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Review Article

Model Prediction of Built-Up Land Use on Flood-Prone Areas (a Systematic Literature Review)

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ABSTRACT

Land use is dynamic due to the influence of population growth in an area. High population growth leads to uncontrolled and unplanned changes in land use in an area, resulting in environmental damage, especially in disaster-prone areas. The aim of this study is to review various models suitable for predicting changes in land use concerning flood-prone areas using a literature review method with PRISM guidelines and visualizing literature results using VosViewer software (1.6.19). The results of this study show that SD (System Dynamic Model) and CA-MC (Cellular Automata – Markov Chain) are the most commonly used models in land use change prediction. Meanwhile, the variables most suitable for land use studies, especially built-up land in relation to flood disasters, are population, growth rate, rainfall, slope, GDP, distance from (roads, rivers, and city centers), and LULC.

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1. INTRODUCTION

Land is an environmental condition on the Earth's surface that is greatly influenced by human life. According to Vink (1975) in Ritohardoyo (2013), land is a unit of territory on the Earth's surface encompassing all components of the biosphere both above and below the soil surface as a result of human activities in the past and present, which have a real impact on current and future life. The influence of humans, whether direct or indirect, that results in the land having specific characteristics is referred to as land use. Land use is a land area related to human activities that is usually not directly visible from satellite imagery (Alsabhan et al., 2022; Sajan et al., 2022). Land use is dynamic and changes with population growth and economic development trends in an area (Debnath et al., 2022; Leta et al., 2021; Sajan et al., 2022).

Increased population growth leads to greater land demand, but on the other hand, the amount of land is fixed. This can lead to serious problems of unplanned urban development due to rapid changes in land use by communities, especially in cities in developing countries (Debnath et al., 2022; Kumar et al., 2021; Lai et al., 2022). These changes in land use can lead to significant setbacks for sustainable development due to their impact on environmental damage and pollution (J. Li et al., 2023; Phinyoyang & Ongsomwang, 2021; Wang et al., 2022; Yangouliba et al., 2022; Zhang et al., 2023). The most risky land use is residential land use. According to Law No. 4 of 1992, residential land use is part of the living environment outside protected areas, both in urban and rural areas, as a place for activities supporting community livelihoods. Proper residential land use directly affects human health and regional economics as well as the level of urbanization (W. Li et al., 2022). Conversely, inappropriate residential land use can pose a threat to communities, especially if the settlements are in disaster-prone areas.

Indonesia is a region with a high level of disaster vulnerability due to its location in an active tectonic plate zone and its tropical climate characterized by high rainfall and humidity (Priyono et al., 2020). This characteristic causes Indonesia to frequently experience disasters, particularly hydrometeorological disasters such as floods, extreme weather, and landslides. According to the Indonesian National Disaster Management Agency in 2022, floods were the most dominant disaster, occurring 1,504 times throughout Indonesia. The causes of floods are not only due to high rainfall but also due to human activities such as land degradation, deforestation in watershed areas, urban growth, and increased population along riverbanks (Phinyoyang & Ongsomwang, 2021).

Spatial modeling to predict land use has been widely used and developed in recent years. Based on previous research, the models used include system dynamics models, Markov Chain, Cellular Automata, Cellular Automata-Markov Chain, Cellular Automata-Artificial Neural Network, ABM (Agent-Based Models), CLUE-S, and various other models (Lai et al., 2022; J. Li et al., 2023; Zhang et al., 2023; Debnath et al., 2022; Faksomboon, 2023; Kumar et al., 2021; Leta et al., 2021; Ruben et al., 2020; Sadhwani et al., 2022; Umar et al., 2021). Among the various models used in previous research, no studies have specifically examined land use prediction for flood-prone areas. Therefore, this research offers novelty by reviewing each method used and examining the functions and results of previous studies. The review is based on previous research using PRISMA guidelines (Rethlefsen, et al. 2021) with results visualized using VOSViewer (Ankrah et al., 2022; Oyewola & Dada, 2022).

2. METHODS

This study is a literature review research systematically examining previous studies relevant to the research objectives. The articles reviewed are obtained from the Scopus database, as it is the largest abstract and citation database compared to others (Wayan Gede Krisna Arimjaya & Dimyati, 2022). The review in this study uses PRISMA guidelines (Preferred Reporting Items for Systematic Review and Meta-Analyses Literature Search Extension) according to the research conducted by Rethlefsen, et al.

(2021), with results visualized through a network map generated by VOSviewer software (1.6.19) (Ankrah et al., 2022; Oyewola & Dada, 2022). A detailed PRISMA diagram is shown in Figure 1.

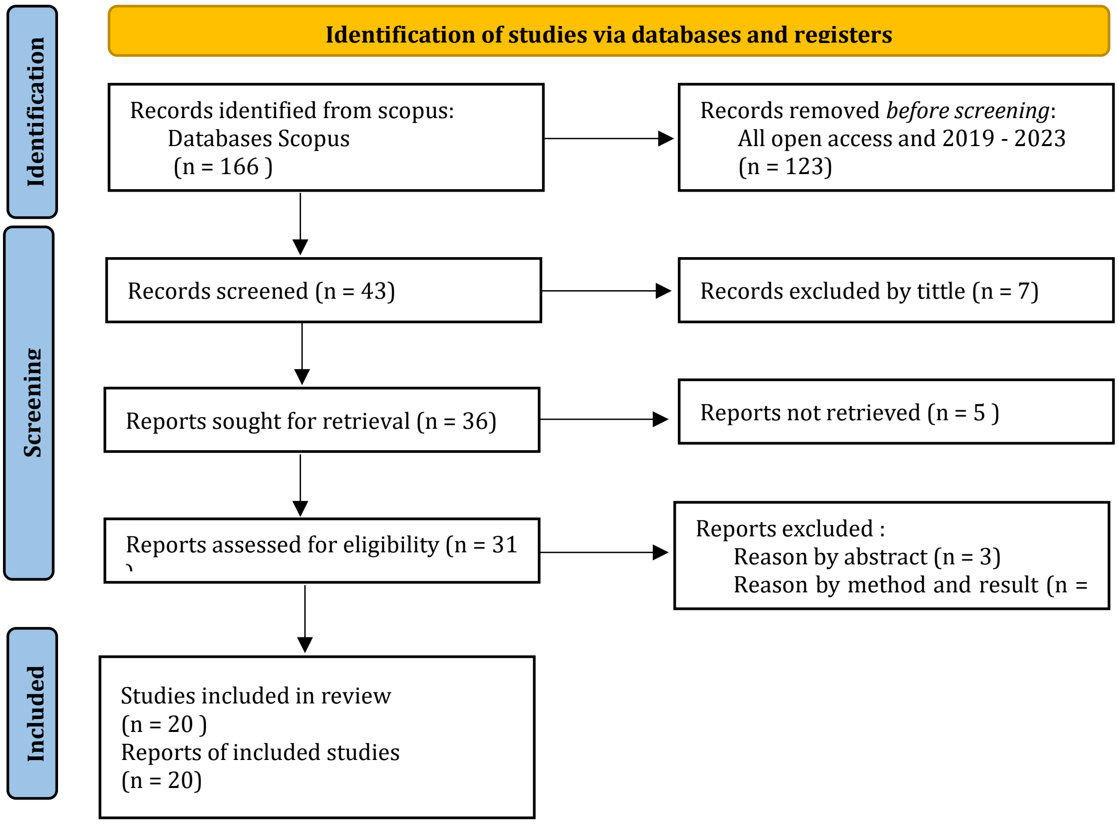

Figure 1. PRISMA Diagram

The study began with a search in the Scopus database using various keywords based on the objectives, methods, and subjects of the research. The keywords used are listed in Table 1.

Table 1. Search Keywords

No	Keywords	Results
1	TITLE-ABS-KEY (prediction, AND LULC, AND flood)	55
2	TITLE-ABS-KEY (spatial, AND dynamic, AND model, AND lulc)	65
3	TITLE-ABS-KEY (system AND dynamic AND model AND lulc)	46
Total		166

The search results from the Scopus database were then limited to the years 2019 – 2023 and articles that are all open access, resulting in 43 articles. These articles were further selected based on title, abstract, methods, and results relevant to the research objectives, leading to the selection of 20 articles for review in this study. The network visualization and density of the number of articles obtained from the Scopus database based on the article keywords are shown in Figures 2 and 3.

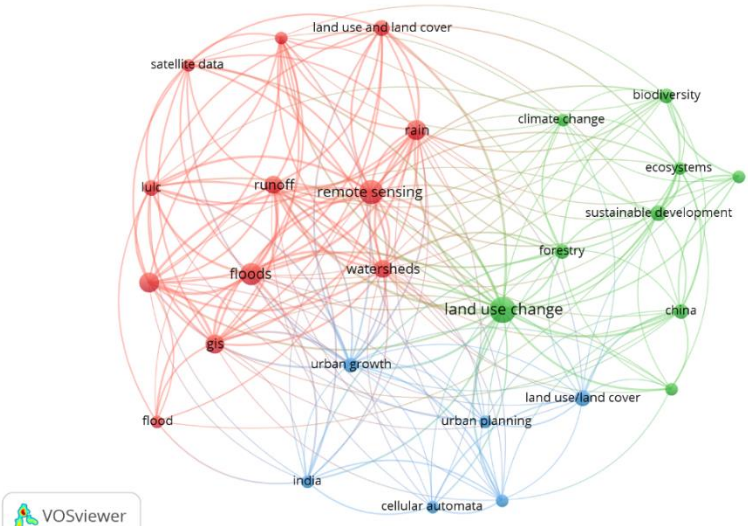

Figure 2. Network Visualization by VOSViewer

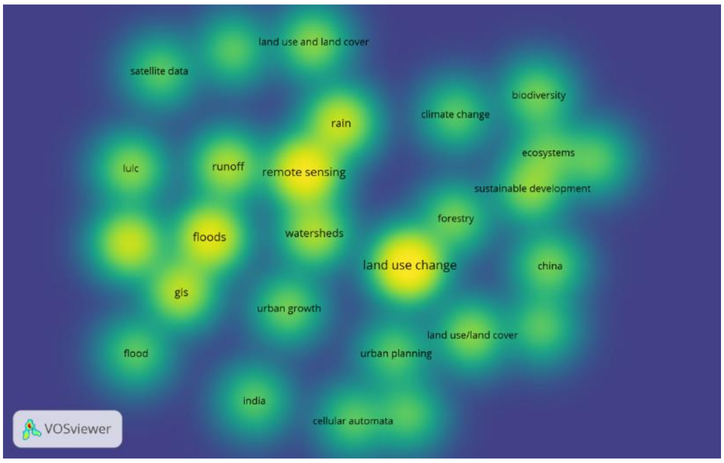

Figure 3. Density Visualization by VOSViewer

Based on Figures 2 and 3, it can be observed that research related to land use change has been quite extensively studied. However, studies focusing specifically on built-up land use in relation to flood-prone areas are still relatively hard to find.

3. RESULTS AND DISCUSSIONS

The research findings based on the 20 reviewed journals reveal several differences in keywords, methods, and results. These differences are summarized in Table 2 and Table 3.

Table 2. Reviewed Journal References

NO	AUTHOR	TITLE	JOURNAL	METHOD
1.	Lai, Z., Chen, C., Chen, J., Wu, Z., Wang, F., & Li, S. (2022).	Multi-Scenario Simulation of Land-Use Change and Delineation of Urban Growth Boundaries in County Area: A Case Study of Xinxing County, Guangdong Province.	Land, 11(9), 1598.	System Dynamic (SD) dan Markov Chain
2.	Yangouliba, G. I., Zoungrana, B. J. B., Hackman, K. O., Koch, H., Liersch, S., Sintondji, L. O., ... & Koffi, B. (2022).	Modelling past and future land use and land cover dynamics in the Nakambe River Basin, West Africa.	Modeling Earth Systems and Environment, 1-17.	Markov Chain
3.	Debnath, J., Sahariah, D., Lahon, D., Nath, N., Chand, K., Meraj, G., ... & Singh, S. K. (2022).	Geospatial modeling to assess the past and future land use-land cover changes in the Brahmaputra Valley, NE India, for sustainable land resource management.	Environmental Science and Pollution Research, 1-24.	Celluar Automata – Matkov Chain (CA-MC)
4.	Leta, M. K., Demissie, T. A., & Tränckner, J. (2021).	Modeling and prediction of land use land cover change dynamics based on land change modeler (Lcm) in nashe watershed, upper blue nile basin, Ethiopia.	Sustainability, 13(7), 3740.	Celluar Automata – Matkov Chain (CA-MC) dan LCM
5.	Wang, B., Liang, Y., & Peng, S. (2022)..	Harnessing the indirect effect of urban expansion for mitigating agriculture-environment trade-offs in the Loess Plateau.	Land Use Policy, 122, 106395	System Dynamic (SD)
6.	Kumar, V., Singh, V. K., Gupta, K., & Jha, A. K. (2021).	Integrating cellular automata and agent-based modeling for predicting urban growth: A case of Dehradun City.	Journal of the Indian Society of Remote Sensing, 49(11), 2779-2795.	Celluar Automata – Matkov Chain (CA-MC) dan ABM
7.	Sajan, B., Mishra, V. N., Kanga, S., Meraj, G., Singh, S. K., & Kumar, P. (2022).	Cellular Automata-Based Artificial Neural Network Model for Assessing Past, Present, and Future Land Use/Land Cover Dynamics.	Agronomy, 12(11), 2772.	CA-ANN (Jaringan saraf tiruan automata seluler)
8.	Ruben, G. B., Zhang, K., Dong, Z., & Xia, J. (2020).	Analysis and projection of land-use/land-cover dynamics through scenario-based simulations using the CA-Markov model: A case study in guanting reservoir basin, China.	Sustainability, 12(9), 3747.	Celluar Automata – Matkov Chain (CA-MC)
9.	Dede, M., Asdak, C., & Setiawan, I. (2022).	Spatial dynamics model of land use and land cover changes: A comparison of CA, ANN, and ANN-CA. Register:	Jurnal Ilmiah Teknologi Sistem Informasi, 8(1), 38-49.	Celullar Automata, Artificial Neural Network dan JST-CA.
10.	Liang, X., Guan, Q., Clarke, K. C., Liu, S., Wang, B., & Yao, Y. (2021).	Understanding the drivers of sustainable land expansion using a patch-generating land use simulation (PLUS) model: A case study in Wuhan, China.	Computers, Environment and Urban Systems, 85, 101569.	Celullar Automata

NO	AUTHOR	TITLE	JOURNAL	METHOD
11.	Mallick, J., AlQadhi, S., Talukdar, S., Pradhan, B., Bindajam, A. A., Islam, A. R. M. T., & Dajam, A. S. (2021).	A novel technique for modeling ecosystem health condition: a case study in Saudi arabia.	Remote Sensing, 13(13), 2632.	CA-ANN (Jaringan saraf tiruan automata seluler)
12.	Gomes, L. C., Bianchi, F. J. J. A., Cardoso, I. M., Schulte, R. P. O., Arts, B. J. M., & Fernandes Filho, E. I. (2020).	Land use and land cover scenarios: An interdisciplinary approach integrating local conditions and the global shared socioeconomic pathways.	Land Use Policy, 97, 104723.	Green Road dan Rocky Road
13.	Li, J., Cao, Y., Li, Y., Chu, J., Wang, Y., & Ma, M. (2023).	Using EL-CA Model to Predict Multi-Scenario Land Sustainable Use Simulation and Urban Development.	Journal of Experimental Nanoscience, 18(1), 2170352.	System dynamic (SD)
14.	Liu, H., Zheng, M., Liu, J., & Zheng, X. (2020).	Sustainable land use in the trans-provincial marginal areas in China.	Resources, Conservation and Recycling, 157, 104783.	Markov Chain
15.	Sadhwani, K., Eldho, T. I., Jha, M. K., & Karmakar, S. (2022).	Effects of Dynamic Land Use/Land Cover Change on Flow and Sediment Yield in a Monsoon-Dominated Tropical Watershed.	Water, 14(22), 3666.	Celluar Automata – Matkov Chain (CA-MC)
16.	Phinyoyang, A., & Ongsomwang, S. (2021).	Optimizing Land Use and Land Cover Allocation for Flood Mitigation Using Land Use Change and Hydrological Models with Goal Programming, Chaiyaphum, Thailand.	Land, 10(12), 1317.	CLUE-S
17.	Srichaichana, J., Trisurat, Y., & Ongsomwang, S. (2019).	Land use and land cover scenarios for optimum water yield and sediment retention ecosystem services in Klong U-Tapao Watershed, Songkhla, Thailand.	Sustainability, 11(10), 2895.	CLUE-S
18.	Rizeei, H. M., Pradhan, B., & Saharkhiz, M. A. (2019).	Surface runoff estimation and prediction regarding LULC and climate dynamics using coupled LTM, optimized ARIMA and distributed-GIS-based SCS-CN models at tropical region.	In GCEC 2017: Proceedings of the 1st Global Civil Engineering Conference 1 (pp. 1103-1126). Springer Singapore.	SVM
19.	Zhang, P., Liu, L., Yang, L., Zhao, J., Li, Y., Qi, Y., ... & Cao, L. (2023).	Exploring the response of ecosystem service value to land use changes under multiple scenarios coupling a mixed-cell cellular automata model and system dynamics model in Xi'an, China.	Ecological Indicators, 147, 110009.	SD, MCCA, NIS, dan EDS
20.	Abba Umar, D. U., Ramli, M. F., Tukur, A. I., Jamil, N. R., &	Detection and prediction of land use change impact on the streamflow regime in Sahelian	H2Open Journal, 4(1), 92-113.	Celluar Automata –

NO	AUTHOR	TITLE	JOURNAL	METHOD
	Zaudi, M. A. (2021).	river basin, northwestern Nigeria.		Matkov Chain (CA-MC)

Based on Table 2, various methods have been used to predict built-up land use. Several models have been developed to achieve the most accurate modeling results, such as System Dynamics models (Lai et al., 2022; J. Li et al., 2023; Zhang et al., 2023), Markov Chain (Lai et al., 2022; Liu et al., 2020; Yangouliba et al., 2022), Cellular Automata-Markov Chain (Debnath et al., 2022; Faksomboon, 2023; Kumar et al., 2021; Leta et al., 2021; Ruben et al., 2020; Sadhwani et al., 2022; Umar et al., 2021), Cellular Automata-Artificial Neural Network (Dede et al., 2022; Mallick et al., 2021; Sajan et al., 2022; Setiawan & Nandini, 2022), ABM (Agent-Based Models) (Kumar et al., 2021), Cellular Automata (Benchelha et al., 2022; Liang et al., 2021), CLUE-S (Phinyoyang & Ongsomwang, 2021; Srichaichana et al., 2019), EL-CA (J. Li et al., 2023), SVW (Rizeei et al., 2019), and LCM (combining TerraSet Geospatial Monitoring and Modeling system) (Leta et al., 2021; Sadhwani et al., 2022). Among the various models used, there are two main models most frequently employed in land use modeling, particularly for built-up land: System Dynamics and Cellular Automata-Markov Chain models. The System Dynamics (SD) model, according to (Dede et al., 2022; Liang et al., 2021b; Utami et al., 2017), provides an overview of the relationship between population growth variables and land availability variables. Based on this SD model, it is possible to find a balance between available land and built-up areas, ensuring that land carrying capacity is maintained and sustainable (Supriatna et al., 2016). Meanwhile, the Cellular Automata-Markov Chain (CA-MC) model is used to model complex dynamic systems with continuous predictive analysis, due to its flexibility, intuition, and capacity to integrate spatial and temporal characteristics of existing procedures (Liu et al., 2020; Umar et al., 2021). The CA-MC combination can simulate the spatiotemporal dynamics of land use change by predicting cell transitions from one land use to another based on physical and socio-economic data (Leta et al., 2021).

Table 3. Keywords dan Object of Reviewed Journal

NO	AUTHOR	KEYWORDS	VARIABLES
1.	Lai, Z., et al. (2022).	urban growth boundaries (UGBs), LULC change simulation, multi-source big data, SD model, PLUS model, county area, and Xinxing County	Population, GDP, Food Production and LULC 2015 - 2020
2.	Yangouliba, G. I., et al (2022).	Land use/land cover, Random forest, Markov chain, Multi-layer-perceptron neural network, Land change modeler, and Nakambé River Basin	LULC 1990, 2005 and 2020
3.	Debnath, J., et al. (2022).	Brahmaputra Valley, Flood plain, CA-Markov, Geospatial, Land use/land cover	LULC 1973, 1988, 1997, 2005, 2011 and 2021
4.	Leta, M. K., et al (2021).	land change modeler, Landsat images, modeling LULC change, multilayer perceptron, TerrSet	LULC 1990, 2005 and 2019
5.	Wang, B., Liang, Y., & Peng, S. (2022)..	Urbanisation, Cropland displacement, Coupled scenarios, Integrated model, Food production, Loess Plateau	LULC, population, GDP, temperature, DEM, and Grain production 2000 - 2018
6.	Kumar, V., et al (2021).	Urban dynamics, Spatial cognition, Sustainable development, Agent-based modeling, LULC	Distance from (Road, hospital, school) and LULC in 2007, 2013 and 2019
7.	Sajan, B., et al (2022).	LULC, remote sensing, QGIS, CA-ANN, prediction	LULC 1990, 2000, 2010, and 2020

NO	AUTHOR	KEYWORDS	VARIABLES
8.	Ruben, G. B., et al (2020).	land-use/land-cover change, Guanting Reservoir Basin, CA–Markov, prediction	LULC 1990, 2000, and 2010
9.	Dede, M., Asdak, C., & Setiawan, I. (2022).	Cirebon's peri-urban, Logistic regression, LULC changes, spatial dynamics	Land slope, distance from (rivers, buildings, CBD), population density, accessibility, disaster risk and LULC in 1999, 2009 and 2019.
10.	Liang, X., et al (2021).	Cellular automata, Drivers of land use change, Sustainable land use, Patch-generating simulation	LULC 2003-2013
11.	Mallick, J., et al (2021).	Ecosystem health conditions, global sensitivity analysis, remote sensing, fuzzy logic, GIS, cellular automata, machine learning	Topography, DEM and LULC tahun 1990, 2000 and 2018
12.	Gomes, L. C., et al. (2020).	Land use, Public policies, Future scenarios, Interdisciplinarity, Forest transition	Biophysical Variables, LULC 1986-2015
13.	Li, J., et al. (2023).	Green development, land use changes, mountainous city, gravity centre of urban development, nanotechnology, the System Dynamics model, the EL-CA model	GDP, population, fixed asset investment, population change rate, GDP change rate, food production, road network, LULC in 1999, 2008, and 2018
14.	Liu, H., Zheng, M., Liu, J., & Zheng, X. (2020).	Trans-provincial marginal areas, Lulc, Markov model, Sustainable development	LULC 1980, 1995, 2000 and 2010
15.	Sadhwani, K., et al (2022).	LULC change projection, Markov chain–cellular automata, sediment yield, SWAT model, Western Ghats of India	Rainfall, temperature, wind speed, solar radiation, humidity, altitude, land slope, and LULC (1988, 1992, 2002, and 2016)
16.	Phinyoyang, A., & Ongsomwang, S. (2021).	optimizing land use and land cover allocation, surface runoff coefficient, goal programming, random forests, SCS-CN model, CLUE-S model, Chaiyaphum province, Thailand	Rainfall data, population density, population income, altitude, slope, road network, rivers and LULC (2001, 2010, and 2019)
17.	Srichaichana, J., Trisurat, Y., & Ongsomwang, S. (2019).	optimum land use and land cover scenario, water yield and sediment retention ecosystem services, Random Forests, InVEST model, CLUE-S model, Khlong U-Tapao watershed, Songkhla Province, Thailand	LULC 2010-2017
18.	Rizeei, H. M., et al (2019).	Land transformation model, ARIMA, SCS-CN, Runoff simulation, GIS	Precipitation, and LULC in 2000, 2010
19.	Zhang, P., et al. (2023).	Ecosystem service value, MCCA, SD, Scenario prediction, Sensitivity analysis	Land slope, soil type, rainfall, temperature, distance from (road and administrative center and LULC 2000-2015)
20.	Abba Umar, D. U., et al (2021).	cellular automata, inverse distance weightage, land use, northwestern Nigeria, streamflow	Climate, sedimentation, temperature, soil, hydrological basins and drainage, rock formations, LULC (1980, 1990, 2000, and 2010), and socio-economic characteristics

Based on Table 3, it is found that among the 20 reviewed journals, various keywords and variables were used in previous research. The keywords used by these studies focus on the methods, objectives, and subjects of each study, while there are similarities in the variables used namely the LULC (Land Use Land Cover) variable which was used as a primary variable across all journals reviewed, with a time span of 10-30 years. Other common variables include socio-economic characteristics such as population size, growth rate, GDP, and food production (Dede et al., 2022; Lai et al., 2022; J. Li et al., 2023; Phinyoyang & Ongsomwang, 2021; Umar et al., 2021; Wang et al., 2022), accessibility such as distance from roads, hospitals, rivers, schools, and city centers (Dede et al., 2022; Kumar et al., 2021; J. Li et al., 2023; Phinyoyang & Ongsomwang, 2021; Zhang et al., 2023), climatic conditions such as rainfall, temperature, humidity, and solar radiation (Phinyoyang & Ongsomwang, 2021; Rizeei et al., 2019; Sadhwani et al., 2022; Umar et al., 2021; Wang et al., 2022; Zhang et al., 2023), and physical characteristics such as slope, elevation, soil type, and geological conditions (Mallick et al., 2021; Phinyoyang & Ongsomwang, 2021; Sadhwani et al., 2022; Umar et al., 2021; Wang et al., 2022; Zhang et al., 2023). In terms of the subject of study, most journals only examine land use in the study area (Debnath et al., 2022; Leta et al., 2021; Liang et al., 2021a; Liu et al., 2020; Ruben et al., 2020; Sajan et al., 2022; Srichaichana et al., 2019; Yangouliba et al., 2022), while some investigate the impact of land use on watershed conditions affecting surface flow, river discharge, and flooding in the study area (Phinyoyang & Ongsomwang, 2021; Rizeei et al., 2019; Sadhwani et al., 2022; Umar et al., 2021; Zhang et al., 2023) Thus, considering the physical conditions of Indonesia and the availability of data for research on predicting land use, particularly built-up land in relation to flood disasters, several key variables can be used such as LULC, population size, growth rate, GDP, slope, soil type, distance from (rivers, roads, city centers), and rainfall.

4. CONCLUSION

The research results based on the review of 20 journals show that there are two most relevant and widely used methods for land use modeling, especially built-up land, namely SD (System Dynamic Model) and CA-MC (Cellular Automata – Markov Chain). The most suitable variables for the study of land use, especially built-up land, in relation to flood disasters are population, growth rate, rainfall, slope gradient, GDP, distance from (road, river, and city center), and LULC. Given Indonesia's disaster-prone areas and the availability of data for each variable, this analysis can be further explored and developed to obtain optimal regional prediction results.

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