theme of predicting changes in land use/land cover in India and Indonesia along with the year of publication. The results of the VOS Viewer can be seen in Figures 3 and 4.

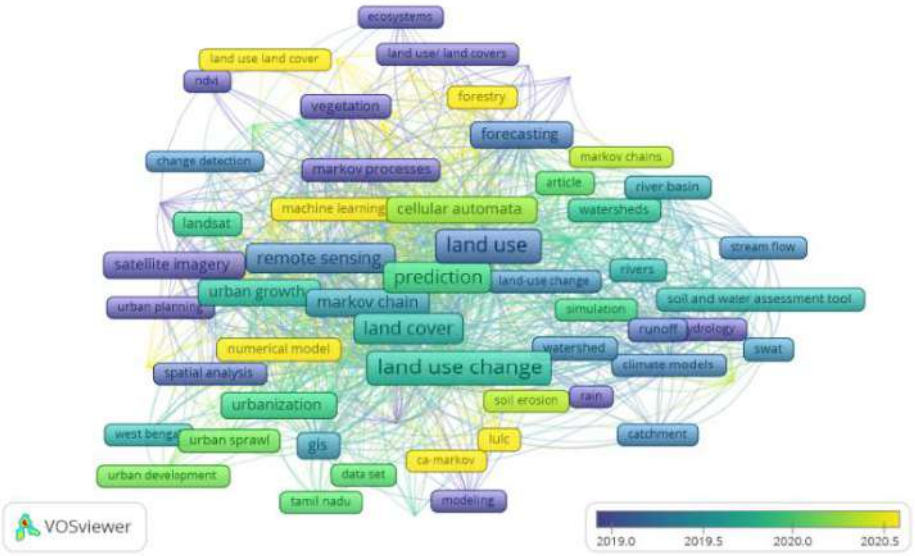


Figure 3.Bibliometric analysis based on frequently appearing keywords along with publication year regarding LULCC Prediction in 2014-2023 in India (Source : Data Analysis, 2023)

Figure 3 explains that the trending method for predicting land use/land cover in India in the 2014-2023 timeframe is the Cellular Automata-Marcov Chain (CA-MC), remote sensing and Machine Learning . CA-MC and remote sensing still dominate research in India. On the other hand the machine learning method is the newest method used. Regarding the research theme, the trend of research themes for prediction of land use/land cover in India is related to forestry, urban sprawl, urban development, urban growth, urban planning, runoff, vegetation and ecosystem . From this theme it can be concluded that urban areas still dominate research in India regarding predictions of land use/land cover.

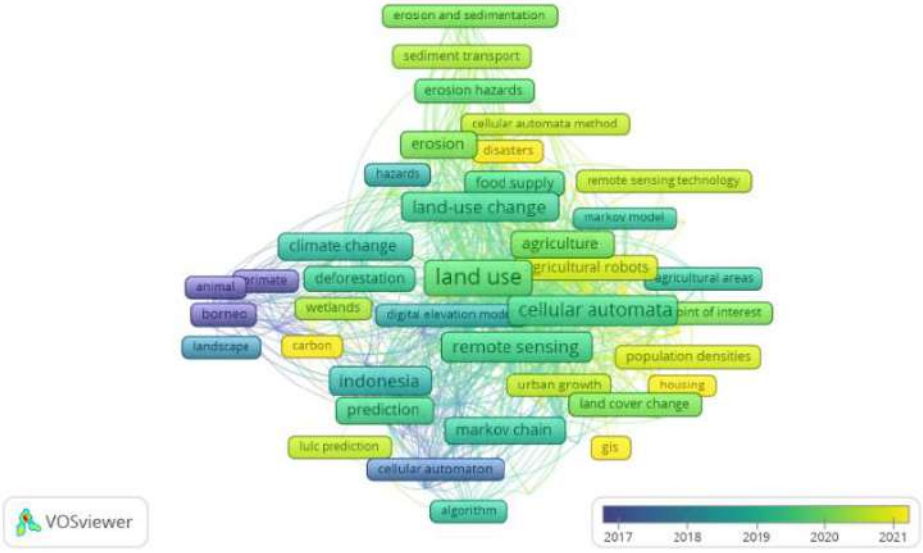


Figure 4. Bibliometric analysis based on frequently appearing keywords along with the year of publication related to LULCC Prediction in 2014-2023 in Indonesia (Source : Data Analysis, 2023)

Figure 4 explains that the trend of land use/land cover change prediction methods in Indonesia is Cellular Automata-Marcov Chain (CA-MC) and remote sensing . Meanwhile, trending themes related to predictions of changes in land use/land cover in Indonesia are disasters, urban growth, agriculture, deforestation, food supply and climate change .

Based on bibliographic analysis related to land cover prediction in India and Indonesia on the Scopus database, the Cellular Automata-Marcov Chain method (CA-MC) and remote sensing is a method that is still a trend in 2014-2023. Meanwhile, the theme that is still a trend in both countries is urban growth . This bibliometric analysis at the same time strengthens the analysis of the study that the Cellular Automata-Marcov Chain method (CA-MC) is still the method often used by India and Indonesia to predict land use/land cover changes in the last 9 years.

3. Cellular Automata-Marcov Chain (CA-MC) applications in India and Indonesia

Several studies in India used the Cellular Automata-Marcov Chain (CA-MC) as a method for predicting land use/land cover. Kumar et al., (2016)conducted research for urban transition monitoring by predicting land use/land cover in 2053 using the CA-MC method in the city of Vijayawada.Yadav & Ghosh, (2021)conducted research related to predictions of land use/land cover for 2021-2051 in Chennai District which is the capital of the state of Tamil Nadu using CA-MC to monitor the impact of urbanization. Mallick et al., (2023)conduct research on land use/land cover prediction in 2031 at The Siliguri Municipal Corporation (SMC)using CA-MC to identify urban growth. And there are many other studies related to prediction of land use/land cover in India using CA-MC .

Cellular Automata-Marcov Chain (CA-MC) method is used as a method for predicting land use/land cover on various themes. Supriatna et al., (2022)used the CA-MC method to carry out an analysis of predictions of land cover in 2030 and monitoring of floods in the city of Banjarmasin. Sejati et al., (2019)conducted research on predicting land cover in 2038 in the Semarang metropolitan area to analyze urban growth and its relation to the Surface Urban Heat Island (SUHI). (Ghani et al., 2021)conducted research in South Kuta using CA-MC to predict land cover and Land Surface Temperature (LST) in 2033.

4. Cellular Automata-Marcov Chain (CA-MC) for Expansion of Built-up Land in Kolkata City, India and Mataram City, Indonesia

In this study, the research publication used as a comparison is the prediction of the expansion of built-up land in Kolkata City, India using the CA-MC method written byHasnine & Rukhsana (2023)and in the City of Mataram, Indonesia, written byPutri et al., (2019).Kolkata City Corporation or often referred to as KMC is one of the cities in India. This city is not the capital of India. In this study, the study area was carried out by buffering KMC. Thus, administratively the study area is bordered by Hugli District in the North, North District 24 Parganas in the Northeast, South District 24 Parganas in the Southwest and Howrah District in the West. Meanwhile, Mataram City is located in the West Nusa Tenggara Province of Indonesia. This city is also not the capital of Indonesia. The city of Mataram is administratively bordered by the Lombok Strait in the west and borders with West Lombok Regency in the North, East and

South. The study locations for the City of Kolkata, India and the City of Mataram, Indonesia can be seen in Figure 5.

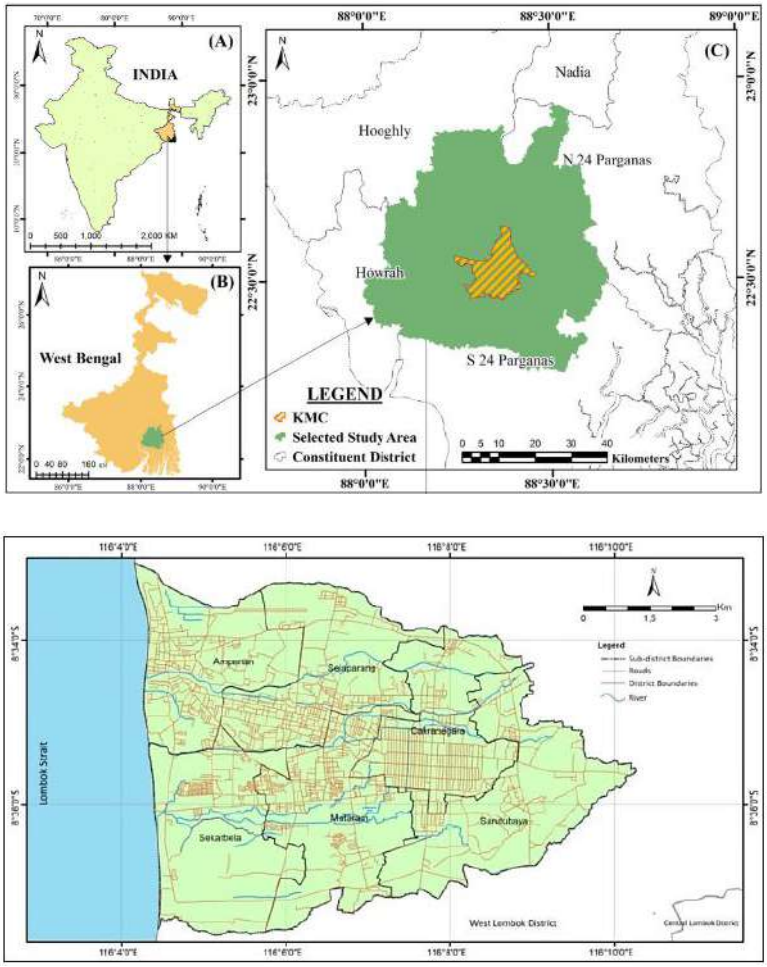


Figure 5.Location of Study Kolkata City, India (above) Mataram City, Indonesia (Bottom)(Source: Hasnine & Rukhsana (2023)and Putri et al., (2019))

The two cities are then compared to see the similarities and differences. The comparison of research between the City of Kolkata, India and the City of Mataram, Indonesia can be seen in table 3.

Table3. Comparison of LU/LC Prediction Research in the City of Kolkata, India and the City of Mataram, Indonesia

Content	**Kolkata City, India** (Hasnine & Rukhsana 2023)	**Mataram City, Indonesia** (Putri et al., 2019)
Data	Landsat TM 1990, Landsat ETM+ 2000 Landsat TM 2010, Landsat OLI/TIRS 2020.	Landsat 7 ETM 2008 and 2013, Landsat 8 OLI 2017 .
Software	IDRISI, ERDAS IMAGINE, ArcGIS.	Idrisi Selva, ENVI, and Arc GIS.
Classification	Supervised Classification.	Supervised Classification.
Land Cover Class:	Built-up areas, bodies of water, vegetation, agricultural land, others (Pasture/Shrub/Bald land).	land and settlements, agricultural land, non - agricultural land , open land .
Modeling Method	Cellular Automata-Marcov Chain (CA-MC).	Cellular Automata-Marcov Chain (CA-MC).

Content	Kolkata City, India (Hasnine & Rukhsana 2023)	Mataram City, Indonesia (Putri et al., 2019)
Driving Factors	Not mentioned.	Slope, elevation, distance from the road, distance from the river, distance from the center of government, distance from the beach.
L Step Research	1. LULC Classification in 1990, 2000, 2010 and 2020; 2. LULC analysis of 1990-2000, 2000-2010, 2010-2020; 3. 2020 Model Validation; 4. LULC modeling of 2030, 2040 and 2050.	1. Classification of LC in 2008, 2013 and 2017; 2. Analysis of LC Changes in 2008-2013 and 2013-2017; 3. 2017 Model Validation; 4. 2031 LC modelling.

Source : Data Analysis, 2023

From table 3, it can be seen that there are similarities, namely the two studies used the Cellular Automata-Marcov Chain (CA-MC) method , Landsat data sources, Supervised Classification techniques and using IDRISI software for modeling land use/land cover changes and ArcGIS for data analysis and presentation. However, from table 3 there are also differences, namely the use of image processing software, land cover classes, driving factors , and the year of classification and model year of land cover. Research Hasnine & Rukhsana (2023)has an advantage in the years of image recording used for modeling, namely 1990, 2000, 2010 and 2020 to predict the 2030, 2040 and 2050 land cover models. The more complete the image/data year range used as a modeling reference, the quality of the land cover model will be better. Meanwhile, research Putri et al., (2019)has advantages in terms of conveying the details of the driving factors used as modeling. The more complete the delivery of a research publication, the easier it will be for readers to understand the flow of research. The results of changes in land cover from these two studies can be seen in tables 4 and 5.

Table 4. Land Cover Change in Kolkata City, India 1990-2020

Class Land Cover	Change (%)		
	1990-2000	**2000-2010**	**2010-2020**
Built-up Land	+3.10	+9.60	+4.58
Agricultural land	-1.55	-2.76	-2,14
Water body	+0.80	-1.06	-0.17
Vegetation	-2.69	-5.01	-2.35
Meadow/ Bush/ Bare land	+0.32	-0.77	+0.09

Source :Hasnine & Rukhsana (2023)

Based on table 4, From 1990 to 2020, the City of Kolkata, India experienced an increase in the area of built-up land by 17.29%. On the other hand, there was a decrease in other land areas such as agricultural land by 6.45%, water bodies by 0.43%, vegetation by 10.05% and other land cover such as grasslands or shrubs or bare land by 0.36%. There is a consistent increase in land area in the built-up land class and a decrease in land area in the agricultural and vegetation classes.

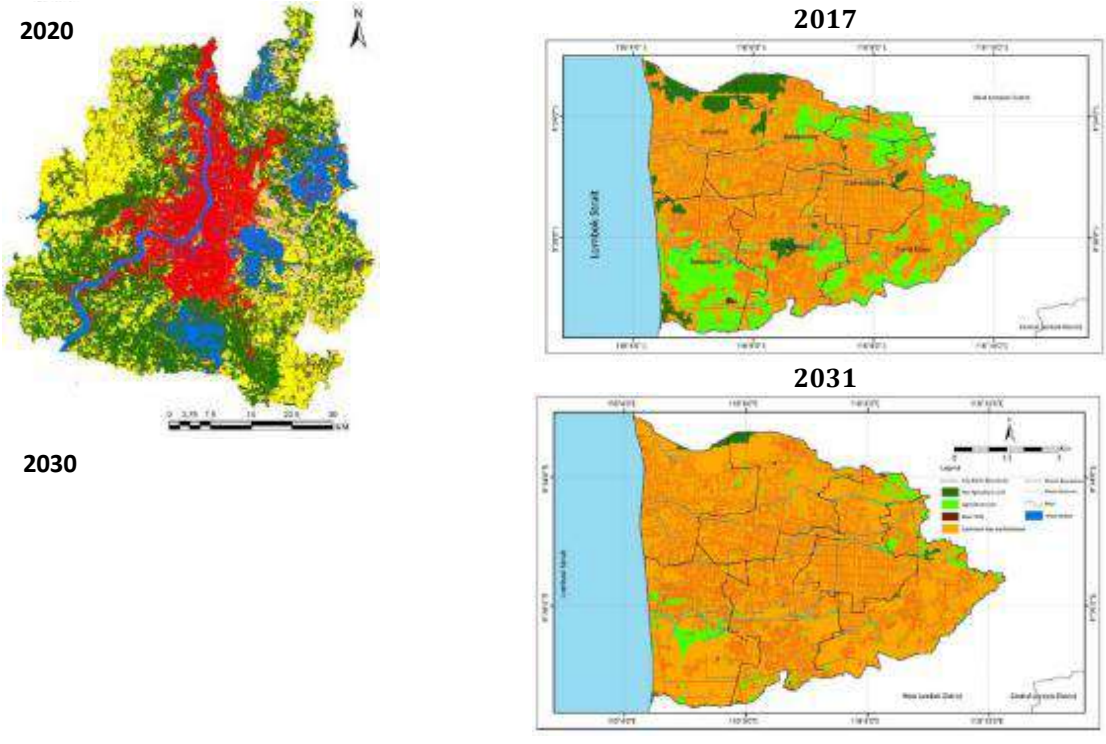
Table 5. Changes in Built-up Land Cover in Mataram City, Indonesia 2008-2017

Class Land Cover	Change (%)	
	2008-2013	**2013-2017**
Built-up Land and settlements	+20.92	+5.43
Agricultural land	-8.33	-4.31
Water body	-0.09	-0.02
Non-Agricultural Land	-12.50	-1.23
Open field	0.00	+0.12

Source :Putri et al., (2019)

Similar to the City of Kolkata, the City of Mataram also experienced an increase in the area of built-up land from 2008 to 2017 based on table 5. The City of Mataram experienced an increase in the area of built-up land and settlements by 26.35%. And accompanied by a significant decrease in land area in the non-agricultural land class of 13.72%, agricultural land of 12.63%. Meanwhile, water bodies and open land experienced a decrease in minor land area, namely 0.11% and 0.12%. In contrast to Kolkata City, Mataram City has consistently decreased land area in the water body class. Meanwhile, the consistency regarding the increase in built-up area and the decrease in agricultural and non-agricultural land area is the same as in Kolkata City. From this presentation, the City of Kolkata (1990-2020) and the City of Mataram (2008-2017) both experienced an increase in built-up land area from year to year.

From the classification of land cover in Kokata City from 1990 to 2020 and Mataram City from 2013 to 2017, then land cover modeling for 2030 and 2031 was carried out using the IDRISI software. The results of the modeling can be seen in Figure 4.



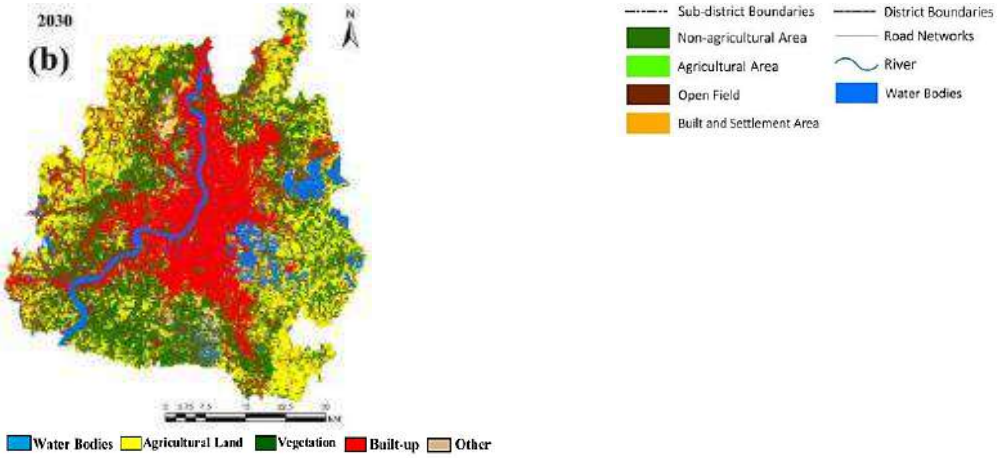


Figure 6. Modeling Land Cover Use inKolkata City, India in 2030 (Left) and in Mataram City, Indonesia in 2031 (Right). Source: Hasnine & Rukhsana (2023)andPutri et al., (2019)

From figure 6, the City of Kolkata and the City of Mataram will experience an expansion of built-up land accompanied by a decrease in other land areas in 2030 and 2031. The simulation model for predicting land use/land cover in Kolkata City shows that there will be an increase in built-up area while other classes will decrease in 2030 Hasnine & Rukhsana (2023). The results of the prediction of land cover in 2031 in the city of Mataram, Indonesia show that the area of agricultural land has decreased by 15.18% and has increased sharply in built-up areas and settlements by 20.52% Putri et al., (2019).

Cellular Automata-Marcov Chain (CA-MC) method illustrate that there has been an expansion of built-up land for the City of Mataram and the City of Kolkata (figure 6). The pattern of expansion of built-up land in Kolkata City is different from that of Mataram City. The pattern of expansion of built-up land in Koltaka City spreads in all directions from the city center (Hasnine & Rukhsana, 2023). This is related to Kolkata City which is in the center and is not bordered by certain natural landscapes such as beaches/rivers/straits which limit the spread of built-up land. Meanwhile, the City of Mataram is experiencing an expansion of built-up land in north, east, south directions but not to the west because it borders the landscape, namely the Lombok Strait. On the other hand, the pattern of distribution of built-up land in Kolkata City and Mataram City has similarities, namely that built-up land has increased in areas where there is infrastructure development such as transportation (roads). This is in line with Shannon's entrophy approach which explains that city propagation is influenced by two dominant aspects, namely the road aspect and the distance from the city center (Yeh & Li, 2001; Prasetyo et al., 2016). This can be used as input in urban planning, especially the development direction based on SDG's.

D. CONCLUSIONS AND SUGGESTIONS

Based on bibliometric analysis, the methods that are still a trend for predicting land use/land cover change in India and Indonesia are Cellular Automata-Marcov Chain (CA-MC) and remote sensing . Meanwhile, the trending theme of the two countries is urban growth. Meanwhile, the results of a comparative study predicting the expansion of built-up land in the City of Kolkata, India and the City of Mataram, Indonesia are that there are similarities in the expansion of built-up land with a pattern following the development of infrastructure development accompanied by a decrease in agricultural land. In the other hand, the two cities have differences, namely related to the direction of the expansion pattern of built-

up land where there are constraints on location characteristics (landscape). This can be input to the government in planning regional development in the city of Mataram.

Suggestions for further research are to conduct a comparative study of predictions of changes in land use/land cover between Indonesia and other countries in order to see the development of science and technology related to changes in land use/land cover.

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REFERENCES

Agustina, IH, Aji, RR, Fardani, I., Rochman, GP, Ekasari, AM, & Mohmed, FAJ (2022). Cellular Automata for Cirebon City Land Cover and Development Prediction. Journal of the Malaysian Institute of Planners VOLUME , 20 , 77–88.

Das, S., Kumar Shit, P., Bera, B., & Adhikary, PP (2022). Effect of urbanization on the dynamics of ecosystem services: An analysis for decision making in Kolkata urban agglomeration. Urban Ecosystems , 25 (5), 1541–1559. https://doi.org/10.1007/s11252-022-01246-3

Debnath, M., Islam, N., Gayen, SK, Roy, PB, Sarkar, B., & Ray, S. (2023). Prediction of spatio-temporal (2030 and 2050) land-use and land-cover changes in Koch Bihar urban agglomeration (West Bengal), India, using an artificial neural network-based Markov chain model. Modeling Earth Systems and Environment . https://doi.org/10.1007/s40808-023-01713-6

Ghani, GA, Dimyati, M., & Damayanti, A. (2021). Prediction of Land Cover and Land Surface Temperature in South Kuta Sub-district, Bali Province. International Journal on Advance Science Engineering Information Technology , 11 (1).

Hasnine, M., & Rukhsana. (2023). Spatial and Temporal Analysis of Land Use and Land Cover Change In and Around Kolkata City, India, Using Geospatial Techniques. Journal of the Indian Society of Remote Sensing . https://doi.org/10.1007/s12524-023-01669-1

Kumar, KS, Kumari, DKP, & Bhaskar, DPU (2016). Application of Markov Chain & Cellular Automata based model for prediction of Urban transitions. International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) , 4007–4012.

Lisanyoto, L., Supriatna, & Sumadio, W. (2019). Spatial Model of Settlement Expansion and its Suitability to the Landscapes in Singkawang City, West Kalimantan Province. IOP Conference Series: Earth and Environmental Science , 338 (1). https://doi.org/10.1088/1755-1315/338/1/012034

Mallick, SK, Rudra, S., & Maity, B. (2023). Unplanned urban built-up growth creates problems in human adaptability: Evidence from a growing up city in eastern Himalayan foothills. Applied Geography , 150 . https://doi.org/10.1016/j.apgeog.2022.102842

Naikoo, MW, Shahfahad, Talukdar, S., Ishtiaq, M., & Rahman, A. (2023). Modeling the built-up land expansion probability using the integrated fuzzy logic and coupling coordination degree model. Journal of Environmental Management 325 .

Prasetyo, A., Hendro Koestoer, R., & Waryono, T. (2016). Spatial Patterns of Urban Sprawl in Bodetabek: Study of the Application of the Shannon's Entropy Model. Gea. Journal of Geography Education , 16 (2).

Putri, IMG, Supriatna, Koestoer, RH, & Siwi, SE (2019). Model of land cover change with cellular automata, Mataram city, West Nusa Tenggara. IOP Conference Series: Earth and Environmental Science , 311 (1). https://doi.org/10.1088/1755-1315/311/1/012075

Ridwana, R., Sugandi, D., Arrasyid, R., Himayah, S., & Pamungkas, TD (2021). Multitemporal landsat image utilization for spatial prediction of built up area in tasikmalaya city, indonesia. IOP Conference Series: Earth and Environmental Science , 683 (1). https://doi.org/10.1088/1755-1315/683/1/012101

True, AW, Buchori, I., & Rudiarto, I. (2019). The spatio-temporal trends of urban growth and surface urban heat islands over two decades in the Semarang Metropolitan Region. Sustainable Cities and Society , 46 . https://doi.org/10.1016/j.scs.2019.101432

Supriatna, Mukhtar, MK, Wardani, KK, Hashilah, F., & Manessa, MDM (2022). CA-Markov Chain Model-based Predictions of Land Cover: A Case Study of Banjarmasin City. Indonesian Journal of Geography , 54 (3), 365–372. https://doi.org/10.22146/IJG.71721

Tupan, T., Rahayu, RN, Rachmawati, R., & Rahayu, ESR (2018). Bibliometric Analysis of Instrumentation Research Development. READ: JOURNAL OF DOCUMENTATION AND INFORMATION , 39 (2), 135. https://doi.org/10.14203/j.baca.v39i2.413

Yadav, V., & Ghosh, SK (2021). Assessment and prediction of urban growth for a mega-city using the CA-Markov model. Geocarto International , 36 (17), 1960–1992. https://doi.org/10.1080/10106049.2019.1690054