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Analysis of Land Use Change Using Landsat Imagery and GIS in West Cikarang District

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Abstract

The research was conducted in West Cikarang Subdistrict which was motivated by the large number of industrial areas which resulted in many agricultural to non-agricultural land uses changing. Based on this, the objectives of this study are 1) To determine the extent of land use change in West Cikarang District, Bekasi Regency in 2010-2020 using Landsat Imagery and GIS; 2) To determine the land use change in 2010-2020 in the West Cikarang District area of Bekasi Regency. The images used are Landsat images in 2010, 2015, and 2020. In this research, the method used is Supervised Image Classification for interpretation. This research uses a composite of bands 4,3,2 for Landsat 8 imagery and 3,2,1 for Landsat 7 imagery. This research uses a descriptive type of research, the method used in this research is a spatial approach. The Kappa accuracy produced in this research is 93.1%. The results of this land use change research that increased significantly were settlements, in 2010 residential land use had an area of 1660.1 Ha, in 2015 the use increased to 2227.8 Ha, and in 2020 residential land use increased again to 2285.3 Ha.

Keywords: Supervised Image, West Cikarang, Land Change

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1. Introduction

About three quarters of the Earth's land surface has beenaltered by humans within the last millennium. Successfully tackling global sustainability challenges such asclimate change, biodiversity loss and food security depends onland use change, since it strongly affects carbon sources and sinks, causes habitat loss6and underpins food production. Inparticular, the mitigation potential of land use activities, includingthose related to forests and agriculture, has been recognised asessential in meeting climate targets under the Paris Agreement, making land use a central component of many internationalpolicy debates. Therefore, quantifying and understanding global land use change and its spatiotemporal dynamics is critical insupporting these debates (Winkler et al., 2021).

The urban population in Indonesia which increases every year has an impact on increasing the financing of urban infrastructure and meeting the needs for residential facilities. This condition is marked by the existence of new areas which are predominantly developed in the suburban areas. Urbanization has an important impact on the environment, changes in land-use intensity, spatial structure, and urban spatial patterns. The urban sprawl that develops in suburban areas occurs due to several factors, namely (i) relatively low land prices, and (ii) low population density. These two factors cause the urban spatial distribution to be efficient and effective in relation to space utilization and its effect on environmental quality degradation. Furthermore, housing and settlement development activities and increased transportation infrastructure development have an impact on the complexity of space utilization. This condition is characterized by environmental imbalance, morphology, and loss of urban natural vegetation. Thus, the construction of new settlements in suburban areas and their impact on the environment are very important in the process of urban growth (Surya et al., 2021).

Land use change and urbanization have altered the landscape patterns of metropolitan areas, as these areas have experienced considerable growth in recent decades. Landscape pattern is defined as the spatial arrangement of various landscape elements in different sizes and shapes. Changes in landscape pattern are strongly influenced by natural factors and human activities that can affect the structure and function of ecosystems (Dadashpoor et al., 2019).

The problem of urban development has become a difficult problem to overcome and often has negative consequences on several aspects, especially the environment. Urban development requires land as a place for people to live with their activities. The increase in the area of built-up land in urban areas occurs due to the development of urban infrastructure and residential development as a result of the increasing number of urban residents. The relatively fixed availability of land will lead to high competition for land use, but in the end the priority of land use change will be won by the pressure of economic and social needs (Monsaputra, 2023).

Many changes in land use arise from annual population growth and increased demand for land. The development of an area will lead to greater pressure on land and changes in land use as a result of social activities, population growth, and economic activities. The demand for residential land increases along with population growth. This is due to the fact that housing is a basic human need that is closely linked to trade and industry. Due to the scarcity of land and the fact that land can only be created through reclamation efforts, the rapid increase in population and consequent increase in demand for land often results in conflicts between land use interests that are incompatible between land use and its planned designation (Adawiyah, 2021).

The extensive industrial expansion in Bekasi District has resulted in the loss of agricultural land. Bekasi Regency has 35,244 hectares of agricultural land, but along with changes in land use for housing and industry, the area of agricultural land in Bekasi Regency continues to shrink (Fabriani et al., 2021).

West Cikarang Subdistrict as one of the areas in Bekasi Regency is not immune to the phenomenon of urbanization. Urbanization is defined as the process of becoming an urban area, a change in occupation from farming to something else, and changes in human behavior patterns. The many attractions that West Cikarang Subdistrict has as an industrial center, residential destination, and shopping center make urbanization unavoidable (Astuti & Lukito, 2020).

Land use/cover change is the most direct manifestation of the impact of human activities on the earth's surface system and is very important in the global environmental change process. Land use/cover change is also one of the important factors characterizing the response of human activities to global change. It is an important input parameter to simulate global climate and biogeochemical effects. The measurement and simulation of its spatiotemporal process and understanding of the dynamic mechanisms have reached the forefront of scientific attention (Ning et al., 2018).

In this case, remote sensing technology can map land use changes that occur. The utilization of remote sensing imagery and GIS is expected to produce spatial data related to abandoned land objects, area, existing land use, and also provide an overview of geomorphological conditions (Utami et al., 2018).

Geographic Information Systems (GIS) have an important role in providing significant information through risk mapping, spatial forecasting, spatial monitoring of supply distribution, and logistics provision. Geographic Information Systems (GIS) with technologies based on big data have played an important role in various aspects, namely the rapid aggregation of multi-source big data, and visualization of big data (Dahlia, 2021).

This research has objectives which include: 1) To determine the extent of land use change in West Cikarang District, Bekasi Regency in 2010-2020 using Landsat Imagery and GIS; 2) To determine changes in the temporal pattern of land use in 2010-2020 in the West Cikarang District area of Bekasi Regency. Research on land use change is very important at this time, because land use change has an impact on the physical and social environment.

2. Method

This research was conducted in West Cikarang District, Bekasi Regency and geographically West Cikarang District is located in the position 107º 01' 21" E - 107º 08' 21" E and 06º 20' 20" S - 06º 15' 40" S.

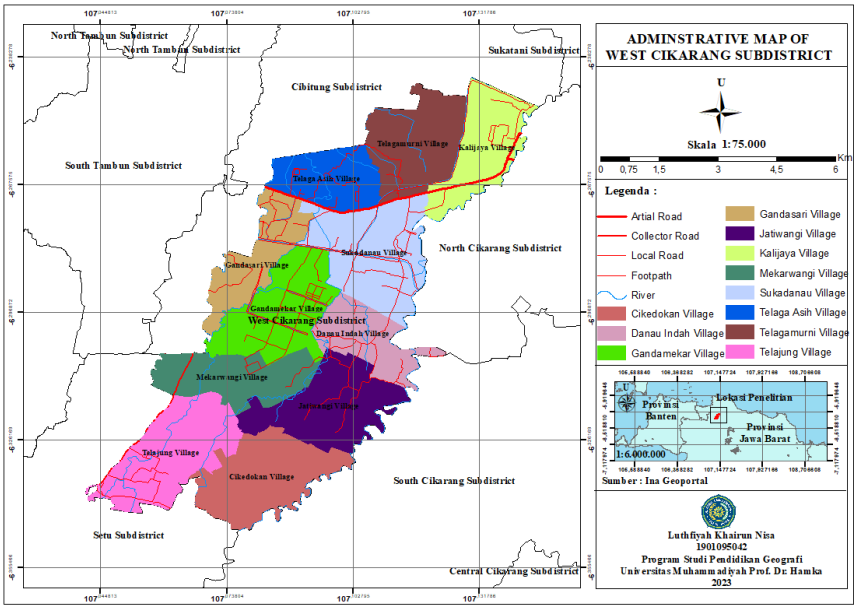

Figure 1. Research Location Map

This research uses a descriptive research method, which is research that leads to disclosing problems or revealing facts that occur. The findings of this research will

provide a true picture of the topic under study. The method used in this research is the spatial approach. The term spatial approach refers to a method that considers spatial utilization patterns in addition to their symptoms and changes. In this case, it is intended to examine and reveal land use changes that will be analyzed in West Cikarang Subdistrict.

The stages in analyzing data include 1) Geometric Correction 2) Band Composite 3) Interpretation 4) Validation 5) Analysis. The image data used in this study are Landsat 7 ETM + Landsat 8 OLI/TIRS images for 2015 and 2020 recordings. This research uses a composite band 4,3,2 for Landsat 8 imagery and 3,2,1 for Landsat 7 imagery. In this research, the researcher also conducts a ground check which has the aim of knowing the truth of objects or land use directly from the interpretation results.

Sampling in this study is part of the land use in West Cikarang District, the samples taken in this study were 36 samples, sampling in this study based on representation of each type of land use. In this study, the Supervised Image Classification method was used for interpretation. Supervised Image Classification is a technique in which the classification process is guided and controlled largely or entirely by the user. In this procedure, a Training Area is selected for each land cover type that serves as the key to interpretation.

The way to check the accuracy of this research is with the Confusion Matrix table. This matrix resembles a square matrix in which the number of categories or classes whose classification accuracy is to be measured is represented by the number of columns and the number of rows. On the main diagonal, each matrix entry corresponds to a valid categorization. Classification errors represented by all matrix members outside the main diagonal fall into two categories: omission (exclusion) errors and commission (inclusion) errors. Column elements that fall outside the main diagonal are referred to as omission errors while row elements that fall outside the main diagonal of commission errors are referred to as commission errors (Muhsoni, 2015). The diagram of this study is presented in Figure 2 and to get accuracy results, formulas 1-4 below are needed.

$$Users\ Accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category}{Total\ number\ of\ Classified\ Pixels\ in\ that\ Category\ (The\ Row\ Total)} \text{ x } 100\% \quad (1)$$

$$Producer\ Accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category}{Total\ Number\ of\ Reference\ Pixels\ in\ that\ Category\ (The\ Column\ Total)} \text{ x } 100\% \quad (2)$$

$$Overall\ Accuracy = \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels\ (Diagonal)}{Total\ Number\ of\ References\ Pixel} \text{ x } 100\% \quad (3)$$

$$Kappa\ Accuracy = \frac{(TS \times TCS) - \sum(Column\ Total \times Row\ Total)}{TS^2 - \sum(Column\ Total\ x\ Row\ Total)} \text{ x } 100\% \quad (4)$$

Flowchart of land use change research. The beginning of this research is to collect Landsat Image data, then cutting the image with shp data. Administrative boundaries of West Cikarang District to limit image coverage to the research area only. Furthermore, combining bands based on the same spatial resolution of 30 m/pixel, including bands 1-8. This aims to facilitate analysis in determining objects in the image. Performed composite on the image, the use of the right band type will facilitate the image interpretation stage. Selection of training samples to group objects separately that have the same characteristics. Then classified using the maximum likelihood method. Ground Check is used to obtain information on the actual state of land use in the field. The accuracy test of image classification is carried out using the confusion matrix calculation, if the correctness test is ≥ 70%, then the interpretation is considered correct. This resulted

in land use maps for 2010, 2015 and 2020. Furthermore, the analysis of the three years was carried out to obtain the results of temporal analysis of land use change in 2010, 2015 and 2020. The flow chart is presented in Figure 2.

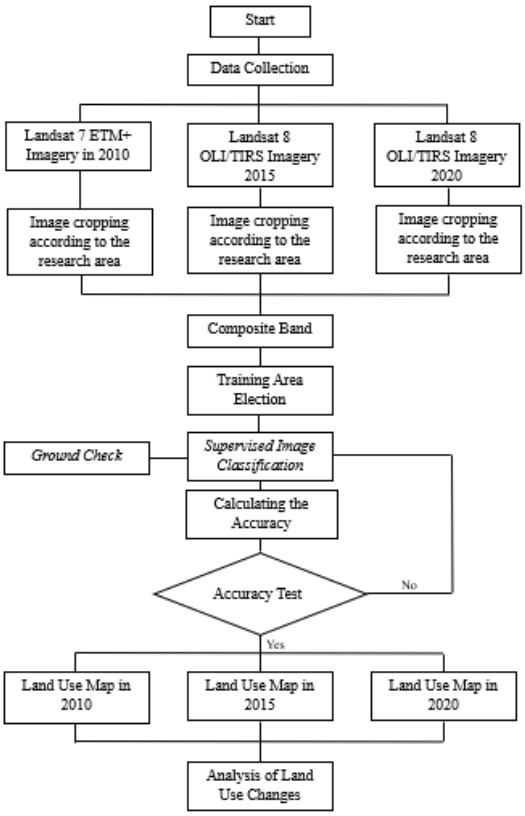

Figure 2. Research Flowchart

3. Result and Discussion

A. Classification Accuracy Assessment Analysis

The accuracy test method using the kappa coefficient approach is used to conduct the classification accuracy test stage in this study. Through the Confusion Matrix in Table 1, user's accuracy, producer's accuracy, overall accuracy and kappa accuracy can be obtained mathematically which can be seen in Tables 2 and 3.

Table 1. Land Use Confusion Matrix Cikarang Barat

	Lake	Industry	Fields	Mixed Plantations	Settlements	Rain-Fed Rice field	Bush	Total (user)	Omissions
Lake	2	0	0	0	0	0	0	2	0
Industry	0	9	0	0	1	0	0	10	1
Fields	0	0	3	0	0	0	0	3	0
Mixed Plantations	0	0	0	2	0	0	0	2	0
Settlements	0	0	0	0	9	0	0	9	0
Rain-Fed Rice field	0	0	0	0	0	6	1	7	1
Bush	0	0	0	0	0	0	3	3	0
Total (Producer)	2	9	3	2	10	6	4	36	
Comissions	0	0	0	0	1	0	1		

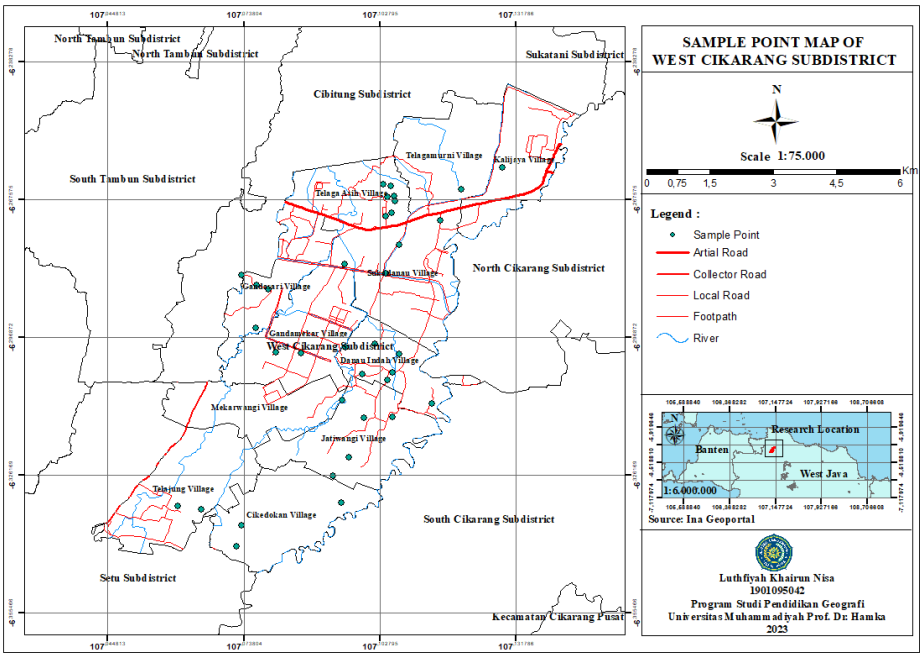

Figure 3. Sample Point Map

Figure 4. Research Documentation

Table 2. User's Accuracy and Producer's Accuracy Calculation

Land Name	User's Accuracy	Producer's Accuracy
Lake	100%	100%
Industry	90%	100%
Fields	100%	100%
Mixed Plantations	100%	100%
Settlements	100%	90%
Rain-Fed Rice Field	85,70%	100%
Bush	100%	75%

Table 3. Overall Accuracy and Kappa Accuracy Calculation

Keterangan	Hasil
Overall Accuracy	94,4%
Kappa Accuracy	93,1%

Producer's Accuracy is the degree to which the real situation matches the reference map from the perspective of the producer. User's Accuracy is the level of map accuracy from the perspective of the map user, and is determined by the likelihood that the area classified in a particular class or layer matches the proportion of the class or layer on the reference map. Overall Accuracy is a metric that describes the detail of correctly identified land areas on the map. Usually, these numbers are summed up into a percentage. In addition, classification results will be better the higher the kappa coefficient (Saputra et al., 2023). The assessment of the Kappa accuracy value can be seen in Table 4. Based on Table 4 below in the calculation of this study, the accuracy value of the kappa coefficient obtained a result of 93.1%, so the interpretation of the resulting kappa value is very good accuracy.

Table 4. Kappa Accuracy Value Interpretation

Kappa Coefficient Value	Kappa Value Interpretation
0 < (0%)	Poor Accuracy
0,01 - 0,20 (1% - 20%)	Low Accuracy
0,21 - 0,40 (21% - 40%)	Sufficient Accuracy
0,41 - 0,60 (41% - 60 %)	Medium Accuracy
0,61 - 0,80 (61% - 80%)	Good Accuracy
0,81 - 1.0 (81% - 100%)	Very good accuracy

Source: (Saputra et al., 2023)

B. Analysis of Land Use in West Cikarang Subdistrict in 2010

Landsat image interpretation is done with the help of interpretation elements to see the basic characteristics of each land use appearance on the image. Land use in West Cikarang Subdistrict in 2010 was in the form of Lake, Industry, Field, Mixed Plantation,

Settlement, Rainfed Rice Field, and Bush. For information on the area and description of land use in West Cikarang Subdistrict in 2010, see Table 5 and Figure 5.

Table 5. Land Use of Cikarang Barat Subdistrict in 2010

No	Description	Broad (Ha)	Percentage (%)
1	Lake	37,6	0,7
2	Industry	1137,4	20,6
3	Fields	663,0	12,0
4	Mixed Plantations	10,9	0,2
5	Settlements	1660,1	30,0
6	Rain-Fed Rice Field	1983,6	35,8
7	Bush	41,8	0,8
	Total	**5534,40**	**100**

Based on Table 5, it shows that the largest land use in West Cikarang Subistrict is in the form of Rainfed Rice Field land use which has an area of 1983.6 Ha with a percentage of 35.8% of the total area contained in West Cikarang Subdistrict. The second largest land use in West Cikarang Subdistrict is in the form of Settlement land use which has an area of 1660.1 Ha with a percentage of 30.0%. In the third largest land use, there is Industrial land use which has an area of 1137.4 Ha with a percentage of 20.6%. Furthermore, there is land use of fields which has an area of 663.0 Ha with a percentage of 12.0%, land use of lakes has an area of 37.6 Ha with a percentage of 0.7%, land use of shrubs has an area of 41.8 Ha with a percentage of 0.8% and the last land use of mixed plantations has an area of 10.9% Ha with a percentage of 0.2%.

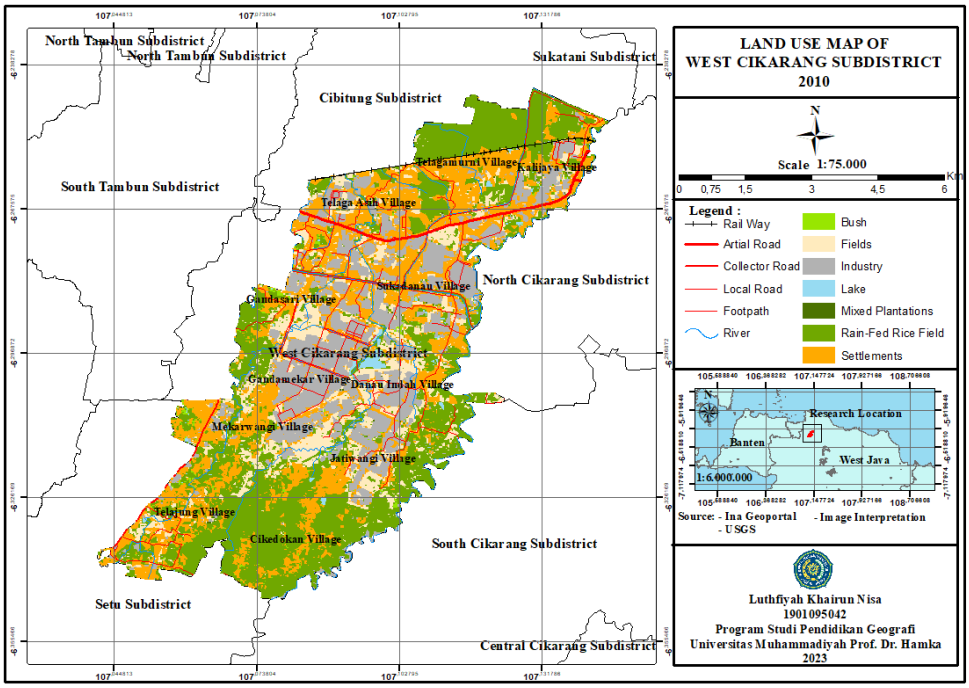

Figure 5. Land Use Map of West Cikarang Subdistrict in 2010

C. Analysis of Land Use in West Cikarang Subdistrict in 2015

Land use in West Cikarang Subdistrict in 2015 was the same as land use in 2010, only the area had changed. For information on the area and description of land use in West Cikarang Subdistrict in 2015, see Table 6 and Figure 6.

Table 6. Land Use of Cikarang Barat Subdistrict in 2015

No	Description	Broad (Ha)	Percentage (%)
1	Lake	66,5	1,2
2	Industry	1331,4	24,1
3	Fields	316,2	5,7
4	Mixed Plantations	68,7	1,2
5	Settlements	2227,8	40,3
6	Rain-Fed Rice Field	1471,7	26,6
7	Bush	52,1	0,9
	Total	5534,4	**100**

Based on table 6 above, it shows that the largest land use in 2015 in West Cikarang Subdistrict is land use for settlements which has an area of 2227.8 Ha with a percentage of 40.3%, while in 2010 residential land use in West Cikarang Subdistrict had an area of 1660.1 Ha, which means that in a period of 5 years residential land use has increased in area. Furthermore, the second largest land use is in the use of Rainfed Agricultural land which has an area of 1471.7 Ha with a percentage of 26.6%, in contrast to residential land use, in 2010 the total area of Rainfed Agricultural land use was 1983.6 Ha, which means that this land use has decreased, this is in line with research (Prasada & Rosa, 2018) The high rate of conversion of paddy fields has implications for the decline in food availability for the population so that it will have an impact on the decline in food production, especially rice, which can pose a threat to population food security, paddy fields need to be properly protected by using clear laws and regulations for Sustainable Food Agricultural Land and can provide incentives for farmers to maintain their agricultural land. These incentives can be in the form of price incentives, which provide price certainty to farmers, as well as incentives in terms of cutting or exempting taxes on paddy fields managed by farmers. This policy can help increase the availability of rice for the population. Then the third largest land use in 2015 was in Industrial land use which had an area of 1331.4 Ha with a percentage of 24.1%. Field land use has an area of 316.2 Ha with a percentage of 5.7%, Mixed Plantation land use has an area of 68.7 Ha with a percentage of 1.2%, Lake land use has an area of 66.5 Ha with a percentage of 1.2% and finally there is Bush land use which has an area of 52.1 Ha with a percentage of 0.9%.

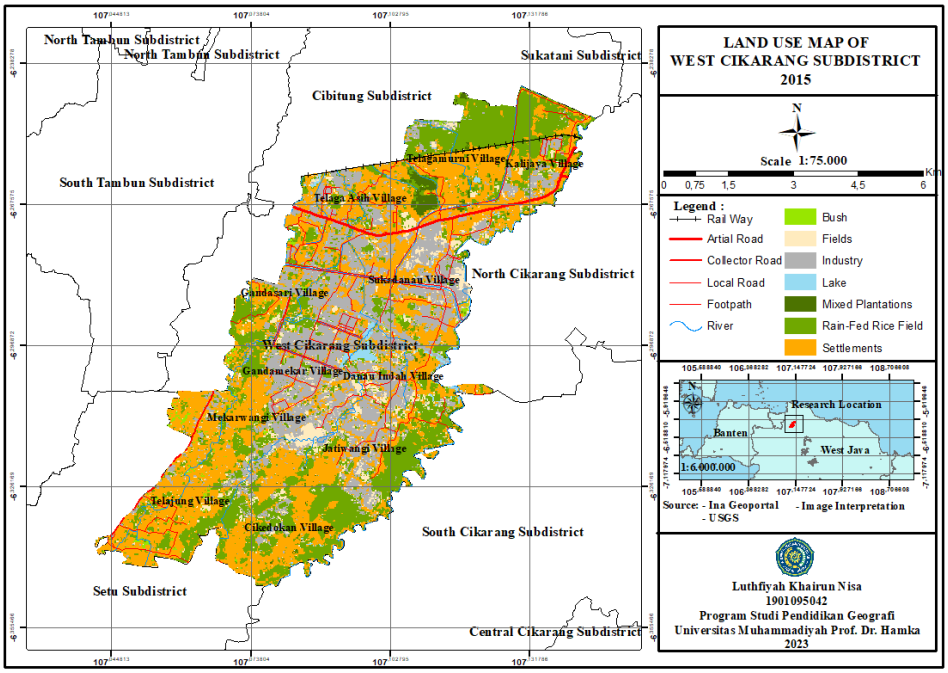

Figure 6. Land Use Map of West Cikarang Subdistrict in 2015

D. Analysis of Land Use in West Cikarang Subdistrict in 2020

Furthermore, land use in West Cikarang Subdistrict in 2020 is the same as land use in 2015 and 2020, only the area and percentage are different. For information on the area and description of land use in West Cikarang Subdistrict in 2020, see Table 7 and Figure 7.

Table 7. Land Use of Cikarang Barat Subdistrict in 2020

No	Description	Broad (Ha)	Percentage (%)
1	Lake	83,6	1,5
2	Industry	1572,4	28,4
3	Fields	304,7	5,5
4	Mixed Plantations	81,1	1,5
5	Settlements	2285,3	41,3
6	Rain-Fed Rice Field	1159,1	20,9
7	Bush	48,2	0,9
	Total	5534,4	**100**

Based on Table 7 above shows that land use in 2020 in West Cikarang Subdistrict is the largest land use for settlements which has an area of 2285.3 Ha with a percentage of 41.3%, this shows an increase when viewed from the area of residential land use in 2010 and 2015. The second largest is Industrial land use which has an area of 1572.4 Ha with a percentage of 28.4% and when viewed within a period of 10 years Industrial land use continues to increase, Industrial development in West Cikarang Subdistrict has had an impact on reducing the area of agricultural land, this is as stated in the study (Niandyti et al., 2019) that industrial development is able to shift the agricultural sector so as to

marginalize farmers' lands and marginalize farming communities who previously controlled the land. This shows that the decrease in the area of agricultural land is an environmental impact caused by the industry so that it can reduce the carrying capacity of nature in the form of a decrease in the amount of agricultural production in supporting food needs. Agricultural lands that were once controlled by farmers, with the rapid development of industry has been able to change the order of land use that leads to industrialization.

Whereas in 2015 Industrial land use in West Cikarang Subdistrict had an area of 1331.4 Ha, which means that in a period of 5 years Industrial land use has increased in area. Meanwhile, the land use of Rainfed Rice Fields has decreased in land area, namely 1159.1 Ha with a percentage of 20.9%. Field land use has an area of 304.7 Ha with a percentage of 5.5%. Lake land use has an area of 83.6 hectares with a percentage of 1.50%. Mixed Plantation land use has an area of 81.1 Ha with a percentage of 1.50%. And the last is Bush land use which has an area of 48.2 Ha with a percentage of 0.9%.

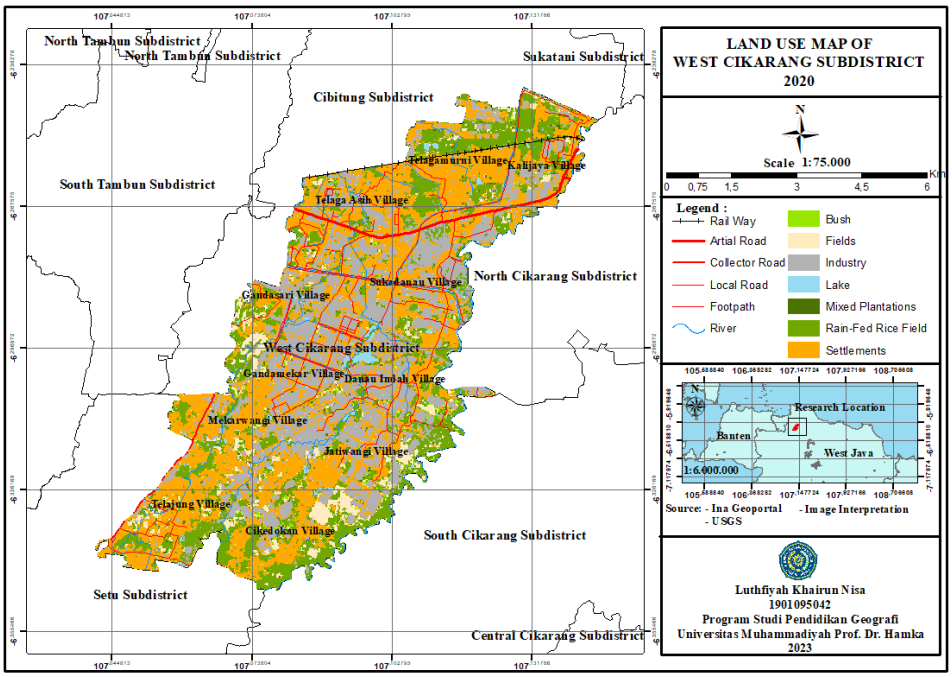

Figure 7. Land Use Map of West Cikarang Subdistrict in 2020

E. Analysis of Land Use Change in West Cikarang Subdistrict 2010-2020

Land use change analyzed in this study is the land use map in 2010, 2015, and 2020 from Supervised classification of Landsat images. Land use maps in West Cikarang Subdistrict in 2010, 2015, and 2020 can be seen in Figure 5, Figure 6 and Figure 7. The area of each land use in West Cikarang Subdistrict can be seen in Table 8.

Table 8. Extent of Land Use Change in West Cikarang Subdistrict in 2010-2020

No	land	2010		2015		2020		Description
		Broad (Ha)	Percentage (%)	Broad (Ha)	Percentage (%)	Broad (Ha)	Percentage (%)	
1	Lake	37,6	0,7	66,5	1,2	83,6	1,5	Increased
2	Industry	1137,4	20,6	1331,4	24,1	1572,4	28,4	Increased
3	Fields	663	12	316,2	5,7	304,7	5,5	Reduced
4	Mixed Plantations	10,9	0,2	68,7	1,2	81,1	1,5	Increased
5	Settlements	1660,1	30	2227,8	40,3	2285,3	41,3	Increased
6	Rain-Fed Rice Field	1983,6	35,8	1471,7	26,6	1159,1	20,9	Reduced
7	Bush	41,8	0,8	52,1	0,9	48,2	0,9	Fluctuating
	Total	**5534,4**	**100**	**5534,4**	**100**	**5534,4**	**100**	

Based on Table 8, Population growth has a significant impact on land use in an area; from 2010 to 2020, changes in land use types for settlements increased as a result of urbanization, population growth, economic factors, and social factors (Adawiyah, 2021). Not only residential land use has increased, but when viewed in table 8, Industrial land use has increased, this has also resulted in many residents urbanizing to meet their needs, resulting in an increase in population.

Agricultural land will become increasingly scarce as a result of land conversion for industrial development and its supporting infrastructure, thus increasing population density. This is because rural economic activities such as agriculture must be reduced to accommodate population growth. The transformation from agricultural land use to urban land use arises from industrial growth and urbanization (Muslim et al., 2023).

In West Cikarang Subdistrict, the conversion of paddy fields to built-up land changes every year, especially for residential land. This occurs as a result of the increasing population of the West Cikarang Subdistrict, which is accompanied by an increase in the need for land for housing. People decide to establish new settlements in previously uninhabited areas, such as rice fields, gardens, moorlands, and even a small part of the forest area, because the available settlement land is insufficient (I Gusti Bagus Indrajaya et al. 2018).

In general, there are several factors that have an impact on changes in agricultural land use that occur in West Cikarang Subdistrict, namely: 1) The need for land for housing is increasing due to the enormous population growth, making human activities inseparable from the phenomenon of agricultural land conversion in West Cikarang Subdistrict. 2) One of the factors that influence the shift in land use in an area is the availability of complete public facilities because the closer a location is to public facilities, the more people are interested in moving or settling in that location. Daily activities can be supported by the availability of complete public facilities. These facilities include education, health, government, and economic facilities, such as markets and shopping centers.

However, if seen in table 8, there is one land use that has experienced fluctuating land changes, namely Bush land use. This is due to human activities that sometimes require vacant land but the land is not developed into built-up land, and afterwards the land is left alone and will gradually grow shrubs again.

Based on the results of the calculation of land use change in West Cikarang Subdistrict from 2010 to 2020, a graph of land use change was made. The graph of land use change aims to see how big the comparison of land changes that occur in West Cikarang Subdistrict, to see the land use change can be seen through Figure 8.

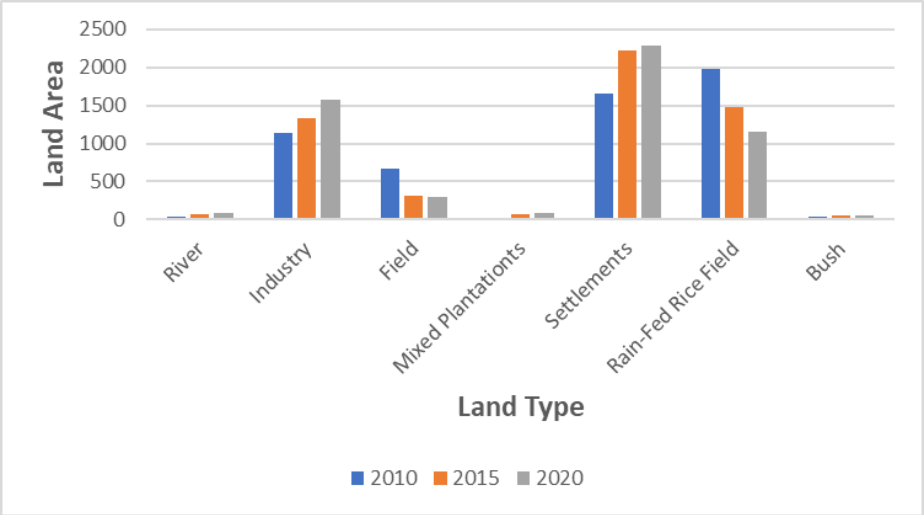

Figure 8. Land Use of West Cikarang Subdistrict in 2010-2020

4. Conclusion

It is known that the largest land use changes occur in residential and industrial land use, both land uses continue to increase every 5 years. In contrast, the land use of Rainfed Rice Fields in West Cikarang District has decreased over a period of 10 years. The occurrence of land use change causes the potential loss of achievable rice and rice production. The conversion of paddy fields that cannot be controlled properly can threaten the food security of the population.

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