

## Analysis of Carbon Stock on Land Surface in Jasinga District Using The Invest Model

### Analisis Stok Karbon Permukaan Tanah di Daerah Jasinga Dengan Menggunakan Model Invest

**Dzahabi Abdul Hakim<sup>1</sup>, Iksal Yanuarsyah<sup>2</sup>, Fetty Fatimah<sup>3</sup>, Dewi Primasari<sup>4</sup>**

<sup>1,2,3</sup> Informatics Engineering, Faculty of Technology & Sains, Universitas Ibn Khaldun Bogor Jl. Sholeh Iskandar, RT.01/RW.10, Kedungbadak, Kec. Tanah Sereal, Bogor City, West Java 16162 Indonesia

Email: <sup>1</sup>dzahabiabdulhakim@gmail.com, <sup>2</sup>iksal.yanuarsyah@ft.uika-bogor.ac.id, <sup>3</sup>fety.fatimah@uika-bogor.ac.id, <sup>4</sup>dewiprimasari@yahoo.com

#### ABSTRACT

This study examines changes in carbon stock and land cover in the Jasinga District from 2020 to 2023. The Reclassify method was used to classify land cover, while the InVEST software was used to estimate carbon stock. The research results show a consistent decrease in carbon stocks every year: from 33,641,249 tons in 2020 to 31,519,223 tons in 2023. Validation of land cover data shows an accuracy level of 84%, with an AUC/ROC value of 0.722 (appropriate category) and a Kappa test value of 80% (high level of reliability). This study examines changes in carbon stocks and land cover in the Jasinga District from 2020 to 2023. The Reclassify method was used to classify land cover, while the InVEST software was used to estimate carbon stocks. The results show a consistent annual decrease in carbon stocks, from 33,641,249 tons in 2020 to 31,519,223 tons in 2023. Validation of land cover data shows a level of accuracy of 84%, with an AUC/ROC value of 0.722 (categorized as good) and a Kappa test value of 80% (high reliability).

*Keywords: Carbon; Carbon Stocks; Reclassify; InVEST; CO<sup>2</sup>*

#### INTRODUCTION

Indonesia is one of the countries with abundant biodiversity, but the threat of environmental damage such as deforestation continues to increase, significantly impacting ecosystem balance and climate change. Bogor Regency, as one of the areas with high urbanization dynamics, serves as a real example of how land cover changes can impact carbon stocks. Jasinga District, which once had dense tropical forests and rice fields as its main carbon sinks, is now experiencing a reduction in its vegetation cover area. This is due to the expansion of agricultural land, urbanization, and other human activities, which contribute to increased carbon dioxide emissions into the atmosphere. Facing challenges due to land cover change, which leads to a decrease in carbon reserves. Therefore, this study aims to analyze land cover changes and carbon stocks in the region using the Reclassify method and InVEST software to support sustainable environmental management.



## PROBLEM STATEMENT

The research questions in this study are as follows:

1. How do I find out the carbon stock of land cover using the InVEST model?
2. What is the potential carbon stock in each type of land cover in Jasinga District in 2020-2023?
3. Analyze the percentage of conformity with the simple accuracy test, AUC/ROC and Kappa on land cover in Jasinga District?

## LITERATURE REVIEW

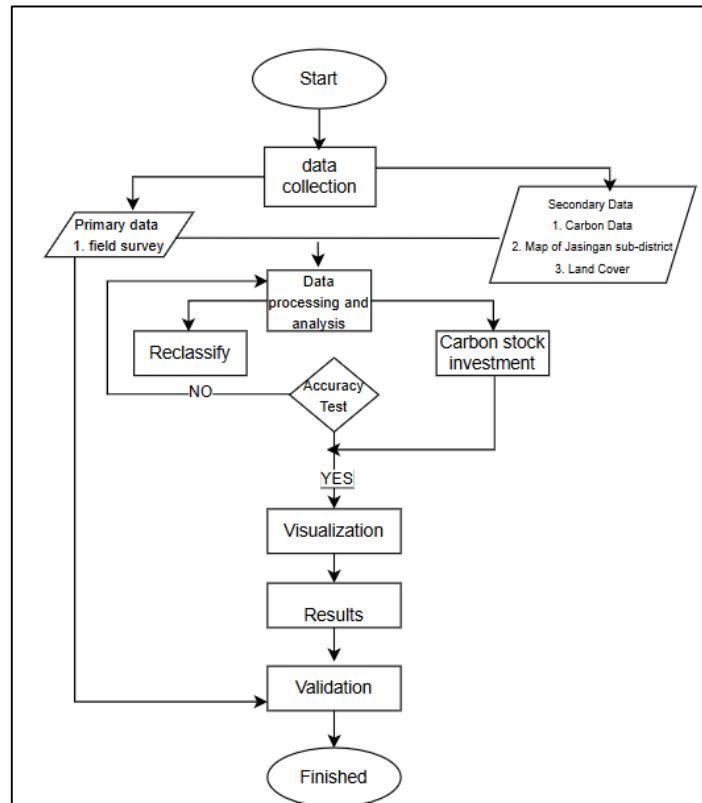
Table 1: Literature review

No	Author Name, Journal Title, Journal Name and Year	Result	Conclusion
1	"Tree Carbon Stocks in the Rinon Pulo Breuh Secondary Forest Area, Aceh Besar Regency", 2016.	Potential Carbon Reserves based on the land cover class also experienced a trend of change during the period of high carbon stocks recorded in 2003 of 656,053 tons, the lowest in 2012 of 620,992 tons, and the last year of observation (2018).	Explaining the potential stock carbon at cover forest land. Carbon Forest Rinon Isle Breuh Secondary School, Banda Aceh Regency reach 0.20231873 g/ha.
2	"Using the InVEST-PLUS Model to predict and Analyze the Pattern of Ecosystem Carbon storage in Liaoning Province, China.", 2023	Study of Storage Distribution Carbon Balance, Balancing Land Use with Ecological Protection, and Development Urban Low carbon is the key deep China's dual carbon strategy. However, the impact of governance policies room on storage carbon at the level province less noticed. Study makes Carbon density database for Liaoning Province, China.	Using the software that same that is InVEST to analyze carbon stocks. This research also analyze the spatial and temporal variations of the backup Carbon in Liaoning Province from 2000 to 2020.

## METHODOLOGY

This research method consists of three main components such as data collection methods, analysis methods, and system design methods. The flow of the conceptual framework in the image below illustrates this research method:

Figure 1: Flowchart of the research



### Data Collection

Data collection is the stage of gathering primary and secondary data to validate land cover in Jasinga District. Primary data consists of field samples of land cover points with a total of 112 samples, while secondary data includes carbon stock values taken from various sources as shown in the table below. The criteria analyzed must be of the same type, including the administrative map of Jasinga District and the land cover map.

Table 2: Carbon pools

lucode	LULC_Name	C_above (ton/ha)	C_below (ton/ha)	C_soil (ton/ha)	C_dead (ton/ha)
1	Water Body	0	0	50	0
2	Forest	400	155	172,5	4,9
3	Agricultural Land	3	4,5	70	1
4	Developed Land	2	0	60	0
5	Thicket	11,4	99	130	2

Source: Geomapid, IPCC, 2006 & Ilmiah Article

## Data Processing

The data processing is as follows:

### 1. Reclassify:

This stage is to classify land cover in Jasinga District obtained from land cover raster data.

### 2. Carbon stock estimation using InVEST:

This stage is to create a carbon stock model from land cover data and the carbon pool values obtained previously.

### 3. Accuracy Test

It is the accuracy test of the land cover changes that have been processed previously using the reclassify method to determine the accuracy value of the land cover in that sub-district. This accuracy test uses simple accuracy tests, AUC/ROC accuracy tests, and Kappa accuracy tests, then links them with the carbon stock that has been analyzed on the land cover in Jasinga District.

### 4. Reporting & Visualization

It is the reporting and visualization stage of the data processed on land cover using the reclassify method and carbon stock results in the InVEST software.

### 5. Result Analysis

The result analysis from the InVEST software is conducted to determine the carbon stock in each land cover class in Jasinga District for the period 2020–2023.

### 6. Validation

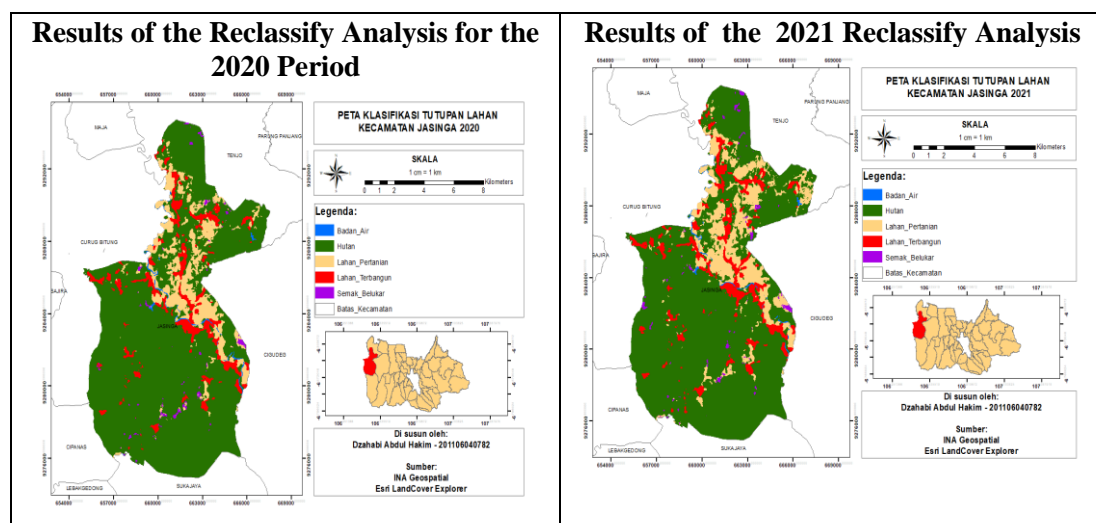
At this stage, the task is to validate land cover in Jasinga District using Avenza Maps by taking 112 samples of land cover in Jasinga District, which consists of water bodies, forests, agricultural land, built-up areas, and shrubs.

## FINDING AND DISCUSSION

### Results of Land Cover Classification Analysis Using the Reclassify Method

The image below is a visualization of land cover classification results using the Reclassify method. Blue indicates water bodies, green indicates forests, cream indicates agricultural land, red indicates built-up areas, and purple indicates shrubland.

Figure 2: Reclassification analysis results



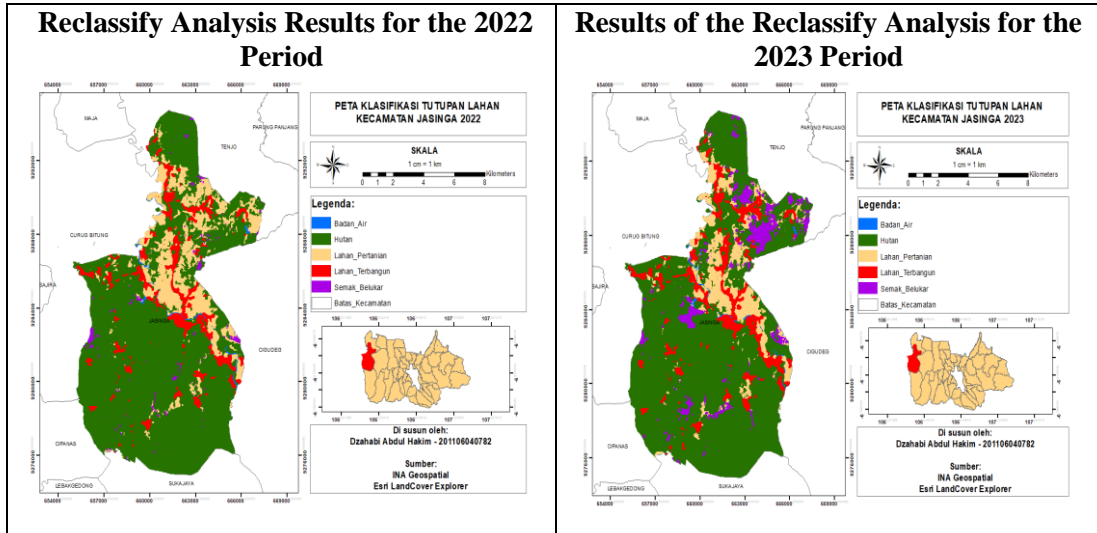


Figure 3: Land cover area diagram (Ha)

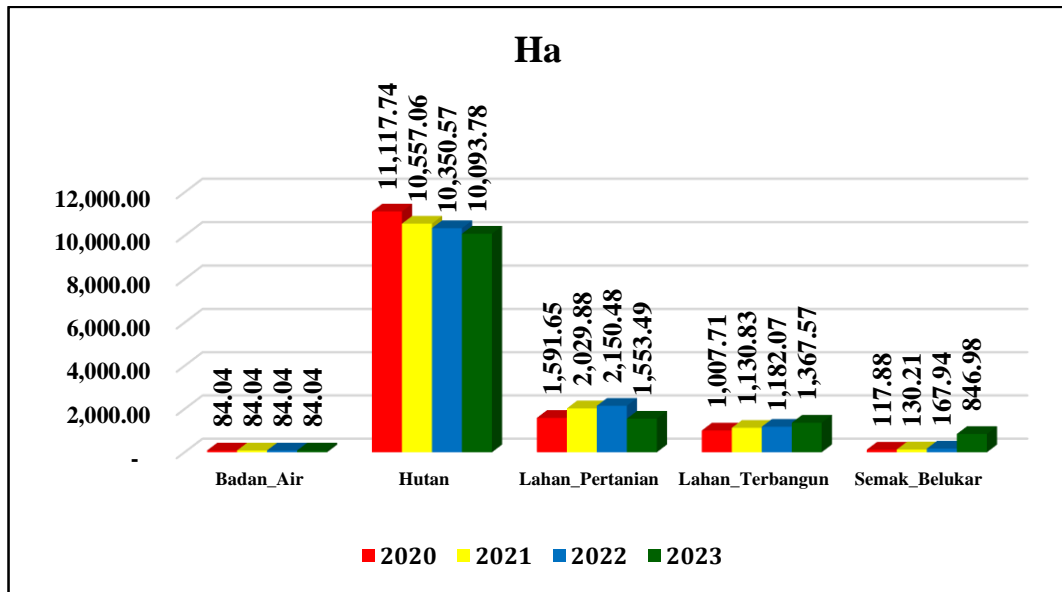


Figure 3 is a land cover area diagram for Jasinga District for the period 2020-2023, where red indicates the year 2020, yellow indicates the year 2021, blue indicates the year 2022, and green indicates the year 2023.

Table 3: Table of land cover area percentage for the year 2020

Land Cover Class	Wide 2020	Percentage
Water Body	84,04	0,60%
Forest	11.117,74	79,87%
Thicket	1.591,65	11,43%
Build Land	1.007,71	7,24%
Agricultural land	117,88	0,85%
Total	13.919,63	100%

**Table 4: Table of land cover area percentage for the year 2021**

Land Cover Class	Wide 2021	Percentage
Water Body	84,04	0,60%
Forest	10.557,06	75,84%
Thicket	2.029,88	14,58%
Build Land	1.130,83	8,12%
Agricultural land	130,21	0,94%
<b>Total</b>	<b>13.919,63</b>	<b>100%</b>

**Table 5: Table of land cover percentage for the year 2022**

Land Cover Class	Wide 2022	Percentage
Water Body	84,04	0,60%
Forest	10.350,57	74,36%
Thicket	2.150,48	15,45%
Build Land	1.182,07	8,49%
Agricultural land	167,94	1,21%
<b>Total</b>	<b>13.919,63</b>	<b>100%</b>

**Table 6: Table of land cover area percentage for the year 2023**

Land Cover Class	Wide 2023	Percentage
Water Body	84,04	0,60%
Forest	10.093,78	72,51%
Thicket	1.553,49	11,16%
Build Land	1.367,57	9,82%
Agricultural land	846,98	6,08%
<b>Total</b>	<b>13.919,63</b>	<b>100%</b>

In Table 3 – 6, there is a table of land cover area and the percentage results of the land cover area.

**Table 7: Land cover change matrix table 2020 – 2021**

	Land Cover Class	2021					Grand Total
		Water Body	Forest	Agriculture Land	Build land	Thicket	
2020	Water Body	84,04					84,04
	Forest		10.557,06	438,23	123,45	13,40	11.118,74
	Agriculture Land			1.591,63			1.591,63
	Build land				1.007,41		1.007,41
	Thicket					117,82	117,82
<b>Grand Total</b>		84,04	10.557,06	2.029,86	1.130,86	130,21	13.919,63

Table 8: Land cover change matrix table 2021 – 2022

	Land Cover Class	2022					Grand Total
		Water Body	Forest	Agriculture Land	Build land	Thicket	
2021	Water Body	84,04					84,04
	Forest		10.350,57	120,60	51,24	34,69	10.557,10
	Agriculture Land			2.029,88			2.029,88
	Build land				1.130,83		1.130,83
	Thicket					130,21	130,21
<b>Grand Total</b>		84,04	10.350,57	2.150,48	1.182,07	164,91	13.919,63

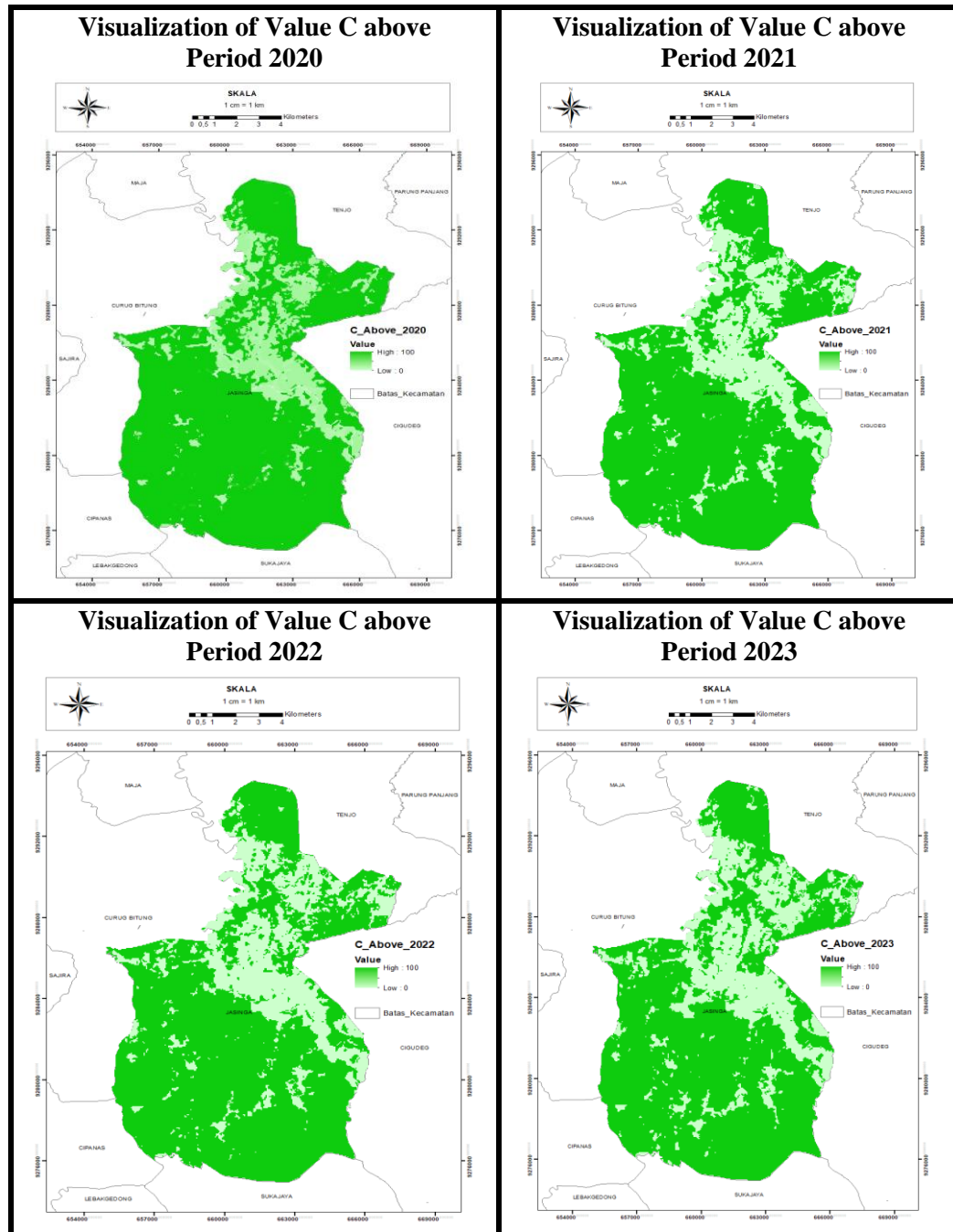
Table 9: Land cover change matrix table 2022 – 2023

	Land Cover Class	2023					Grand Total
		Water Body	Forest	Agriculture Land	Build land	Thicket	
2022	Water Body	84,04					84,04
	Forest		10.093,78		185,50	71,29	10.350,57
	Agriculture Land			1.553,49		597,00	2.150,48
	Build land				1.182,07		1.182,07
	Thicket					167,94	167,94
<b>Grand Total</b>		84,04	10.093,78	1.553,49	1.367,57	836,22	13.919,63

In tables 7 – 9, there are matrix tables showing land cover changes in Jasinga District for the period from 2020 to 2023.

## Results of Carbon Stock Analysis Using INVEST Software

Figure 4: Figure C\_Above Period 2020-2023



In Figure 4, the value of C\_Above for land cover from 2020 to 2023 can be seen, with the lowest value being 0 and the highest value being 100.

Figure 5: Figure C\_Below Period 2020-2023.

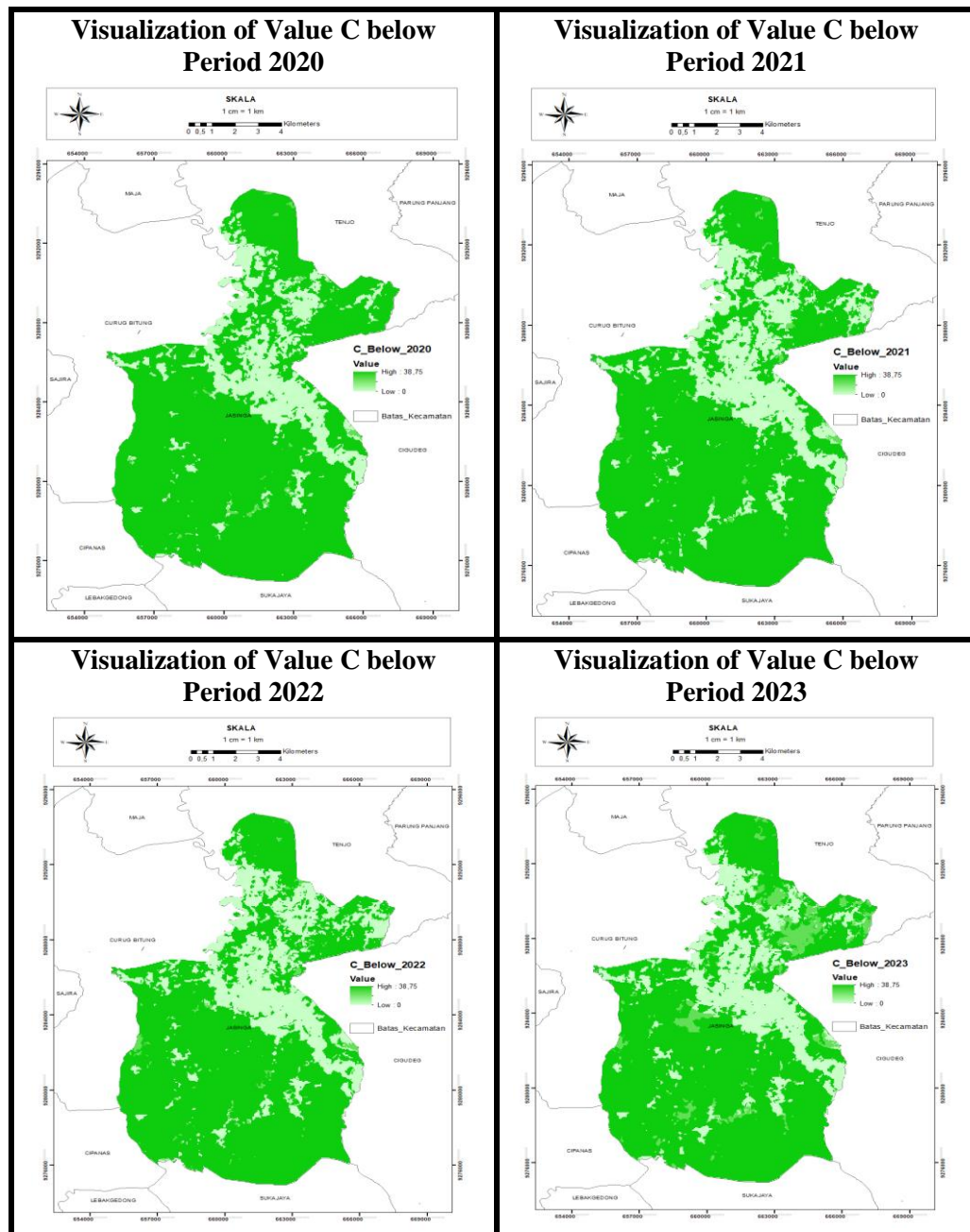


Figure 5 Figure C\_Below Period 2020-2023. In Figure 5, the value of C\_below from the period 2020 to 2023 can be seen, with the lowest value at 0 and the highest value at 38.75.

Figure 6: Figure C\_Soil Period 2020-2023

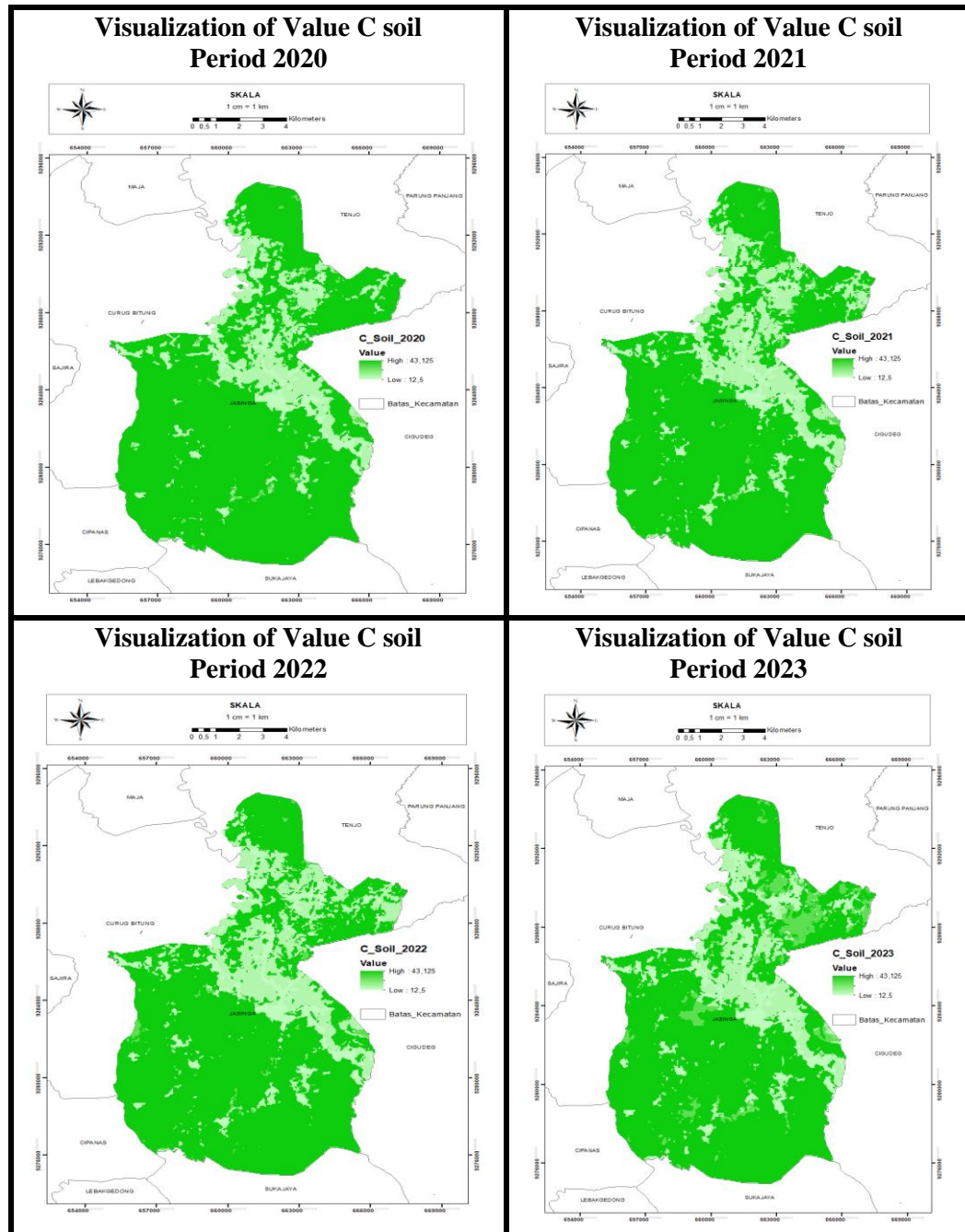
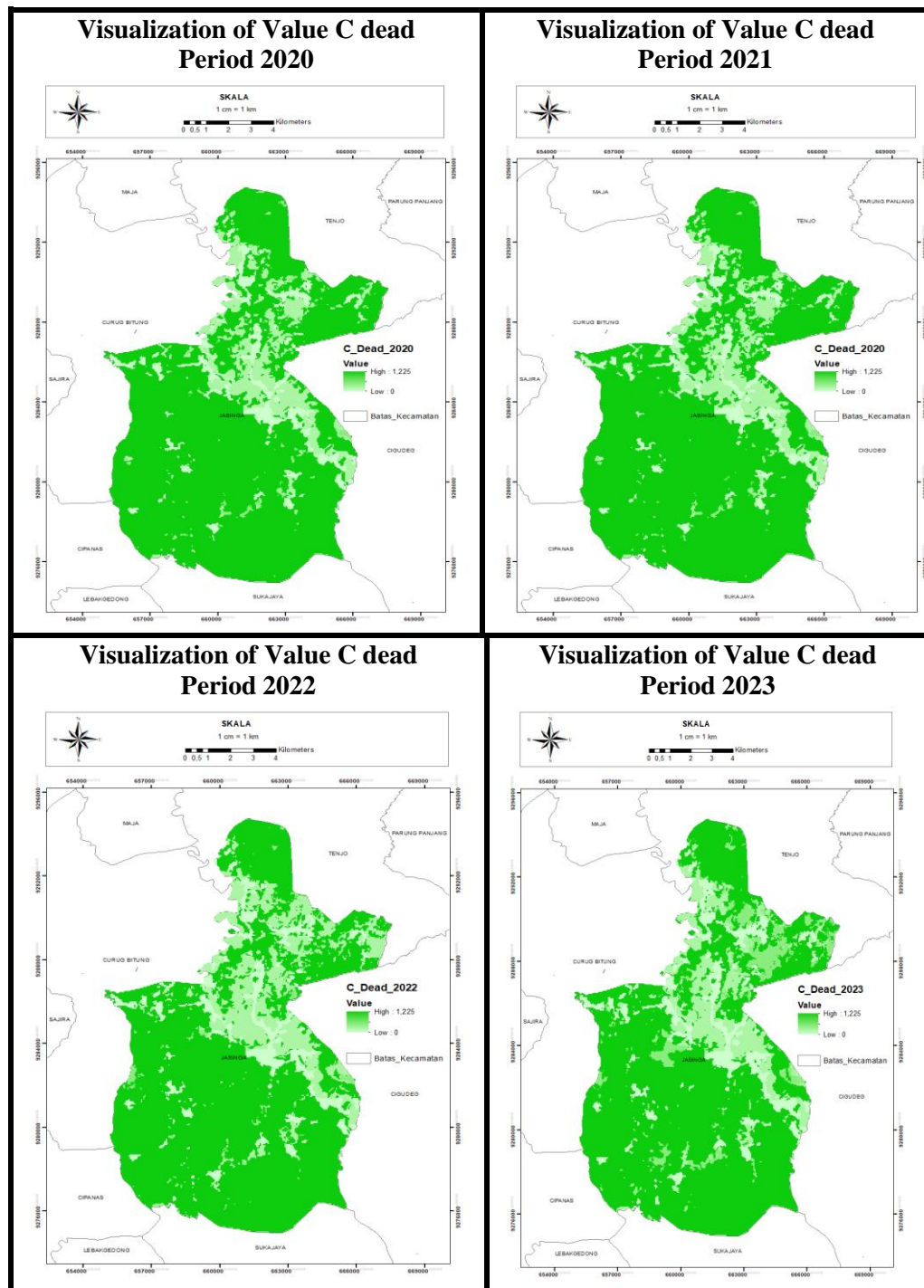


Figure 6 C\_Soil Image Period 2020-2023 In Figure 6, the value of C\_Soil from 2020 to 2023 can be seen, with the lowest value at 12.5 and the highest at 43.125.

Figure 7: Figure C\_dead Period 2020-2023



In Figure 7, it can be seen that the value of  $C_{\text{dead}}$  from 2020 to 2023 has the lowest value at 0 and the highest value at 1.25.

Figure 8: Figure C\_Total Period 2020-2023

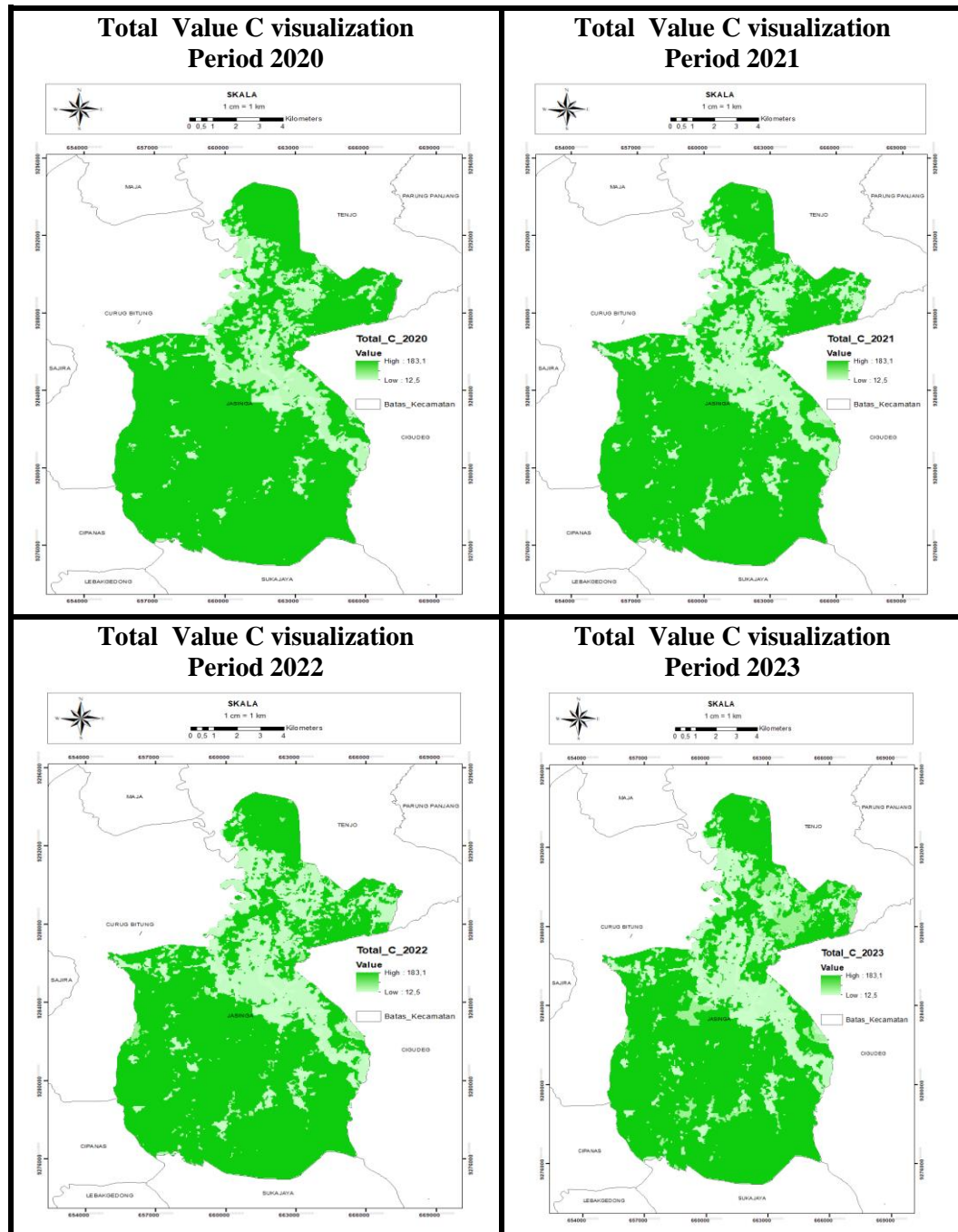


Figure 8 Figure C\_Total Period 2020-2023 In Figure 8, the value of C\_Total for the period 2020 to 2023 can be seen, with the lowest value at 12.5 and the highest at 183.1.

Table 10: Carbon stock 2020

No	Land Cover Class 2020	Carbon Stock (Ton) Pixel	Carbon Stock (Ton) Ha
1	Water Body	6.866	27.465
2	Forest	8.145.388	32.581.553
3	Thicket	150.321	601.283
4	Build Land	70.183	280.731
5	Agricultural land	37.554	150.216

Table 11: Carbon stock 2021

No	Land Cover Class 2021	Carbon Stock (Ton) Pixel	Carbon Stock (Ton) Ha
1	Water Body	6.297	25.188
2	Forest	7.735.891	30.943.563
3	Thicket	185.339	741.354
4	Build Land	76.401	305.605
5	Agricultural land	39.169	156.675

Table 12: Carbon stock 2022

No	Land Cover Class 2022	Carbon Stock (Ton) Pixel	Carbon Stock (Ton) Ha
1	Water Body	6.152	24.607
2	Forest	7.587.288	30.349.153
3	Thicket	202.533	810.131
4	Build Land	80.946	323.784
5	Agricultural land	57.172	228.690

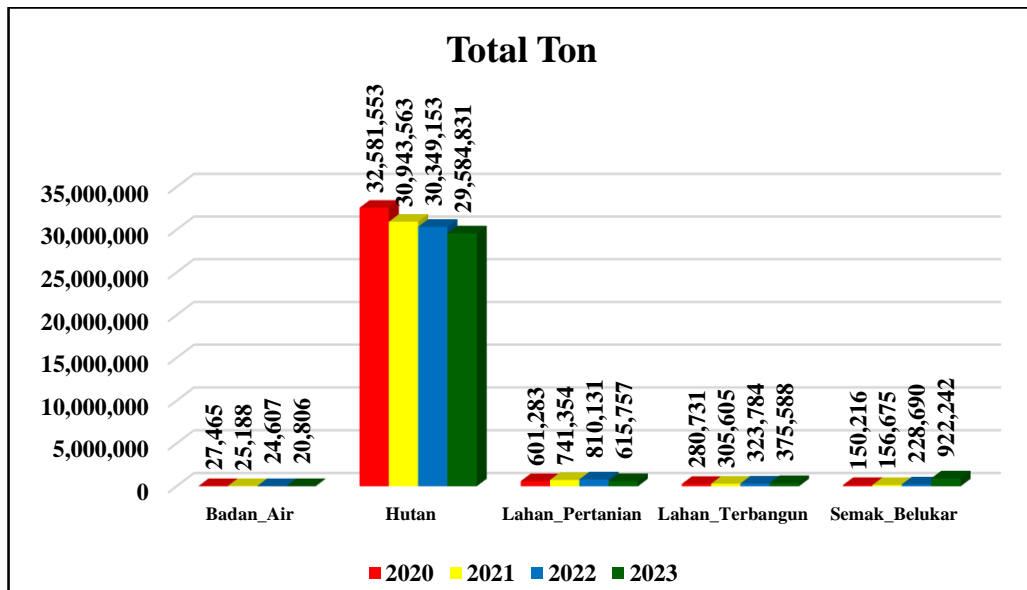
Table 13: Carbon stock 2023

No	Land Cover Class 2023	Carbon Stock (Ton) Pixel	Carbon Stock (Ton) Ha
1	Water Body	5.202	20.806
2	Forest	7.396.208	29.584.831
3	Thicket	153.939	615.757
4	Build Land	93.897	375.588
5	Agricultural land	230.560	922.242

Tables 10 - 13 show the carbon stock in Jasinga District from 2020 to 2023, which has been converted to tons/ha. The conversion is done using the formula:  $\text{ton/ha} = 4 \times \text{ton/pixel}$ . The area of one pixel (50x50 meters) is 2,500 m<sup>2</sup> or 0.25 ha. So, to convert the value from tons/pixel to

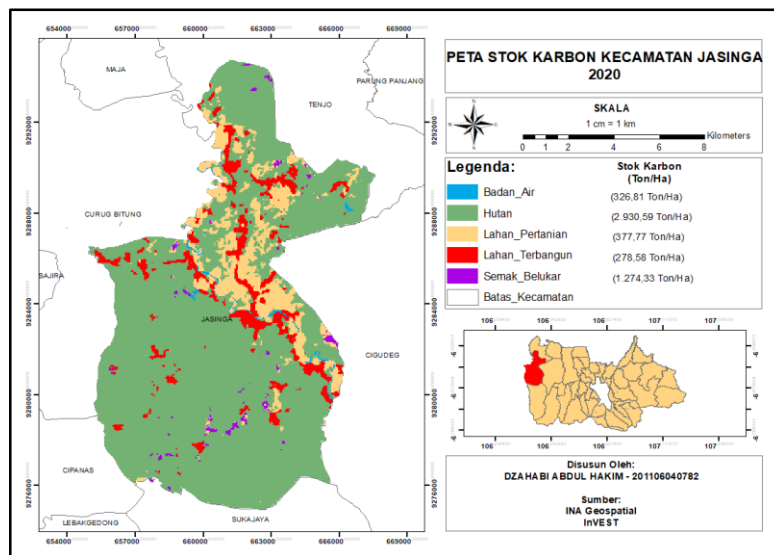
tons/ha, simply multiply the tons/pixel value by 4. For example, if the density of an area is 2 tons/pixel, the result in tons/ha is 8 tons/ha.

Figure 9: Total carbon stock diagram (Ton)



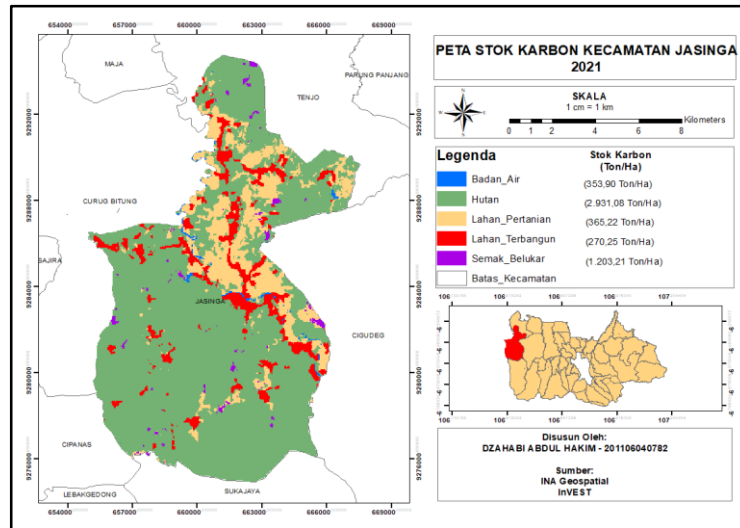
In Figure 9, the amount of carbon stock in each land cover class in Jasinga District for the period from 2020 to 2023 can be seen. The red color indicates the year 2020, yellow indicates the year 2021, blue indicates the year 2022, and green indicates the year 2024.

Figure 10: Carbon stock map for the year 2020



In Figure 10, there is a carbon stock map of land cover in Jasinga District for the year 2020, where blue is marked as water bodies, green is marked as forests, cream is marked as agricultural land, red is marked as built-up land, and purple is marked as shrubs.

Figure 11: Carbon stock map for the year 2021



In Figure 11, there is a carbon stock map of land cover in Jasinga District for the year 2021, where blue is marked as water bodies, green is marked as forests, cream is marked as agricultural land, red is marked as built-up land, and purple is marked as shrubs.

Figure 12: Carbon stock map for the year 2022

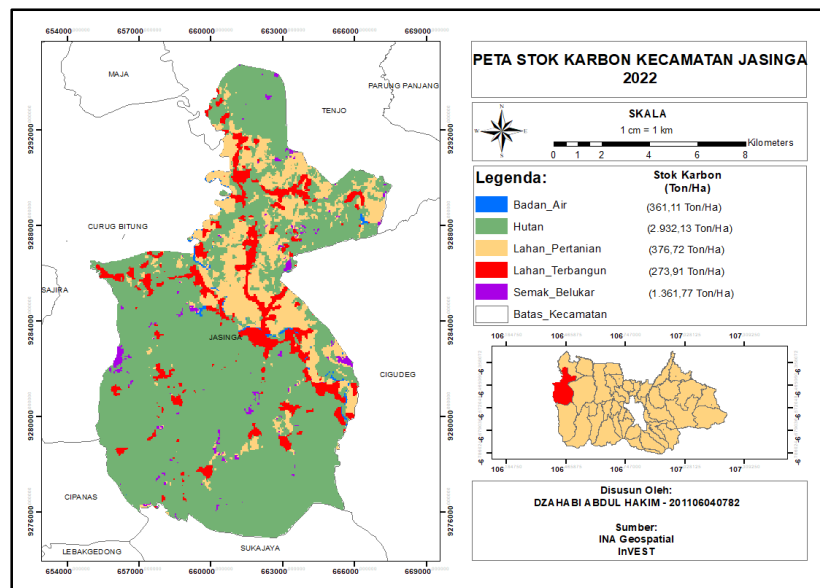
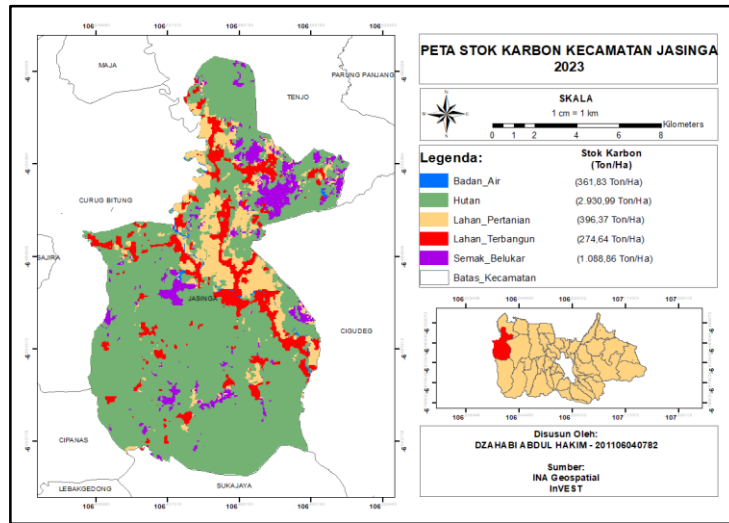


Figure 12 Carbon Stock Map for the 2022 Period In Figure 12, the carbon stock map of land cover in Jasinga District for the year 2022 is shown, where blue is marked as water bodies, green as forests, cream as agricultural land, red as built-up areas, and purple as shrubs.

Figure 13: Carbon stock map for the 2023 period



In Figure 13, there is a carbon stock map of land cover in Jasinga District for the year 2023, where blue is marked as water bodies, green is marked as forests, cream is marked as agricultural land, red is marked as built-up areas, and purple is marked as shrubs.

Figure 14: Carbon stock diagram (Ton/Ha)

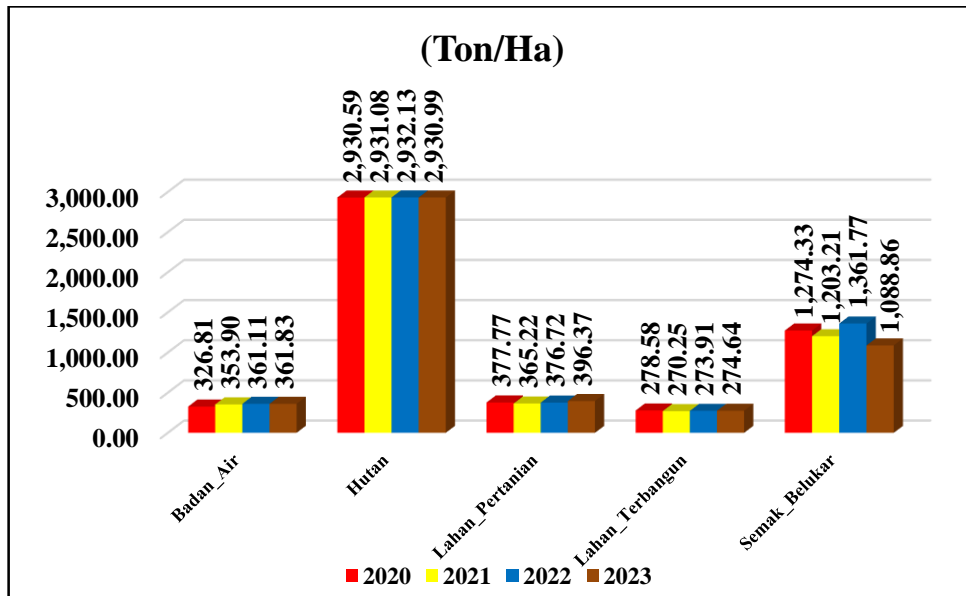


Figure 14 Carbon Stock Diagram (Ton/Ha) in the following Figure 14, the amount of carbon stock in each land cover class in Jasinga District from 2020 to 2023 can be seen.

Figure 15: Annual carbon stock diagram

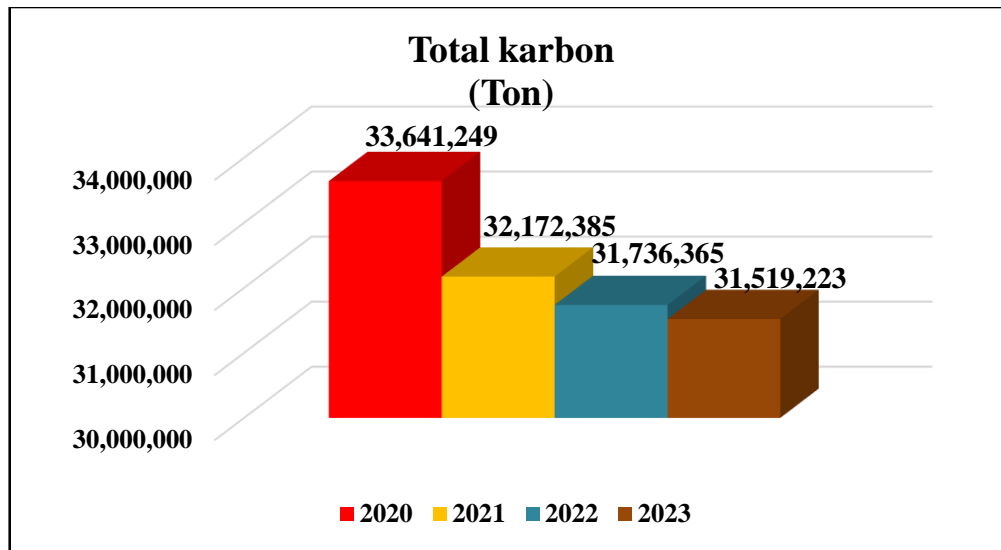


Figure 15 Annual Carbon Stock Diagram In the following Figure 15, it can be seen that the carbon stock in Jasinga District has decreased each year, with a carbon stock of 33,641,249 tons in 2020, 32,172,385 tons in 2021, 31,736,365 tons in 2022, and 31,519,223 tons in 2023.

### Final Test

Based on the results of the field survey, 112 sample points were taken. The analysis results show that there are 94 correct sample points out of the 112 sample points taken. The following is the calculation of the accuracy level.

$$\begin{aligned} \text{LEVEL ACURACCY} &= \frac{\text{NUMBER OF COREECT POINT}}{\text{POINT SAMPLE}} \times 100\% \\ &= \frac{94}{112} \times 100\% = 84\% \end{aligned}$$

The results of the satellite image validation test with the field conditions in the Jasinga District, Bogor Regency, showed an accuracy level of 84%. Based on the AUC/ROC accuracy test results, an AUC curve value of 0.722 was obtained, indicating that the modeling can effectively distinguish between the true class and the false class. It can be seen in the image below.

Figure 16: AUC/ROC Accuracy Test Result Image

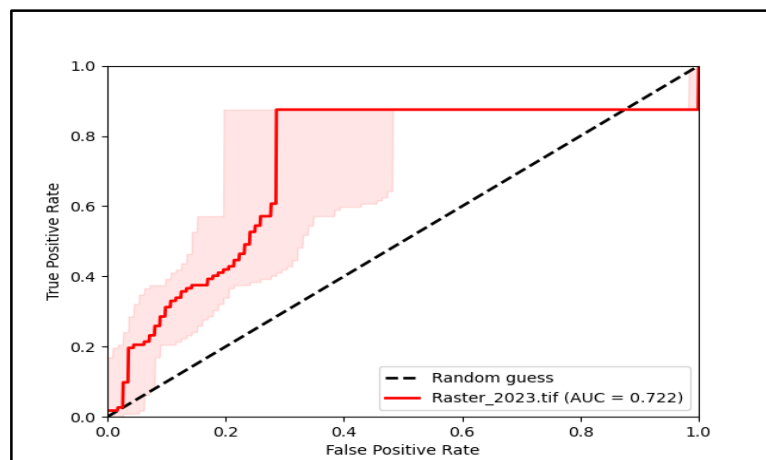


Figure 16 Accuracy Test Results AUC/ROC in Figure 16, there is a classification level based on the AUC calculation results. The higher the number, the better the model is at distinguishing between different classes.

**Table 14: AUC classification levels**

Classification Values	Result
0,0-0,5	Not Good
0,5-0,7	Pretty Good
0,7-0,8	Good
0,8-0,9	Excellent
> 0,9	Almost Perfect

Source: Rakhmat Purnomo (2017)

In the table above, where the classification value is the same as the tested result, according to (Rakhmat Purnomo), 0.0 – 0.5 indicates poor, 0.5-0.7 indicates fair, 0.7-0.8 indicates good, 0.8-0.9 indicates very good, and more than 0.9 indicates nearly perfect.

**Table 15: Kappa accuracy test table**

	2023 Field Verification Results						Total	User Accuracy	UA %
	Land Cover Class	Water Body	Forest	Agriculture Land	Build land	Thicket			
Results	Water bodies	15					15	1,00	100%
	Forest		25			4	34	0,74	74%
	Farmland		1	18		2	21	0,86	86%
	Built Land		1		18		19	0,95	95%
	Bushes			5		18	23	0,78	78%
<b>Total</b>	15	27	28	18	24	<b>112</b>			
<b>Producer Accuracy</b>	1,00	0,93	0,64	1,00	0,75		<b>Overall Accuracy</b>	84%	
<b>PA%</b>	100%	93%	64%	100%	75%		<b>Kappa Accuracy</b>	80%	

All correct classifications 94 rows\* and Column rows 2652 based on the results of the simple accuracy test, AUC/ROC, and Kappa on land cover in Jasinga District, the carbon stock on land cover in the area has a simple accuracy test score of 84%, while the AUC/ROC accuracy test falls into the good category with a score of 0.722, and the Kappa accuracy test score is 80%. All have been tested and sampled from 112 land cover class samples surveyed in Jasinga District.

## CONCLUSION

Based on the results of the research analysis regarding carbon stock analysis in land cover in Jasinga District, it can be concluded that:

1. It can be concluded that to determine the carbon stock value in the land cover, two types of data are needed: the first is carbon pools data or carbon stock values corresponding to the land cover classes used, and the second is raster data or land cover data of the area to be studied.
2. It can be concluded that the carbon stock value in Jasinga District has shown a declining trend each year, with 33,641,249 tons in 2020, 32,172,385 tons in 2021, 31,736,365 tons in 2022, and 31,519,223 tons in 2023.
3. The accuracy test results on land cover in Jasinga District, which sampled 112 points, using a simple accuracy test obtained 84%, and the AUC/ROC test results obtained 0.722, indicating good and the Kappa test obtained 80%.

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