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LAND USE CHANGE PATTERN OF CHANGE AND STRATEGY DIRECTIONS FOR SPATIAL UTILIZATION CONTROL IN BOGOR REGENCY

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ABSTRACT
The designation of Bogor Regency as a National Activity Center encourages regional development, a very high population leads to rapid development and uncontrolled land use change. Therefore, spatial modeling based on land change prediction is needed that can be used as a basis for directing spatial utilization control policies. The purpose of this research is to know and analyze the pattern of land use change and analyze the direction of spatial use control strategies in Bogor Regency. The research was conducted in Bogor Regency. The analysis used ArcGIS 10.8 Overlay and IDRISI Selva Edition and ISM v. 2.3. The results of the analysis of land use change in between 1997 and 2010, 87.98% of land use remained unchanged, while 12.01% changed. From 2010 to 2023, 73.16% remained unchanged, and 26.84% changed. The predominant land change pattern was from Dry Land Agriculture to Dry Land Agriculture-Rice Fields, while the least common was Open Land to Dry Land Agriculture and back to Open Land. By 2036, expected increases include settlements, shrubs, and Open Land, with decreases anticipated in dryland agriculture, forests, and paddy fields. The alignment of land use with the RTRW spatial plan shows 58.68% aligned, 23.85% transitional, and 17.46% misaligned. It is recommended to maintain land use aligned with the spatial plan, utilize transitional areas, and revise the RTRW for areas that are permanently misaligned. Strategies to control spatial utilization include enhancing technical training, improving infrastructure, aligning staff with organizational needs, and refining spatial planning policies and dispute resolution.

Keywords: CA-Markov, Land Suitability, Land Use Prediction.

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INTRODUCTION

Bogor Regency has a very strategic location because it borders 7 (seven) regencies, namely Sukabumi, Lebak, Tangerang, Bekasi, Purwakarta, Karawang, and Cianjur, as well as 4 (four) cities, namely Bogor City, South Tangerang, Bekasi and Depok. Bogor Regency is part of the National Strategic Area (KSN, *Kawasan Strategis Nasional*) (Trimarmanti, 2014). The position of Bogor Regency in the National Spatial Plan (RTRWN, *Rencana Tata Ruang Wilayah Nasional*) is directed as the Jabodetabekpunjur National Activity Center (PKN, *Pusat Kegiatan Nasional*) and as one of the buffer zones of the capital city of Jakarta. The most common phenomenon that occurs as a buffer zone from the core city is the emergence of land use inconsistencies against the Regency RTRW's spatial pattern (Nabawi et al., 2020). Population growth in Bogor Regency is relatively rapid, where in 2014, the population reached 5,331,149 people, increasing to 5,566,840 people in 2022 (Statistics, 2016). Moreover, it became the largest population in Indonesia.

Research results (Fajarini et al., 2015) showed that land use in Bogor Regency from 1999 to 2013 experienced rapid changes, especially in agricultural land, and 1995-2001 was a significant

change. The cause of land use change is the issuance of many new housing location permits, the establishment of several industrial areas, and the increasing number of collector roads connecting to urban centers.

In general, the conversion of paddy fields in Bogor Regency during the 2003-2019 period experienced fluctuations from year to year. The area of converted paddy fields from 2003 to 2019 reached 11,822 hectares or an average of 695.41 hectares per year. The conversion of paddy fields reduced the area of paddy fields in Bogor Regency from 48,177 hectares in 2003 to 36,355 hectares at the end of 2019 (Statistics, 2016).

According to Septiono (Cahyono & Dunggio, 2021), uncontrolled land use change can impact environmental aspects such as climate change and natural disasters, and uncontrolled land control can cause urban sprawl. Urban Sprawl can occur as a result of rapid infrastructure development and the development of industrial and residential activities (Gusandra et al., 2023). Urban sprawl is often considered to have adverse effects on the development of cities, referred to as obese cities, with heavy traffic and damaging conditions (Prayitno, 2022).

According to (Akhmad & Meisandy 2021), information related to land use is a significant aspect of planning an area. Therefore, there is a need for harmonized land use planning, such as policies that regulate land use growth to prevent uncontrolled development.

Since land use change continues to grow, prediction-based spatial modeling of land change is needed (Syafitri & Susetyo, 2019). This modeling is done to determine future development forecasts, evaluate plans, and identify threatened conservation areas (Nong & Du, 2011). The prediction results can be used to direct spatial utilization control policies.

Previously conducted research related to land use change is Land Use Analysis and Direction of Space Utilization Control in Bogor Regency, which shows that most of the land use is by the spatial pattern, both in the form of existing land use and those that have not yet been implemented. In contrast, the existing land use that is not suitable is only a tiny part (Dani et al., 2017). Research on spatial patterns of land cover change/land use using Google Earth Engine in Majalengka Regency shows the results of a decrease in the area of rice fields and fields by 4457.36 Ha in ten years; it is necessary to make efforts/planning strategies in the future to anticipate changes in agricultural land that occur massively in Majalengka Regency, the results of land use classification using the smile-Random Forest algorithm on the GEE platform can produce maps with high accuracy, namely >98%, and can shorten the process and analysis time.

Other research, namely prediction modeling and suitability of land use change using Cellular Automata-Artificial Neural Network (CA-ANN), shows the results of settlements increasing by 287.342 Ha, rice fields and open land decreasing in area by 291.93 Ha and 433.21 Ha, prediction modeling in 2015 and 2017 with road to campus and campus to road variables showing a Kappa value of 0.95621 (powerful) and a correction of 97.14% (Nabila, 2023). The following research, namely the direction of Land Use Change Control Using Markov-Cellular Automata in Cianjur Regency, resulted in a prediction that the percentage of land use non-conformity to the RTRW increased sharply by 20.5%, the direction of scenario three, where forests and shrubs in protected areas are maintained or not allowed to change function and dry land agriculture which is also in protected areas is returned to forest function (Yudarwati et al., 2017).

The objectives of this study are as follows: (1). Analyzing land use change in 1997-2010-2023 and its pattern of change (2). Predicting the direction of land use change (3). Analyzing the alignment

of land use and spatial pattern of RTRW (4). Formulate directions for improving the spatial pattern of the Bogor Regency RTRW (5). Formulate directions for spatial utilization control plans and strategies in Bogor Regency. As for the benefits, the findings will contribute to more informed land use planning, helping policy makers and planners to anticipate and manage future land use changes, thereby enhancing regional development and environmental sustainability.

METHOD

Research Location

This research was conducted in Bogor Regency, West Java Province. Bogor Regency has an area of ± 2,664 km². It is geographically located between 6018'0" - 6047'10" South latitude and 106023'45" - 107013'30" East longitude, consisting of 40 sub-districts. Bogor Regency is bordered to the north by Depok City, Bekasi Regency, Bekasi City, DKI Jakarta, South Tangerang City, and Tangerang Regency, to the east by Karawang Regency, to the west by Lebak Regency and to the south by Sukabumi Regency and Cianjur Regency. More details can be seen in Figure 1.

Figure 1. Study Location Map (Bapedalitbang, 2023)

Research Data

This research uses two types of data: primary and secondary. Primary data is in the form of ground check results in the field to check image interpretation. Primary data is obtained from observation, namely observing conditions that occur in the field. (Mokodongan et al., 2019)Primary data is obtained from observation, namely observing the conditions in the field and interviews with figures and parties who know the problems studied. Secondary data in SPOT image maps of land use in 1997, 2010, and 2023 were processed to produce land use maps using Idris Selva 17 and ArcGIS 10.8 software. The resulting maps include 1997, 2010, and 2023 land use maps. More details about the types of data, data sources, data collection techniques, data analysis techniques, and outputs can be seen in Table 1.

Table 1. Data Type, Data Source, Data Analysis Technique, and Research Outputs

No.	Research Objectives	Data Type	Data Source	Data Collection Technique	Data Analysis Techniques	Output
1	They are analyzing	Land Use/Land Cover Map 1997	Bappedalitbang Bogor	Secondary Survey and		Knowing the pattern of

No.	Research Objectives	Data Type	Data Source	Data Collection Technique	Data Analysis Techniques	Output
	changes in land use/land cover from 1997-2010-2023 and their patterns of change.	Land Use/Land Cover Map 2010	Regency and BIG	Field Ground Check with GPS	Image Interpretation and CA Markov	Land Use/Land Cover changes in 1997-2010-2023
		Land Use/Land Cover Map 2023	BRIN			
2	Predicting the direction of land use/land cover change	Land Use/Land Cover Map 2023	Analysis	Analysis Result	CA Markov Chain	Prediction map of land use/land cover in 2036
		Transition Probability Matrix (TPM) 2023-2036	Analysis	Analysis Result		
3	Analyze the alignment of land use and spatial pattern of the RTRW	Land Use/Land Cover Map 2023	Analysis	Analysis Result	GIS Overlay and Alignment Matrix	Map of Alignment of Space Utilization
		Spatial Pattern Map of Bogor Regency RTRW 2016-2036	Bappedalitbang Bogor Regency	Secondary Survey		
4	Formulate directions for improving the spatial pattern of the RTRW	Spatial Pattern Map of Bogor Regency RTRW 2016-2036	Bappedalitbang Bogor Regency	Secondary Survey	GIS Overlay	Knowing the Direction of Space Utilization from Land Suitability
		Land suitability map	Soil Research Center	Secondary Survey		
		Land Use/Land Cover Map 2023	Analysis	Analysis Result		
5	Formulate directives for spatial utilization control plans and strategies	Results of Land Use Pattern Alignment Analysis	Analysis Result	Interview and Questioner	*Interpretive Structural Modeling* (ISM) Analysis Method	Direction of Space Utilization Control Plan and its Strategy
		Prediction Map of Land Use/Land Cover in 2036	Analysis Result			
		Direction for improving the spatial pattern of the RTRW	Analysis Result			

Data Collection Technique

Land Use/Land Cover Change 1997-2010-2023 and its Pattern of Change

To find out the dynamics of land use change, the data used are Shapefile data and SPOT images of land cover/use in 1997 and 2010 obtained from Bapedalitbang Bogor Regency; the 1997 and 2010 land cover/use data were then reclassified according to the SNI 7645: 2010 classification of Land Cover Classification, the images were then interpreted visually using Idrisi Selva 17 and ArcGis v.10.8

software. Land cover/use types on satellite imagery were updated with field checks in 2023 for sampling points totaling 200 points spread across all sub-districts.

Predicting the Direction of Land Use/Land Cover Change

Land use/land cover modeling in 2023 and 2036 was carried out using the Idrisi Selva 17 modeling software. The modeling process requires the ability to use the tools in this software, namely LCM (Land et al.). After the model is generated, the accuracy of the model is tested using the calculation of the K-standard (Kappa Coefficient) in the Idrisi Selva 17 software. Suppose the simulation accuracy results are achieved >70%. In that case, there is no need to repeat the accuracy process, and we can proceed to the following modeling process.

Alignment of Existing Land Use with Spatial Pattern of RTRW

The data used is the 2023 land use map overlaid with the 2016-2036 Bogor District RTRW spatial pattern map. The overlay results are queried based on the logic matrix of land use alignment with spatial patterns to produce a map of existing land use alignment with the direction of the RTRW spatial pattern.

Formulate directions for improving the spatial pattern of the RTRW.

The data used is the 1: 50,000 scale land suitability map of Bogor Regency obtained from the Soil Research Institute overlaid with the 2016-2036 Bogor Regency RTRW spatial pattern map and the 2023 land use map. The results are overlaid to obtain spatial utilization direction based on the direction of land potential from the analysis of land suitability and spatial pattern of RTRW and land use.

Formulate Direction Plans and Strategies for Controlling Space Utilization

The interview is a method of collecting data by asking directly (communicating directly) with respondents. This interview uses a sample of participants to find out more in-depth things in interpreting the situations and phenomena that occur. Sampling uses the purposive sampling technique, which determines specific criteria. (Sugiyono, 2013). The target sample for this research is respondents who have knowledge or are experts in regional planning and are competent according to the research title so that their answers can be represented based on these considerations. The respondents selected were from academics, totaling 2 (two) respondents, and agencies such as The Land Office, Bapedalitbang, and the Bogor Regency Public Works and Spatial Planning Office each had 1 (one) respondent, totaling 5 (five) respondents.

Data Analysis Technique

Land Use Change Analysis

The focus of the research is land use change in Bogor Regency. The stages of analyzing land use/cover change are as follows: The Interpretation of satellite images is intended to identify objects and assess their importance. (Chairunnisa et al., 2017).. Based on the stages, SPOT image data from 1997, 2010, and 2023 were interpreted using the visual interpretation method (digitized on screen) based on the results of sample points from the field. The map overlay method is used to analyze land use change. The overlay can be done on vector and raster data (Larasati et al., 2017). More details can be seen in Figure 2.

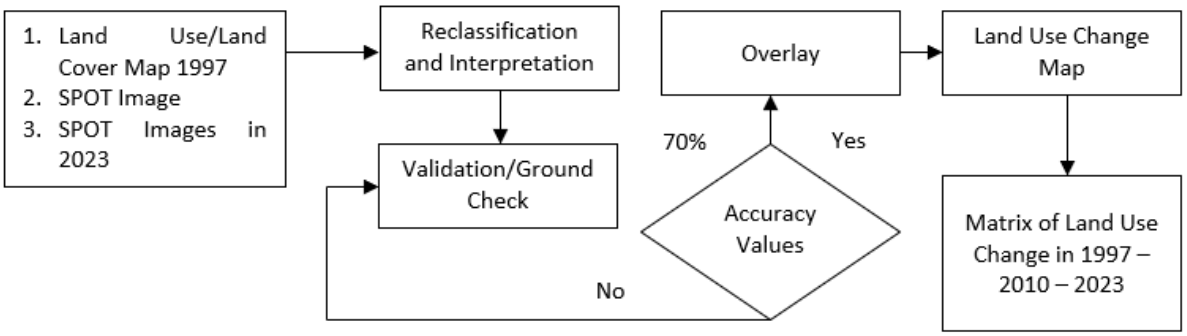

Figure 2. Flowchart of Land Use/Land Cover Change

Land Use Prediction

This analysis was run using the 1997 and 2010 land use change raster data as the base land use image, then inputting the Markov Transition Area File obtained from the Markov probability transition results. Next, it entered the Transition Suitability Image Collection built in the MCE module by entering several driving factors determining 13 for 13 years of change as the number of CA literacies and selecting the 5×5 filter type, which is the standard filter in Cellular Automata. The 5×5 filter produces an image that is not too blurry and does not have too much noise. (Awal et al., 2023).

With the input of land use in 1997 and 2010, a prediction of land use in the existing year, namely land use in 2023, was made. This aims to obtain a projection map used in data validation analysis. The next step is to run the Cellular Automata model to obtain land use predictions for 2036. The data entered is a land use transition matrix for 2023-2036, which is assumed not to be influenced by other factors that affect land cover/land use change. More details about the flow chart of prediction of land use/land cover change direction can be seen in Figure 3.

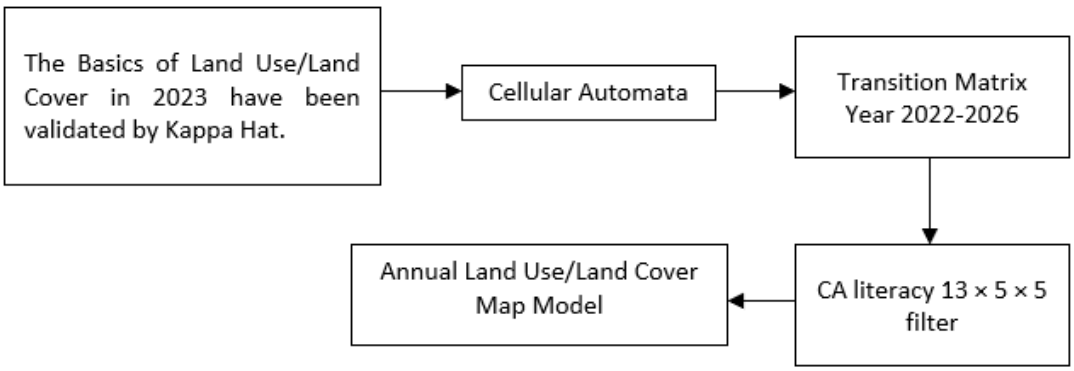

Figure 3. Flowchart for Predicting the Direction of Land Use/Land Cover Change

Analysis of Land Use Alignment and Spatial Pattern of RTRW

Alignment analysis was conducted by overlaying the existing land use map with the RTRWmap (Sejati et al., 2020). The 2023 land use map overlaid the 2016-2036 Bogor District RTRW spatial pattern map. The first step was to match the type of space utilization allocation in the Bogor District RTRW spatial pattern. The second stage is to build a logic matrix of misalignment. The third stage is to analyze the alignment of land use with the spatial pattern and map the results of the alignment and misalignment of land use against the RTRW spatial pattern plan. More details on the flow chart of overlaying and matching land use types with the RTRW spatial pattern can be seen in Table 2 and Figure 4.

Table 2. Land Use Type Match with Spatial Pattern of RTRW

No.	Land Use	District RTRW
1	River, Lake, Reservoir	Reservoir Plan
2	Forest	Protected Forest
3	Forest	Limited Production Forest Area
4	Forest	Permanent Production Forest Area
5	Sawah	Wetland Farming Area
6	Rice fields, Dryland farming, Mixed farming	Dryland Farming Area
7	Plantation	Plantation and Annual Crops Area
8	Settlements	Rural Settlement Area
9	Settlements	High-Density Urban Residential Area
10	Settlements	Medium-Density Urban Settlement Area
11	Settlements	Low-Density Urban Residential Area
12	Settlement, Airport	Defense and Security Area
13	Industry	Industrial Designation Area
14	*Enclave*	*Enclave* Area

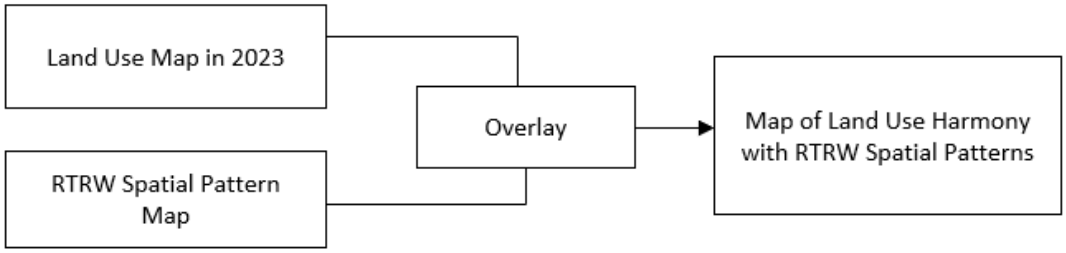

Figure 4. Flowchart of Overlaying Land Use Alignment Map with Spatial Pattern of RTR

Preparation of RTRW Spatial Pattern Refinement Directive

The direction for improving the Bogor Regency spatial pattern was prepared by overlaying the 1:50,000 scale land suitability map with the 2016-2036 Bogor Regency RTRW spatial pattern plan map. Considerations in the analysis of spatial utilization direction are based on the results of land use alignment with RTRW, existing land use, land suitability, and RTRW spatial pattern. More details can be seen in Figure 5.

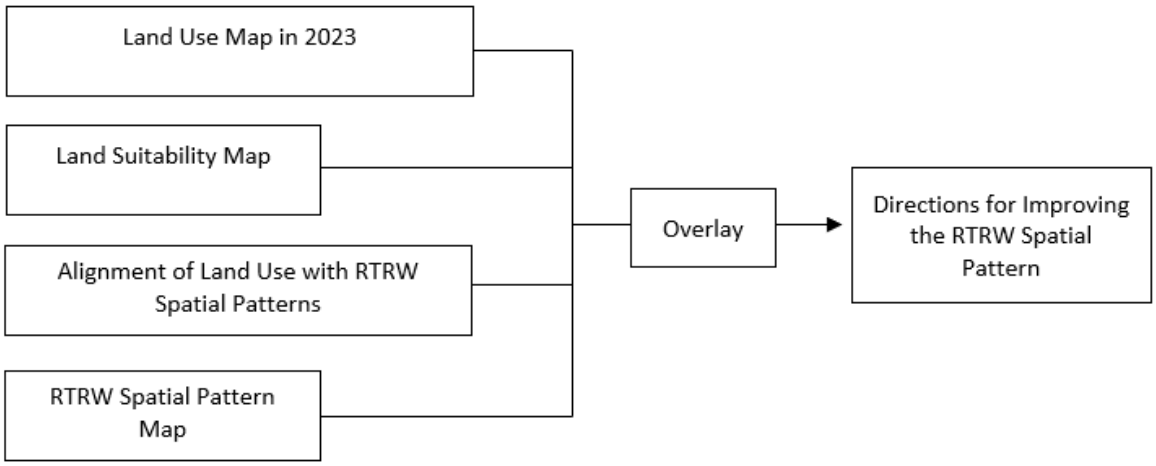

Figure 5. Flow Chart of Overlaying the RTRW Spatial Pattern Refinement Directive

Analysis of Space Utilization Control Directives and Strategies

The formulation of spatial utilization control directions and strategies uses the ISM method, which can summarize experts' opinions and provide specific opinions on the hierarchy of sub-elements according to each element in the system (Rifaldi et al., 2021). The ISM method is a method that can prove the relationship between existing elements. This method can be used to plan strategic policies (Khalil & Sutjahyo, 2008). According to (Sianipar, 2012), There are two parts to the ISM: the hierarchical structure and the arrangement of elements. ISM is not only used for evaluation but can also be used by researchers. In the program studied by the ISM method, each level of the structure is divided into several elements, and each element is further divided into several sub-elements.

Creating a Structural Self Interaction Matrix (SSIM) is where the variables are contextual relationships made by making one variable, i, and j variables. Next, a Reachability Matrix (RM) will be created by changing V, A, X, and O with numbers 1 and 0. The last step is to create a Canonical Matrix to determine the level through iteration. After there are no more intersections, a model generated by ISM is made, which is a model for solving problems, in this case, a directive strategy for controlling space utilization. A road map for institutional development (level) will be made from the model (Rusydiana, 2018).

This analysis results in a Driver-Dependence matrix and hierarchy of each element. The data used as input for processing is obtained from interviews with respondents. The respondents are parties from related fields, namely the Land Office, Bappedalitbang, the PUPR Office, and academics.

RESULTS AND DISCUSSION

Land Use Change and Patterns of Change

Based on the land use map of Bogor Regency in 1997, 2010 and 2023. The land use classification is divided into 13 (thirteen) categories: Airports, Lakes, Forests, Industries, Plantations, Settlements, Mining, Dry Land Agriculture, Rice Fields, Bushes, Rivers, Open Land, and Reservoirs. The most dominant land use changes in 1997-2010 were settlements from 15,308.87 Ha to 36,762.35 Ha or an increase of 21,453.48 Ha (58.36%), shrubs from 5,295.12 Ha to 7,354.53 Ha or an increase of 2.059.41 Ha (28%), then dry land agriculture from 132,670.26 Ha to 123,065.96 Ha or decreased by 9,604.30 Ha (7.80%), forest land use from 67,871.24 Ha to 62,284.27 Ha or decreased by 5,586.97 Ha (8.97%).

The most dominant land use changes in 2010-2023 are settlement land use in 2010 of 36,762.35 Ha to 49,618.38 Ha or an increase of 12,856.03 Ha (25.91%), dry land agriculture from 123,065.96 Ha to 130.958.34 Ha or increased by 7,892.38 Ha (6.03 %), then plantation land use from 16,745.74 Ha to 10,635.10 Ha or decreased by 6,110.65 Ha (57.46 %), paddy fields decreased from 48,149.72 Ha to 40,301.45 Ha or 19.47 %. The results of the GIS overlay of land use change in Bogor Regency in 1997-2010, the area of land use remained at 263,288.35 Ha or 87.98% while for land use that changed amounted to 35,937.07 or 12.01%. For land use change in 2010-2023, the area of land use that remained was 218,907.52 Ha or 73.16%, while for land use that changed was 80,317.90 or 26.84%. More details can be seen in Tables 3, 6, and 7.

Table 3. Land Use Change 1997-2010-2023 (Analysis Result, 2024)

No.	Land Cover	Year (Ha)			Changes			
					1997-2010		2010-2023	
		1997	2010	2023	Ha	%	Ha	%
1	Airport	42,32	42,32	42,32	-	-	-	-
2	Lake	490,60	490,60	490,60	-	-	-	-
3	Forest	67.871,24	62.284,27	56.397,38	-5.586,97	-8,97	-5.886,89	-10,44
4	Industry	392,39	531,38	3.887,25	+138,99	+26,16	+3.355,87	+86,33
5	Plantation	21.954,45	16.745,74	10.635,10	-5.208,71	-31,10	-6.110,65	-57,46
6	Settlements	15.308,87	36.762,35	49.618,38	+21.453,48	+58,36	+12.856,03	+25,91
7	Mining		1,39	1.862,50	+1,39	+100,00	+1.861,11	+99,93
8	Dryland Agriculture	132.670,26	123.065,96	130.958,34	-9.604,30	-7,80	+7.892,38	+6,03
9	Sawah	50.962,29	48.149,72	40.301,45	-2.812,56	-5,84	-7.848,27	-19,47
10	Shrubs/Bushes	5.295,12	7.354,53	2.434,92	+2.059,41	+28,00	-4.919,62	-202,04
11	River	1.902,38	1.902,38	1.897,64	-	-	-4,74	-0,25
12	Open Land	2.335,49	1.894,76	560,23	-440,73	-23,26	-1.334,53	-238,21
13	Reservoir			139,30	-		+139,30	+100,00
Total Area (Ha)		**299.225,41**	**299.225,41**	**299.225,41**				

The factor of land use change from 1997-2010 is that many agricultural lands were converted into housing and industry, generally on non-built land (dryland and paddy fields). This is because the need for land increases along with the increase in population. This is in line with the results of research from (Fajarini et al., 2015) from 1995 to 2001 in Bogor Regency, there was a conversion of the use of paddy fields, gardens, and built-up land and research (Ilham et al., 2005) which stated that economic pressure during the economic crisis caused many farmers to sell rice fields to meet their needs. The impact generally increases the conversion rate of paddy fields and concentrates land control in certain parties. In 2007, the concept of Megapolitan was established to integrate the development of Jakarta and its surrounding cities that had been a buffer, including Bogor Regency, which was expected to become an independent city. One example is the provision of housing on the outskirts of Jakarta, which is a result of the high housing prices in Jakarta.

Factors of land use change from 2010-2023 are internal and external policy factors for Bogor Regency such as the RTRW Directive, which saves Bogor Regency as part of Jabodetabekjur as a National Activity Center (PKN), Presidential Regulation No. 60 of 2020 as a National Strategic Area (KSN) from the point of economic interest, the change in the Bogor Regency RTRW from Perda No. 19 of 2008 to Perda No. 11 of 2016 has an impact on land use change, especially in areas bordering Depok City, Bekasi City, South Tangerang City, Bogor City and Tangerang Regency, a population of 5,627,060 people. 19 of 2008 to Perda No. 11 of 2016 has an impact on land use changes, especially in areas bordering Depok City, Bekasi City, South Tangerang City, Bogor City, and Tangerang Regency, a population of 5,627,020 people (BPS et al., 2024) which is the highest in Indonesia.

The construction of the Bogor-Ciawi-Sukabumi (BOCIMI) Toll Road, which began operating in 2018 to serve the southern part of Bogor Regency, including Ciawi, Caringin, Cijeruk, and Cigombong

Districts, caused many investors to buy land around the area, especially with the planned development of a large-scale tourism area, namely the Lido SEZ.

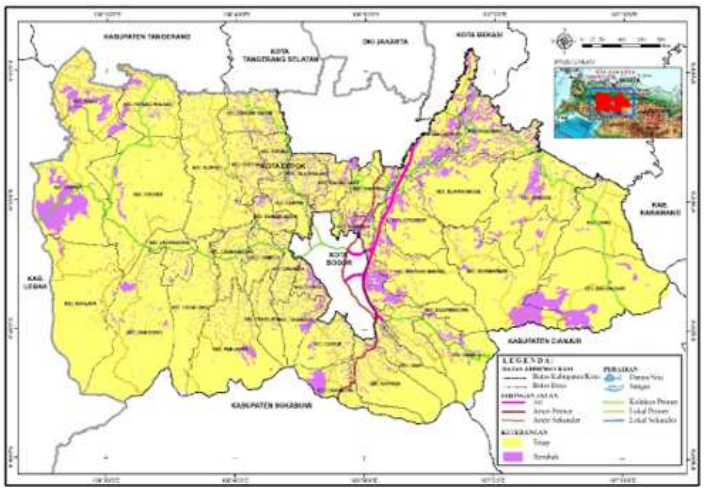

Figure 6. Map of Land Use Change 1997-2010
(Analysis Result, 2024)

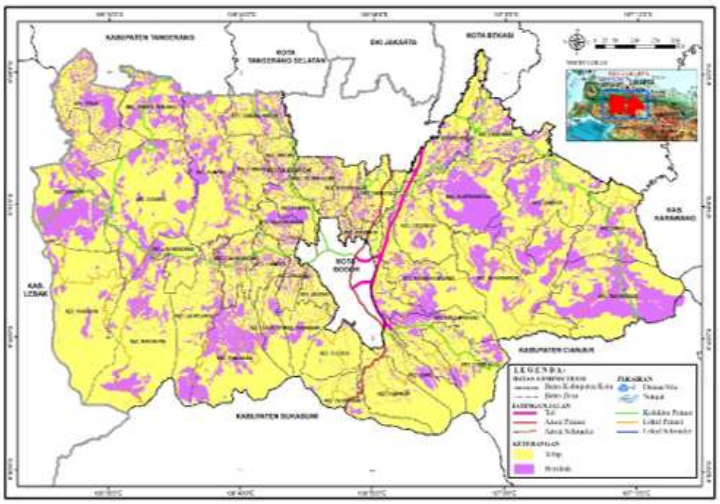

Figure 7. Map of Land Use Change 2010-2023
(Analysis Result, 2024)

The pattern of land change that occurred in Bogor Regency in the period 1997-2010-2023 from the most dominant is:

(1) Dryland Agriculture → Dryland Agriculture → Rice Fields
(2) Plantation → Plantation → Dryland Farming
(3) Forest → Forest → Dryland Farming
(4) Rice Field → Rice Field → Settlement.

The smallest pattern of change is :

(1) Open Land → Open Land → Dryland Farming
(2) Settlement → Industry → Industry.

For more details, please refer to Table 4.

Table 4. Land Use Change Pattern (Analysis Result, 2024)

No.	Land Use 1997	Land Use in 2010	Land Use in 2023	Area (Ha)
1	Forest	Forest	Plantation	1780,95
		Forest	Dryland Agriculture	4794,22
		Dryland Agriculture	Dryland Agriculture	4080,94
2	Plantation	Plantation	Dryland Agriculture	7181,61
		Shrubs/Bushes	Dryland Agriculture	2354,27
		Plantation	Shrubs/Bushes	2003,75
3	Settlements	Industry	Industry	129,03
		Settlements	Industry	626,21
4	Dryland Agriculture	Dryland Agriculture	Sawah	11.651,40
5	Sawah	Settlements	Settlements	2.976,15
		Sawah	Settlements	4.434,85
6	Shrubs/Bushes	Shrubs/Bushes	Plantation	2229,91
		Dryland Agriculture	Dryland Agriculture	1215,32
7	Open Land	Open Land	Dryland Agriculture	435,8

Predicted Land Use Change

Land use prediction using the Cellular Automata (CA) model is widely adopted and applied in the field of earth science, one of which is for the study of land use change. (Yudarwati et al., 2017).. Before predicting land use in 2036, an accuracy test was conducted on land use in 2023 and land use prediction in 2023, which obtained a Kappa value of 0.74, as shown in Figure 8, which means it is included in the good/strong Interpretation (0.61-0.80).

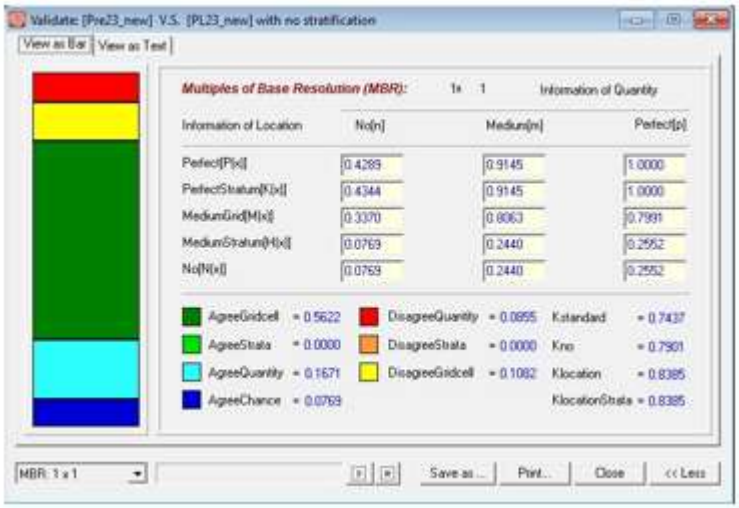

Figure 8. Data Accuracy Test Results (Analysis Results, 2024)

The prediction results of land use change in 2036 are the increase in residential land use from 2023 of 49,618.38 Ha to 96,585.66 Ha in 2036 or an increase of 46,967.28 Ha; the increase from dry land agricultural land use of 35,507.14 Ha and rice fields of 9,462.48 Ha. Industrial land use has increased from 2023 3,887.25 Ha to 4,148.35 Ha in 2036, or an increase of 261.09 Ha. The land use class that experienced the most significant decrease in 2036 was dry land agriculture, in 2023 amounting to 130,958.34 Ha, predicted in 2036 to be 97,073.13 Ha or reduced by 25.87%. More details about the 2036 prediction can be seen in Table 5 and Figure 9.

Table 5. Predicted Land Use in 2036 (Analysis Results, 2024)

No.	Land Cover	Year 2023		2036 Prediction		Changes
		Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)
1	Airport	42,32	0,01	42,32	0,01	-
2	Lake	490,60	0,16	490,60	0,16	-
3	Forest	56.397,38	18,85	44.720,78	14,95	- 11.676,59
4	Industry	3.887,25	1,30	4.148,35	1,39	261,09
5	Plantation	10.635,10	3,55	8.325,23	2,78	- 2.309,87
6	Settlements	49.618,38	16,58	96.585,66	32,28	46.967,28
7	Mining	1.862,50	0,62	3,56	0,00	-1.858,94
8	Dryland Agriculture	130.958,34	43,77	97.073,13	32,44	- 33.885,21
9	Sawah	40.301,45	13,47	34.611,23	11,57	-5.690,23
10	Shrubs/Bushes	2.434,92	0,81	8.769,67	2,93	6.334,75
11	River	1.897,64	0,63	1.897,64	0,63	-
12	Open Land	560,23	0,19	2.417,94	0,81	1.857,70
13	Reservoir	139,30	0,05	139,30	0,05	-
	Total Area (Ha)	**299.225,41**	**100,00**	**299.225,41**	**100,00**	

Predicted Land Use Change

Land use prediction using the Cellular Automata (CA) model is widely adopted and applied in the field of earth science, one of which is for the study of land use change (Yudarwati et al., 2017). Before predicting land use in 2036, an accuracy test was conducted on land use in 2023 and land use prediction in 2023, which obtained a Kappa value of 0.74, as shown in Figure 8, which means it is included in the good/strong Interpretation (0.61-0.80).

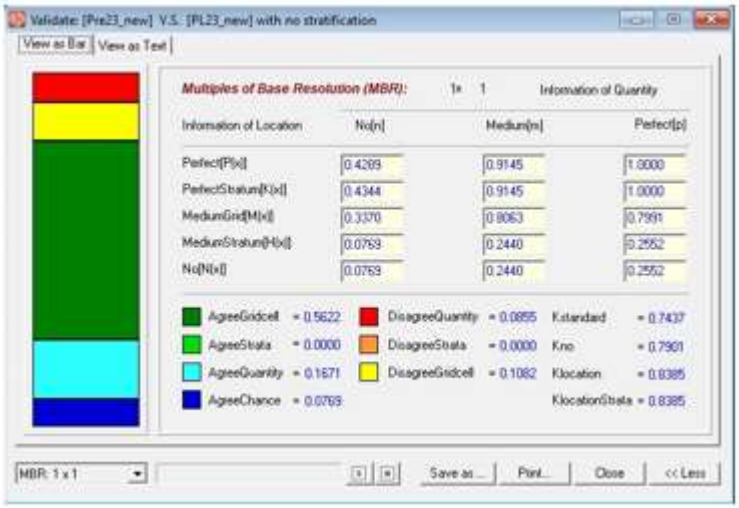

Figure 8. Data Accuracy Test Results (Analysis Results, 2024)

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6	Settlements	49.618,38	16,58	96.585,66	32,28	46.967,28
7	Mining	1.862,50	0,62	3,56	0,00	-1.858,94
8	Dryland Agriculture	130.958,34	43,77	97.073,13	32,44	- 33.885,21
9	Sawah	40.301,45	13,47	34.611,23	11,57	-5.690,23
10	Shrubs/Bushes	2.434,92	0,81	8.769,67	2,93	6.334,75
11	River	1.897,64	0,63	1.897,64	0,63	-
12	Open Land	560,23	0,19	2.417,94	0,81	1.857,70
13	Reservoir	139,30	0,05	139,30	0,05	-
	Total Area (Ha)	**299.225,41**	**100,00**	**299.225,41**	**100,00**	

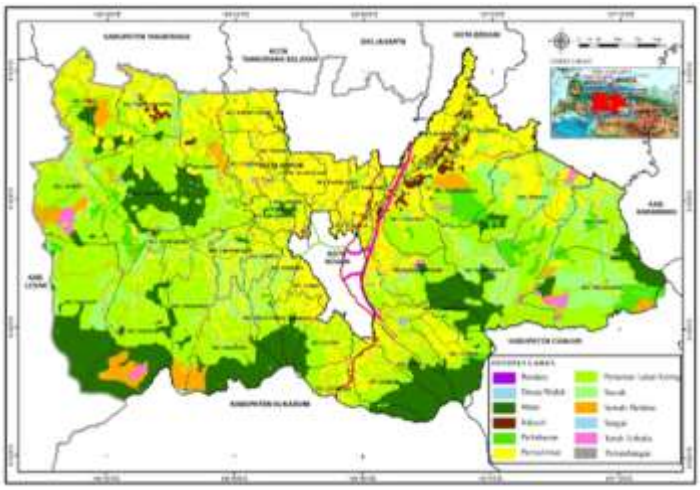

Figure 9. 2036 Prediction Map (Analysis Results, 2024)

Alignment of Land Use and Spatial Pattern of RTRW

Overlay analysis of the 2023 land use map with the 2016-2036 Bogor District RTRW spatial pattern map found that 175,299.52 Ha (58.68%) of land use in Bogor District is consistent with the RTRW direction, 71,242.36 Ha (23.85%) of transitional land use and 52,175.97 Ha (17.47%) of land use that is not consistent with the RTRW direction. The spatial misalignment includes non-forest land uses such as plantations, settlements, rice fields, and shrubs located in protected forest areas; Bogor District cannot realize a forest area as large as the space allocation planned in the RTRW. The total land use area of plantations, settlements, dry land farming, rice fields, and shrubs located in protected forest areas amounted to 2302.95 ha or 0.76% of the total area of Bogor Regency. For more details on land use and RTRW alignment, see Table 6 and Figure 10.

Table 6. Alignment of Land Use and RTRW (Analysis Results, 2024)

No.	Land Use/Land Cover	Aligned	Not Aligned	Transition	Quantity (Ha)
1	Airport/Airfield	42,32	-	-	42,32
2	Lake	465,92	24,68	-	490,60
3	Forest	50.903,55	4.441,89	824,47	56.169,91
4	Industry	2.702,31	1.183,91	-	3.886,23

No.	Land Use/Land Cover	Aligned	Not Aligned	Transition	Quantity (Ha)
5	Plantation	5.942,68	3.131,46	1.560,82	10.634,96
6	Settlements	39.610,96	9.918,28	-	49.529,24
7	Mining	570,86	1.291,65	-	1.862,50
8	Dryland Agriculture	55.056,01	22.198,82	53.568,36	130.823,18
9	Sawah	19.955,57	5.551,39	14.768,33	40.275,30
10	Shrubs/Bushes	-	2.279,91	155,01	2.434,92
11	River	-	1.874,12	-	1.874,12
12	Open Land	-	189,90	365,37	555,27
13	Reservoir	49,33	89,96	-	139,30
	Quantity (Ha)	**175.299,52**	**52.175,97**	**71.242,36**	**298.717,85**

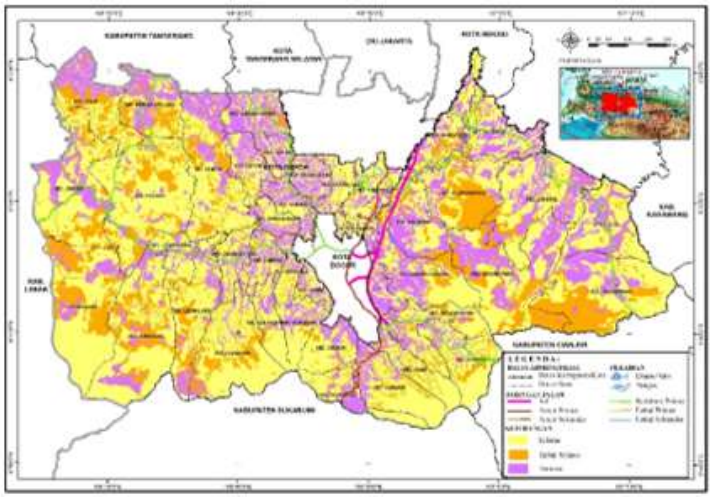

Figure 10. Map of Land Use Alignment and RTRW (Analysis Result, 2024)

RTRW Spatial Pattern Refinement Directive

Refinement of the Bogor District RTRW Spatial Pattern based on the results of overlaying the RTRW spatial pattern, land use, and land suitability obtained results:

a) The wetland (LB) designation zone that has been determined in the RTRW, covering an area of 38,095.37 hectares, is utilized other than for agricultural activities in the S1 land suitability class covering an area of 760.42 hectares (1.99%), S2 land covering 296.52 hectares or 0.77%, S3 land covering 1904.14 or 4.99% of the LB zone designation area. This shows that land that has the potential for agricultural activities has been converted; the most dominant is for residential activities, covering an area of 2,749.81 Ha or 7.21%.

b) Land use in high-density urban settlement areas (Pp1) that have been determined in the RTRW of 40,904.43 Ha is utilized for settlement activities in land suitability class N of 425.18 or 1.03 %. The most significant trend of residential land use is in the S1 land suitability of 12,906.07 Ha or 31.55%, meaning that land suitable for agriculture has changed its function to housing/settlement.

c) Land use in the industrial allotment area (KPI) is determined in the RTRW of 10,116.71 hectares and utilized for industrial activities in land suitability class N of 96.82 hectares, or 0.95%. This means that land unsuitable for agriculture is only a tiny part of the area turned into an industrial area. The most significant trend of industrial land use is in land suitability S1, which should be suitable for agricultural activities, amounting to 1,693.91 Ha or 16.74%, meaning that very suitable land has been converted into industry.

Direction of Space Utilization Control Plan in Bogor Regency

The direction of the spatial utilization control plan in Bogor Regency based on the Development Area (WP), namely in the Eastern WP, controlling mining activities in the Permanent Production Forest and Limited Production zones, controlling spatial violations in the form of settlement activities in wetland agricultural zones and dry land zones and Plantation Designation Zones so as not to increase, controlling changes in agricultural activities and rice fields to settlements so as not to increase.

Control directives in the Central WP include preventing the conversion of plantation activities into built-up land, preventing the conversion of dryland and paddy fields into settlements, and controlling buildings that violate licensing provisions.

Control directives in the Western WP include controlling settlements built in protected forest areas into enclaves, controlling the conversion of dry land and paddy fields into settlements so that they do not increase, supervising and controlling annual plantation zones so that they do not change function, and controlling buildings that stand on riverbanks.

Strategy for Controlling Space Utilization in Bogor Regency

The results of the questionnaire distributed to experts consisting of two academics and three agencies, namely the Public Works and Spatial Planning Office, Bapedalitbang, and the Land Office, related to the preparation of Directions/Strategies for Controlling Spatial Utilization in Bogor Regency, which are processed in ISM Software version 2.3, are shown in Table 7.

Table 7. Space Utilization Control Strategy Variables

A1	Improved knowledge and skills of the apparatus through technical spatial training
A2	We are optimizing the spatial planning forum (FRD) 's role as a coordination forum for the utilization and control of spatial planning.
A3	Improved carrying capacity of facilities and infrastructure
A4	Drafting of regent regulations regarding incentive and disincentive rules
A5	Imposition of Sanctions for activities that violate the KKPR that has been issued
A6	Increased knowledge and role of the community in the form of socialization of spatial plans
A7	Placement of structural officials and staff by the needs and functions of the organization
A8	Institutional arrangement of the organization in spatial planning in the face of changes in spatial utilization policies and dispute resolution.
A9	Utilization of information system technology to support spatial supervision function

The results of the recapitulation of the questionnaire results matrices and quadrants are in Table 8, Figure 11, and Figure 12.

Table 8. Strategy Matrix (Analysis Results, 2024)

NO	A1	A2	A3	A4	A5	A6	A7	A8	A9	DP	R
A1	1	1	1	1	1	1	1	1	1	9	1
A2	0	1	1	1	1	1	1	1	1	8	2
A3	1	1	1	1	1	1	1	1	1	9	1
A4	0	1	1	1	1	1	1	1	1	8	2
A5	0	1	1	1	1	1	1	1	1	8	2
A6	0	1	1	1	1	1	1	0	1	7	3
A7	1	1	1	1	1	1	1	1	1	9	1
A8	0	1	1	1	1	1	1	1	1	8	2
A9	0	1	1	1	1	1	1	1	1	8	2
D	3	9	9	9	9	9	9	8	9		
L	3	1	1	1	1	1	1	2	1		

Description: D = Dependent, L = Linkage, DP = Driven Power, R = Ranking

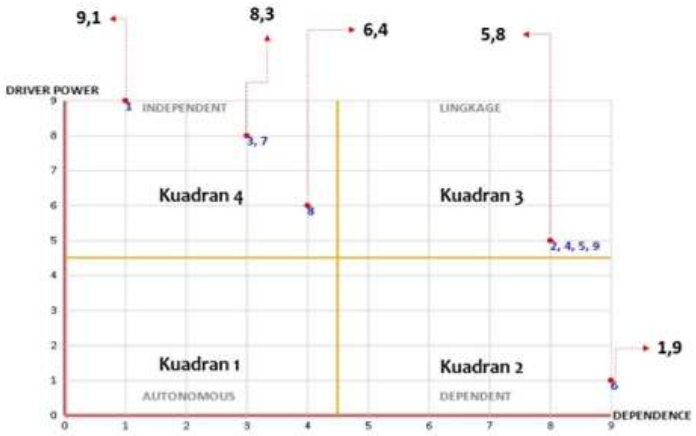

Figure 11. Strategy Quadrant (Analysis Result, 2024)

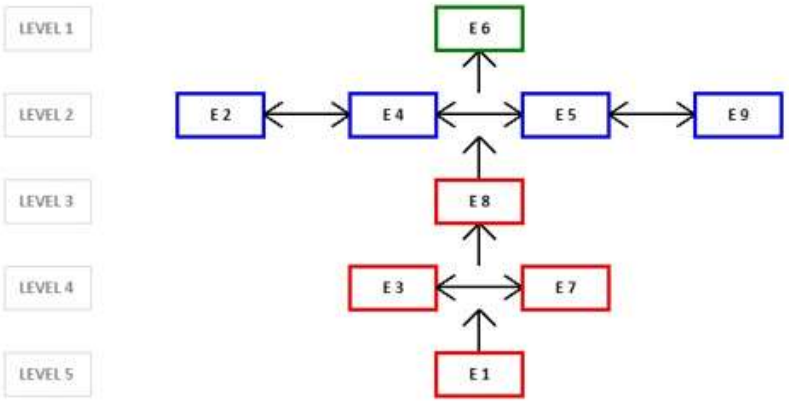

Figure 12. Strategy Structure (Analysis, 2024)

Figure 12 shows that the spatial utilization control strategy in Bogor Regency is divided into 5 (Five) levels. Based on Figure 11, the priority strategy for controlling spatial utilization in Bogor Regency is quadrant 4.

In the priority strategy classified, this strategy is included in quadrant 4, which is Strong Drive Weak Dependent Variables (INDEPENDENT), where strategies that enter this quadrant are elements that have driving force and strong dependence. This priority strategy is also critical in controlling spatial utilization in Bogor Regency because it is a strategy in quadrant 4, namely Strong Drive Weak Dependent Variables (INDEPENDENT). Strategies that are included as priorities are:

a) A1: Improved knowledge and skills of apparatus through technical spatial training
b) A3: Improved carrying capacity of facilities and infrastructure
c) A7: Placement of structural officials and staff by the needs and functions of the organization
d) A8: Institutional arrangement of spatial planning organizations in the face of changes in spatial utilization policies and dispute resolution.

CONCLUSION

A reduction in the area of forests, plantations, and rice fields dominates land use change in Bogor Regency from 1997 to 2023. Land use areas that increased were settlements and industry. The most dominant patterns of land use change are (1) Dryland Agriculture → Dryland Agriculture → Rice Fields, (2) Plantation → Plantation → Dryland Agriculture, (3) Forest → Forest → Dryland

Agriculture, (4) Rice Fields → Rice Fields → Settlement. The most miniature pattern of change is (1) Open Land → Open Land → Dry Land Agriculture, (2) Settlement → Industry → Industry.

By area, predicted additions to land use in 2036 are settlements, shrubs, and Open Land. Predicted reductions, by area, are Dry Land Agriculture, Forest, and Rice Fields. The alignment of land use with the spatial pattern of the RTRW shows 58.68% aligned, 23.85% transitional, and 17.46% not aligned. The dominant land use that needs to be aligned is dryland agriculture. The direction for improving the spatial pattern of the RTRW, for land use that is in line with the spatial pattern, is recommended that land use be continued in the future. Transitional land uses are recommended to be allocated and utilized by the direction of the RTRW spatial pattern. Land use that is not aligned and is permanent should be accommodated in the revision of the Bogor District RTRW.

The direction of the spatial utilization control plan in Bogor Regency is to control mining activities in the Permanent Production Forest zone and limited production, control spatial violations in the form of settlement activities in the wetland agricultural zone, dry land zone, and plantation zone so as not to increase, control the change of dry land agricultural land and rice fields into settlements, control buildings that violate licensing provisions, control settlements built in protected forest areas to become enclaves, control buildings that stand on riverbanks. The main priority strategies for controlling spatial utilization are increasing the apparatus's knowledge and skills through technical spatial training, increasing the carrying capacity of facilities and infrastructure, and placing structural officials and staff in accordance with the organization's needs and functions.

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