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Dynamics and Predictions of Land-Use Changes in Serang Raya and Their Conformity to the Spatial Plan of Banten Province

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ABSTRACT

Serang Raya is developing rapidly, characterized by the growing population, and increasing socioeconomic activities would threaten the sustainability as one of the food storage areas and guard the natural ecosystem in Java. The need for urban land may lead to land use with various protection functions and productive agricultural land, resulting in a decrease in food production and environmental degradation. This study aims to analyze the dynamics of land-use change in Serang Raya in 2000-2018, to predict land use in 2030, and to analyze the unconformity between land use in 2018 and the expected land use in 2030 with the spatial plan of Banten Province 2010-2030. The analytical methods used image interpretation, CA-Markov land use predictions, and overlay analysis to identify unconformity. The results showed that land use in Serang Raya had changed with a dominant pattern of change: rice fields became open land, plantations became built-up areas, and rice fields became built-up areas. Prediction of land use in 2030 shows an increase of built-up area, which is relatively high along with a decrease in paddy fields and plantations. The existing land use conditions in 2018 led to unconformity with the space allocation of 8.92% and increased to 9.31% compared to the predicted land in 2030.

INTRODUCTION

Land use is a materialization of continuous humanistic activities to fulfill the needs of available land resources. Land use is dynamic and adapts to human development and culture (Sitorus, 2017).

The development of an area changes its land-use patterns; its built-in area expands, and its natural spaces, including spaces intended for conservation, change their purposes (Pribadi et al., 2006). Changing the land use of an area would change its functions from its initial purposes and brings negative impacts on the environment and the land potential (Christiawan, 2019; L. M. Putri & Wicaksono, 2021). The expansion of urban areas and an increase in their population might decrease the available fertile agricultural land (Sadali, 2018; Subkhi & Mardiansjah, 2019), which also is driven by capitalistic factors in society (Setiadi et al., 2021).

According to Rustiadi et al. (2015), the changes in land use usually are influenced by natural factors, such as geographical conditions and land characteristics, as well as socioeconomic factors, such as population growth, development plans, land use control, and changes on accessing resources in social organizations, and behaviors (Lambin et al., 2003). Population growth, new city and big manufacturer projects, higher job opportunities, and easy transportation access could be the factors driving land conversion (Nurhanifah, 2021; Pravitasari et al., 2015; R. F. Putri et al., 2020). The infrastructure development of that city, including its access, will drive area expansion and economic growth in that area, which will cause changes in the land use of that area and its surroundings (Sari & Kushardono, 2019).

According to Pravitasari et al. (2016), Western Java is the most prone to be converted to urban areas. According to Pravitasari et al. (2018), several factors that influence this urban expansion, who researched the mega-urban area Jakarta-Bandung are population density, population socioeconomic conditions, the distance to the city center, and road access.

Serang Raya, located in the west end of Java Island, is the economic hub and land transit area of Java and Sumatera. This strategic location makes it one of the significant national locations in the Bojonegara-Merak-Cilegon area, prioritized for industry, agriculture, fishing, tourism, geothermal, and mining. Based on Government Regulations no. 13 the year 2017 about RTRWN revision, in addition to being in the Bojonegara-Merak-Cilegon area, Serang Raya is also located in the strategic national area of Sunda Strait. In addition, because of its position that adjoins with the megapolitan area Jabodetabek and the support of toll roads, national roads, and train tracks, the urban sprawl from Jabodetabek reaches the Serang Raya area. In addition to those external factors, several internal factors include its appointment as the capital city of Banten Province in 2000 and the expansion of city administration area (Cilegon City in 1999 and Serang City in 2007), which accelerated the urban growth. The change in its status caused the faster development of its metropolitan area and larger built-up area (Lamidi et al., 2018).

Information related to the spatial and temporal patterns of changes in land use resulting from remote sensing technology can be used to analyze the changes in land use and predict those patterns for the future. The information would help determine the area susceptible to land conversion that doesn't fit its function and purpose (Kurniawan et al., 2017). Detection of changes in land use for built-in areas and agricultural land used for other purposes has been conducted in Egypt (Mosammam et al., 2017); Iran (Karimi et al., 2018); Thailand (Boonchoo, 2018). Meanwhile, in Indonesia, detection of land-use changes in urban areas had been conducted in Bandung (Fardani, 2020); Kota Sorong (Kesaulija et al., 2021).

The increase of human activity in various sectors, especially in the economic sector, causes increases in land needs and demands. Consequently, the land is used with the function that generates the highest value. The rise in land needs can cause unconformity between land use and the current spatial plan (Tejaningrum et al., 2017). By observing the land use set in the spatial plan, the existing land use will be appropriate and minimalize inconsistency between land use and the spatial plan (Sillia & Yuliastuti, 2020). Early detection of any land-use change in the future is essential as material for land use control to minimalize inconsistency on future land use (Kurnianti et al., 2015).

This study makes the study predict future land-use changes and their conformity with the spatial plan to detect any unconformity in the future. The results can be used as a material for land use control and additional reference to improve the spatial plan of an area. The purpose of this research is: (1) Analyze the land-use changes in Serang Raya between 2000 and 2018. (2) Predict any land-use change in Serang Raya for the year 2030; (3) Analyze any unconformity between actual land use in 2018 and the predictions for 2030 with the spatial plan.

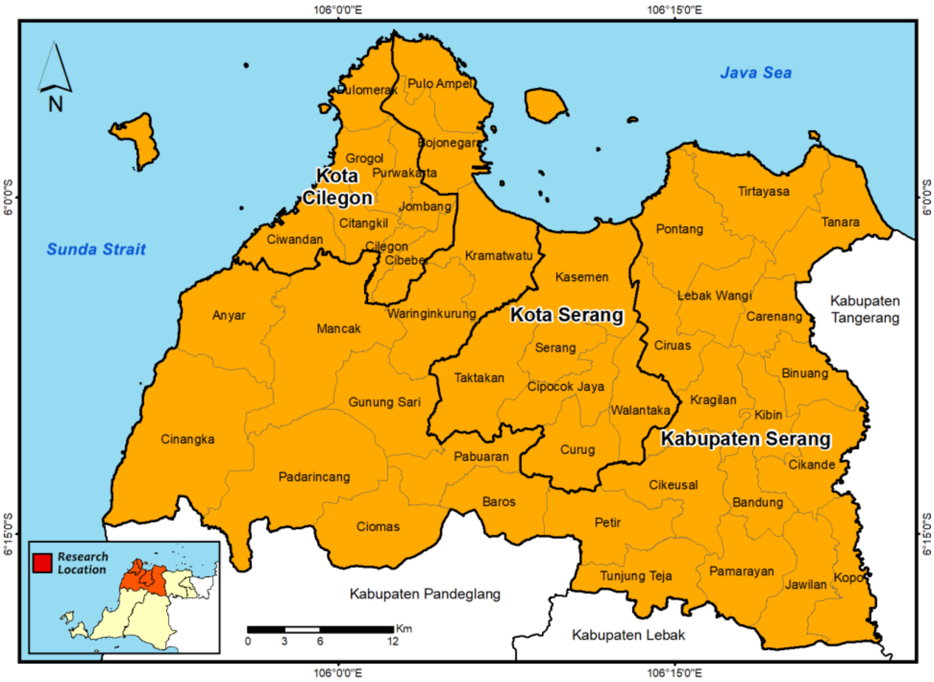

Figure 1. Map of the research location

RESEARCH METHOD

Material

Data used in this research is Landsat-7 image data from 2000, SPOT-4 from 2010, SPOT-7 from 2018, and the spatial plan shapefile of Banten Province from 2010-2030. These data include Serang Regency, Serang City, and Cilegon City.

The image data is different for each year due to the availability of image type at the research location in those years.

Table 1. Research Material and Equipment

No	Material	Equipment/Software
1	Landsat-7 Image from 2000	SWMaps
2	SPOT-4 image from 2010	ArcGIS Desktop 10
3	SPOT-7 image from 2018	Erdas Imagine 2014
4	Spatial Plan Shapefile Map of Banten Province between 2010-2030	Idrisi Selva

Method

The analytical techniques used in this research are Image visual interpretation, land use prediction with CA-Markov, and land use map overlay. The type and distribution of land use are received through a visual understanding of satellite images and border delineation of every land use. Object introduction in image interpretation is observed through characteristics illustrated in the images. The elements used are shape, hue, pattern, texture, shadow, size, site, and association (Sutanto, 1994). The results of the interpretation are verified on-site to get its accuracy value. The sample point of accuracy test of land use is found through equalized random calculation in 50 points for every land use. According to Jensen (1996), overall accuracy can be categorized as good if higher than 85%.

CA-Markov model combines Cellular Automata and transitional probability matrix created through cross-tabulation between two different images (Hamad et al., 2018). This combination provides a robust approach to Spatio-temporal modeling. This analysis process uses raster data, where every pixel represents specific use, and any change on every pixel is dynamic and depends on its neighbor's spatial and temporal conditions. The formula of the CA model is:

$$S\ (t, t+1) = f(S\ (t), N)$$

Where $S\ (t+1)$ is the status of the system on time (t, $t+1$), based on the probability condition from time (N).

The 5x5 contiguity filter determines the neighborhood on every cell of the land use type. The higher the number of cells from the same land use in that area, the higher the compatibility of that land-use type. In other words, the pixel closer to the existing land use has higher compatibility than the one further from the land use. The standard contiguity filter used for analysis is

$$Contiguity\ filter\ 5\ x\ 5 = \begin{vmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{vmatrix}$$

The prediction map was created two times for the years 2018 and 2030. The predictions of the land use for the year 2018 are used for model validation through comparison with the map of actual land use from 2018 with the image interpretation results. The results can prove that the model can predict future land use.

The unconformity between land use and the spatial plan is analyzed to determine how significant the deviation between land use and the spatial goal is. In the comparative analysis between the spatial plan of Banten Province for 2010-2030 and actual land use map in 2018 and land use prediction maps for 2030, a class reclassification of land use is needed for two maps to have the same use class. The concept implemented in determining unconformity between land use and the spatial plan is based on land rent theory; when land use has higher land rent than the one set in the spatial plan, land use is considered to not conform to the spatial plan. A conformity matrix was made to translate regulations to spatial planning data by adjusting land use data with its rules which will be used for consistency analysis (Kurnianti et al., 2015). The conformity matrix of land use to the spatial plan is shown in Table 2.

Table 2. Conformity matrix of land use to the spatial plan

Land Use	Spatial Plan							
	Protected Area	Limited Production Forest	Permanent Production Forest	Fishing Area	Plantation Area	Wet Agricultural Land Area	Dry Agricultural Land Area	Built-in Area
Forest	S	S	S	T	T	T	T	T
Shrubs	T	T	T	T	T	T	T	T
Swamp	T	TS	TS	T	T	T	TS	T
Pond	TS	TS	TS	S	T	TS	TS	T
Paddy Field	TS	TS	TS	TS	T	S	T	T
Field	TS	TS	TS	TS	T	TS	S	T
Plantation	TS	TS	TS	TS	S	TS	S	T
Open land	TS	TS	TS	TS	TS	TS	TS	T
Built-in Area	TS	TS	TS	TS	TS	TS	TS	S

Source: Kurnianti et al., 2015

Where: S: Conforms
T: Transition (land use could still change according to the spatial plan)
TS: Does not conform.

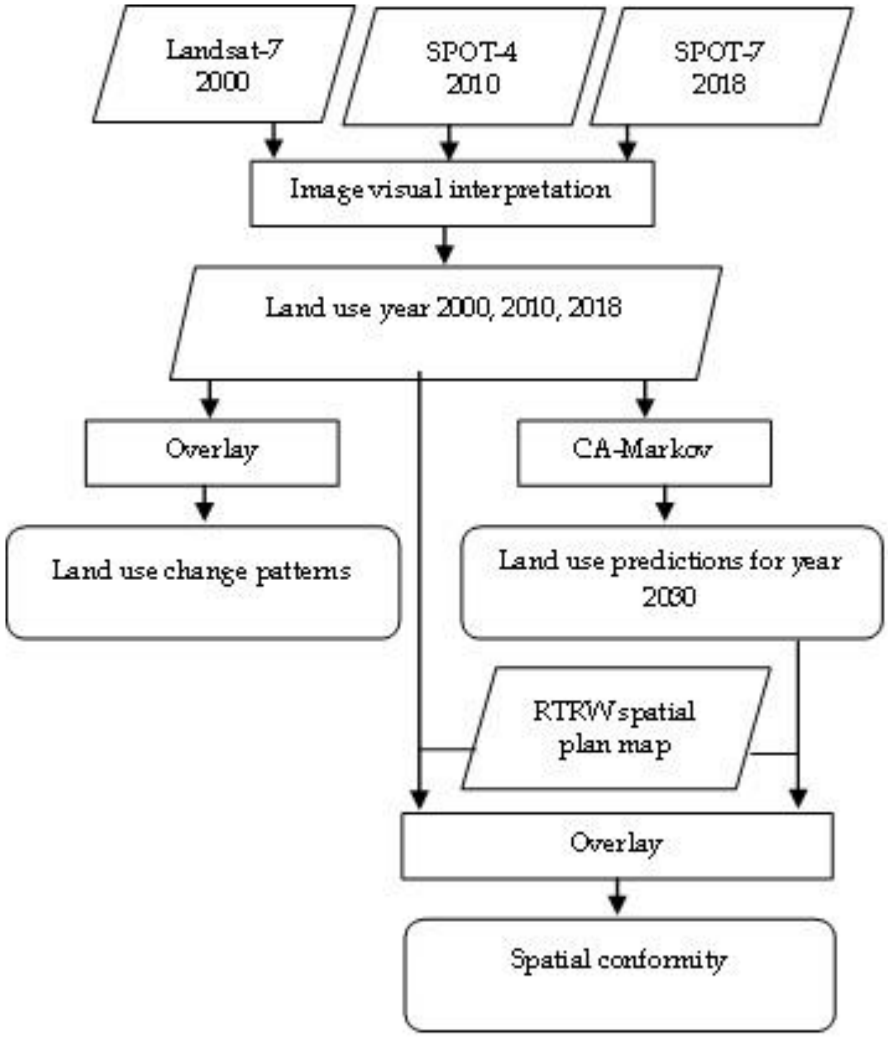

Figure 2. Research flow diagram

RESULTS AND DISCUSSION

Analysis of Changes in Land Use in Serang Raya between 2000-2018

The thematic map of land use from visual interpretation is validated to get the overall classification accuracy and overall kappa statistics on every land use by ground checking it on-site and using other reference images such as multitemporal Google Earth, shown in Table 3.

Table 3. The validation value of the validation of the thematic map of land use from visual interpretation

No	Image Source	Overall classification accuracy	Overall kappa statistics
1	Landsat-7-year 2000	87.83 %	0.8673
2	SPOT-4 year 2010	89.67 %	0.8873
3	SPOT-7 year 2018	87.50 %	0.8636

Source: Analysis results, 2020.

Based on the image interpretation conducted at the research location, there are ten types of land use: waterbody, pond, swamp, open land, built-in land, paddy field, field, Shrubs, plantation, and forest. The data is available in Table 4.

The highest land use in Serang Raya every year is still dominated by paddy fields, but their size decreases each year. In 2000 the land area for ricefield was 66,528 ha or around 35.10% of the total land area. The number decreased in 2010 to 64,430 ha or 34.00%, and in 2018 to 62,422 ha or 32.94%. The size of open lands and built-in areas kept increasing between 2000 and 2018. Any change in land use of a site is a physical manifestation of economic and social changes. According to Martanto (2012), population, economic and social growth will cause changes in land use. Agricultural land, both wet and dry agricultural, is the most prone to land conversion (Rokhmah, 2012).

Table 4. Land Use Serang Raya

No.	Land Use Type	The Year 2000		The Year 2010		The Year 2018	
		Area (ha)	Percentage (%)	Area (Ha)	ercentage (%	Area (ha)	Percentage (%)
1	Waterbody	1,248	0.66	1,249	0.66	1,260	0.67
2	Pond	7,904	4.17	7,958	4.20	7,651	4.04
3	Swamp	333	0.18	333	0.18	314	0.17
4	Open land	4,668	2.46	5,082	2.68	7,363	3.89
5	Built-in Area	18,447	9.73	21,475	11.33	23,432	12.36
6	Paddy field	66,528	35.10	64,430	34.00	62,422	32.94
7	Field	11,989	6.33	11,943	6.30	11,971	6.32
8	Shrubs	5,487	2.90	5,009	2.64	4,161	2.20
9	Plantation	46,807	24.70	46,076	24.31	46,280	24.42
10	Forest	26,110	13.78	25,966	13.70	24,667	13.02
	Total	189,526	100.00	189,526	100.00	189,526	100.00

Source: Analysis results, 2020.

The analysis of land-use changes uses an overlapping method. The change matrix of every year point is then arranged to find any land-use changes in more detail based on every land-use type, presented in Table 5 and Table 6.

From the two land-use change matrix tables, it is clear that the most significant change in land use happened on agricultural land (paddy field and plantation), some of which were converted to non-agricultural land (open land and built-up area). This most significant land conversion happened on paddy fields, where 1,066 hectares of paddy fields were converted to open lands between 2010 to 2018. Meanwhile, between 2000 to 2010, 850 hectares of plantation land were converted into built-in areas. Seven hundred seventy-seven hectares of built-in area and 767 hectares of open land were created from paddy fields in the same period.

Between 2000 and 2010, when observed based on subdistrict, Ciwandan Subdistrict went through the most effective land conversion, where 301 hectares of Shrubs area were converted into built-in regions, most of which is for the expansion of industrial estates in Cilegon City. The second biggest conversion happened in the Cikande Subdistrict, where 282 hectares of paddy field were converted to open areas for industrial estates such as the Modern Cikande Industrial Estate.

Between 2010 and 2018, Gunung Sari Subdistrict went through the highest land conversion, with the highest transformation happening in the forest area, where 561 hectares of forest area were converted to plantation areas. It is followed by the Kramatwatu Subdistrict with the conversion of 304 hectares of paddy field to open lands, most of which is intended for land expansion for The Wilmar Integrated Industrial Estate. There is also the conversion of 236 hectares of Shrubs area to open lands in the Jawilan Subdistrict to expand industrial estates along the Cikande-Rangkasbitung road.

Table 5. Matrix of Land Use change in Serang Raya Between 2000-2010 (Ha)

Land Use		The year 2010										Total 2000
		Waterbody	Pond	Swamp	Open land	Built-in Area	Paddy Field	Field	Shrubs	Plantation	Forest	
The year 2000	Waterbody	1,248	-	-	-	-	-	-	-	-	-	1,248
	Pond	-	7,903	-	-	1	-	-	-	-	-	7,904
	Swamp	-	-	333	-	-	-	-	-	-	-	333
	Open land	-	-	-	4,041	626	-	-	-	-	-	4,668
	Built-in Area	-	-	-	-	18,447	-	-	-	-	-	18,447
	Paddy Field	1	19	-	767	777	64,430	211	225	96	-	66,528
	Field	-	32	-	42	186	-	11,727	1	-	-	11,989
	Shrubs	-	3	-	154	573	-	-	4,755	-	-	5,487
	Plantation	-	-	-	47	850	-	2	28	45,879	-	46,807
	Forest	-	-	-	27	12	-	2	-	100	25,966	26,110
Total 2010		1,249	7,958	333	5,082	21,475	64,430	11,943	5,009	46,076	25,966	189,526

Source: Analysis results, 2020.

Table 6. Matrix of Land Use change in Serang Raya Between 2010-2018 (ha)

Land Use		The year 2018										Total 2010
		Waterbody	Pond	Swamp	Open land	Built-in Area	Paddy Field	Field	Shrubs	Plantation	Forest	
The year 2010	Waterbody	1,249	-	-	-	-	-	-	-	-	-	1,249
	Pond	-	7,636	-	237	75	-	9	-	-	-	7,958
	Swamp	-	-	314	19	-	-	-	-	-	-	333
	Open land	-	-	-	4,431	651	-	-	-	-	-	5,082
	Built-in Area	-	-	-	-	21,475	-	-	-	-	-	21,475
	Paddy Field	3	-	-	1,066	438	62,422	193	103	204	-	64,430
	Field	8	2	-	436	189	-	11,303	2	-	-	11,943
	Shrubs	-	12	-	788	210	-	-	3,998	-	-	5,009
	Plantation	-	-	-	308	366	-	112	27	45,261	-	46,076
	Forest	-	-	-	76	25	-	352	29	814	24,667	25,966
Total 2018		1,260	7,651	314	7,363	23,432	62,422	11,971	4,161	46,280	24,667	189,526

Source: Analysis results, 2020.

The results of this research are in line with the study conducted by Pravitasari et al. (2019) about the spatial distribution patterns of paddy field area decrease in Serang Regency. It concluded that the most significant drop in the paddy field area happened in the eastern region of Serang Regency, which is directly next to Tangerang Regency. That area is very prone to converting agricultural land to open lands for industrial estates because land rent of industrial land is much higher than agricultural land.

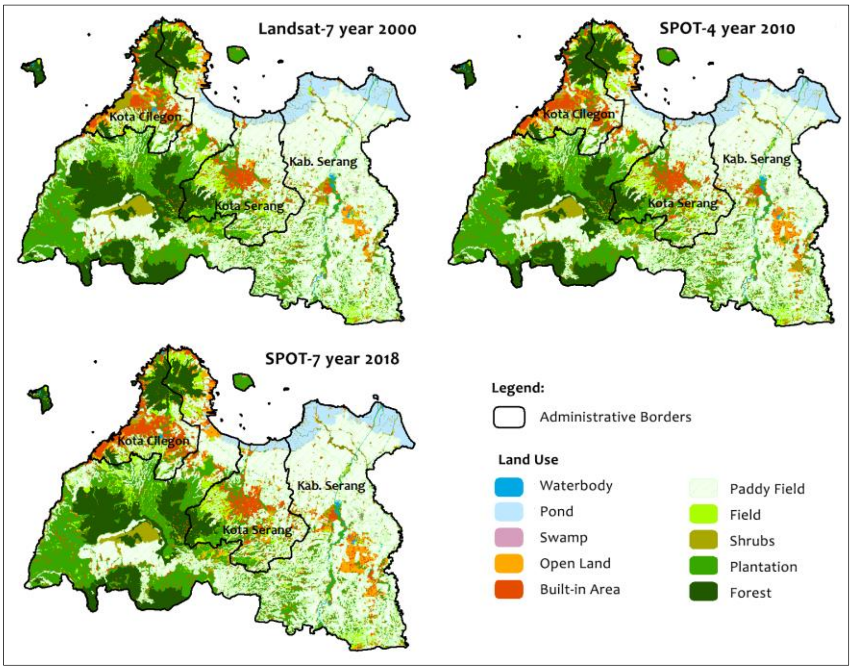

Figure 3. Land Use in Serang Raya in 2000, 2010, dan 2018 (Research results, 2020)

The predictions of the changes in land use in Serang Raya for 2030

The Kappa value from the land use prediction model validation is 0.9122. This value indicates that the prediction model can be used to predict future land use. The table for comparing land use predictions in Serang Raya in the year 2030 with actual conditions from 2018 can be seen in Table 7.

The most significant result from the predictions is the 7,082 hectares increase of the built-in area, from 23,432 hectares in 2018 to 30,514 hectares in 2030. This might happen because there might be some conversion from agricultural land (paddy field and plantation) to non-agricultural land, where there is 4,622 hectares decrease in the paddy field area, from 64,422 in hectares to potentially 57,799 hectares in 2030. The plantation area would reduce by 2,452 hectares, from 46,280 hectares in 2018 to 43,828 hectares in 2030. The map of land use distribution based on the predictions for the year 2030 can be seen in Figure 4.

Table 7. The Existing Land Use in 2018 when compared to Land Use Predictions for 2030 in Serang Raya

No	Land Use (LU) Type	Existing LU Year 2018 (Ha)	LU Prediction Year 2030 (Ha)	Change Prediction 2018-2030	
				(Ha)	(%)
1	Waterbody	1,260	1,144	-116	-9.21
2	Pond	7,651	7,737	86	1.13
3	Swamp	314	322	8	2.59
4	Open Land	7,363	7,045	-318	-4.32
5	Built-in Area	23,432	30,514	7,082	30.23
6	Paddy field	62,422	57,799	-4,622	-7.41
7	Field	11,971	11,726	-244	-2.04
8	Shrubs	4,161	4,892	731	17.58
9	Plantation	46,280	43,828	-2,452	-5.30
10	Forest	24,667	24,475	-192	-0.78

Source: Analysis results, 2020.

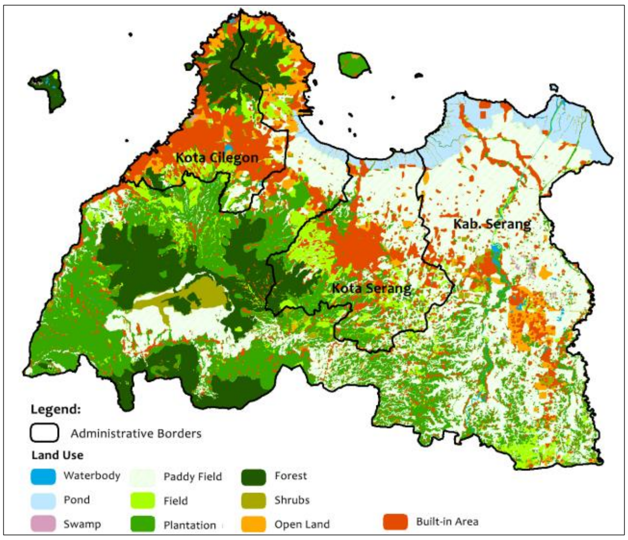

Figure 4. Prediction Map of Land Use for the year 2030 in Serang Raya (Research results, 2020)

Analysis of Actual Spatial Unconformity in 2018 and Predictions for 2030 with the Spatial Plan

An analysis of potential spatial unconformity to the spatial pattern was conducted to find how spatial use in the future will conform to the spatial plan. With the study, we can determine the potential violation of spatial use in the future. The conformity comparison between land use in Serang Raya from 2018 and predictions for 2030 with the spatial plan of Banten Province is available in Figure 5.

The results of the analysis of actual spatial use from 2018 on the spatial plan in Serang Raya show 8.92% unconformity, while 42.53% of spatial use fits with the spatial plan and 48.55% is still in transition. Meanwhile, the analysis results on potential unconformity in spatial use for 2030 to the spatial plan show 9.31% unconformity, while 46.23% of the spatial use conforms to the spatial plan, and 44.46% is still in transition.

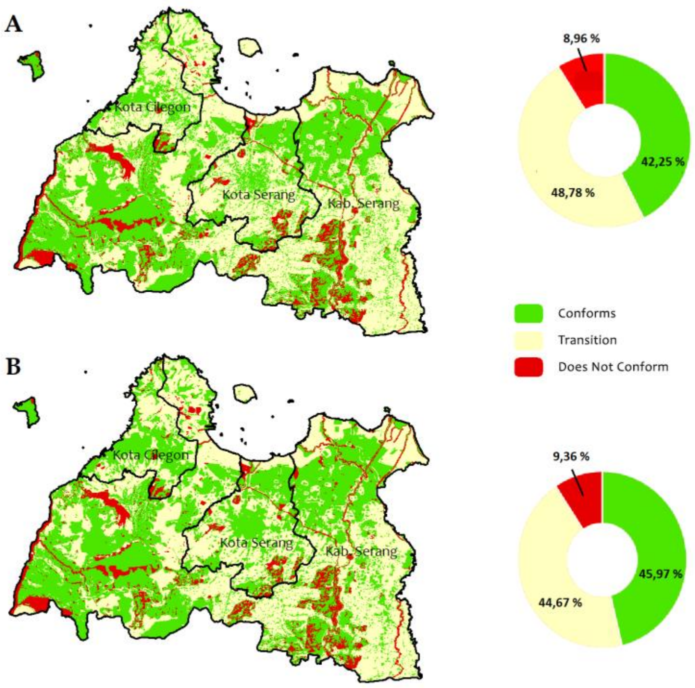

Figure 5. Spatial Use Conformity Map (A. Actual Land Use in 2018 to the spatial plan, B. Predictions of Land Use for 2030 to the spatial plan) (Research results, 2020)

The increase in potential unconformity is caused by the built-in area and open land use, even though some are not built in their spatial plan. This can be seen in the two land-use where their unconformity number keeps increasing between 2018 and 2030. The built-in area has the highest unconformity, 877 hectares, followed by the open land type with 213 hectares. Table 8 details the conformity comparison between land use from 2018 and the predictions for 2030 with the spatial plan.

Table 8. Conformity Comparison Between Land Use in 2018 and 2030 with Spatial Plan

No	Land Use	Land Use in 2018			Land Use in 2030		
		S	T	TS	S	T	TS
1	Waterbody	1,257	-	-	1,171	-	-
2	Pond	139	6,457	655	140	6,427	663
3	Swamp	36	276	-	33	287	-
4	Open land	-	6,375	847	-	5,626	1,061
5	Built-in area	19,719	-	3,454	27,043	-	4,332
6	Paddy field	27,213	32,571	2,636	26,734	28,665	2,384
7	Field	292	10,175	1,501	287	9,888	1,498
8	Shrubs	1,926	2,199	-	2,045	2,192	20
9	Plantation	19,432	19,008	7,811	19,601	16,394	7,688
10	Forest	9,650	14,993	-	9,634	14,814	-
Total		79,706	92,021	16,907	86,721	84,264	17,649
Proportion		42.25	48.78	8.96	45.97	44.67	9.36

Source: Analysis results, 2020.

The current land use from 2018 with the highest unconformity in Serang Raya is wet agricultural land, where 5,078 hectares or 30.04% of the total area was used for plantation. It is followed by riparian zones, where 1,340 hectares or 7.93% of its total area is used for plantation. Next is wet agricultural land, where 1,233 hectares or 7.30% of its location were converted into built-in areas. Meanwhile, 1,183 hectares or 7% of plantation area was converted to built-in areas. The prediction for the largest unconformity of spatial use in 2030 is the wet agricultural land, where 5,019 hectares or 28.44% of its area was used for plantation, and 1,464 hectares or 8.3% of its area was converted for built-in areas. Meanwhile, 1,424 hectares or 8.07% of plantation area was converted into built-in areas. Table 9 details the highest unconformity in the 12 land-use types in Serang Raya.

Table 9. The highest unconformity in spatial use in Serang Raya

No	Unconformity Type		The Year 2018		The Year 2030	
	Spatial Plan	Land Use	Area (Ha)	Percentage (%)	Area (Ha)	Percentage (%)
1	Nature Reserve	Paddy Field	1,157	6.85	981	5.56
2	Cultural and natural heritage area	Plantation	619	3.66	640	3.63
3	Tourism Area	Built-in Area	218	1.29	341	1.94
4	Tourism Area	Plantation	523	3.09	467	2.65
5	Plantation Area	Open Land	345	2.04	467	2.65
6	Plantation Area	Built-in Area	1,183	7.00	1,424	8.07
7	Wet Agricultural Land	Built-in Area	1,233	7.30	1,464	8.30

8	Wet Agricultural Land	Field	1,105	6.54	1,196	6.78
9	Wet Agricultural Land	Plantation	5,078	30.04	5,019	28.44
10	Riparian zones	Built-in Land	393	2.33	529	3.00
11	Riparian zones	Paddy field	1,110	6.57	1,039	5.89
12	Riparian Zones	Plantation	1,340	7.93	1,265	7.17

Source: Analysis results, 2020.

CONCLUSION

The highest land use in Serang in 2018 is agricultural land with 62,422 hectares or 32.94%, followed by plantation, forest, and built-in area with 46,280, 24,667, and 23,432 hectares, respectively. The most considerable land-use change happened on the conversion of 1,066 hectares of paddy field area to open land between 2010 and 2018, followed by 850 hectares of plantation area to open land between 2000 and 2010.

The predictions of land use in Serang Raya for 2030 show the most significant results in the built-in land, from 23,432 hectares in 2018 to 30,514 hectares in 2030, a 7,082-hectare increase. This might happen due to converting agricultural land (paddy fields and plantation) to non-agricultural land. There would be a 4,622-hectare decrease in the paddy field area and a 2,452-hectare decrease in the plantation area.

The unconformity analysis on actual spatial use in 2018 to the spatial plan in Serang Raya shows 8.92% unconformity on the spatial use. Meanwhile, 42.53% of the spatial use conforms to the spatial plan, and 48.55% are still in transition. The results of the potential unconformity in spatial use for 2030 to the spatial plan show 9.31% unconformity, while 46.23% of the spatial use conforms to the spatial plan, and 44.46% are still in transition.

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