SRSD
Spatial Review for Sustainable Development
SRSD 2(1): 21–37
ISSN 3062-8229

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Spatiotemporal analysis of land surface temperature and land cover change: Assessing the impact of urbanization and vegetation dynamics

Muhammad Annas Fathoni[1,*]
[1] *Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, West Java 16424, Indonesia.*
*Correspondence: muhammad.annas@ui.ac.id

Received Date: January 24, 2025 Revised Date: February 27, 2025 Accepted Date: February 28, 2025

ABSTRACT
Background: Land cover change refers to changes in the surface cover of an area over time due to natural and human factors. The urbanization of Cibadak District, near the toll exit, contrasts with the rural Cikidang District, resulting in different dynamics of land surface temperature (LST) and land cover change. This study focuses on the observed temperature increase in both districts from 2013 to 2023, aiming to analyze the relationship between land cover change and LST variation. **Methods:** This study used a spatiotemporal analysis method, with land cover as the independent variable and LST as the dependent variable. Clustered purposive sampling was used. Land cover was validated using Google Earth imagery, while LST was validated with air temperature data from BMKG. Landsat 8 imagery was processed using the Google Earth Engine (GEE) platform to create spatiotemporal maps of land cover and LST. The relationship between the two variables was analyzed through cross-sectional spatial analysis and statistical calculations, including Spearman correlation and multiple linear regression. **Findings:** From 2013 to 2023, the average increase in LST in land cover was 7.76°C. The analysis showed that vegetated land cover (forest and garden) showed temperatures between 24-32°C, while bare land had temperatures between 32-36°C, with bare land exceeding 40°C in 2023. The statistical results showed a strong positive correlation between land cover changes and LST increases. The correlation coefficient between 2013-2018 was 0.8117 (R^2 = 0.6588), and between 2018-2023, it was 0.7925 (R^2 = 0.6560). **Conclusions:** This study revealed a significant increase in LST in both study sites from 2013 to 2023, with land cover changes playing a key role in this trend. Urban areas with less vegetation contribute to higher temperatures, while vegetated areas help mitigate temperature increases. **Novelty/Originality of this article:** This study uniquely combines spatiotemporal analysis and statistical methods to assess the impact of land cover change on LST dynamics.

KEYWORDS: GEE; land cover change; LST; Sukabumi; spatiotemporal.

1. Introduction

Land cover change refers to changes in the surface cover of an area over time due to natural and human factors (Achmadi et al., 2023). Studies have analyzed land cover change across different regions and time periods and have shown that grasslands, wetlands and forest areas tend to decrease, while shrubland, cropland and built-up land tend to always increase (Healey et al., 2023). Economic and population growth have a considerable impact on land cover change (Afasel et al., 2023). As more people build homes and settle in an area, the demand for land for settlements, businesses and public infrastructure increases

Cite This Article:
Fathoni, M. A. (2025). Spatiotemporal analysis of land surface temperature and land cover change: Assessing the impact of urbanization and vegetation dynamics. *Spatial Review for Sustainable Development, 2*(1), 21-37. https://doi.org/10.61511/srsd.v2i1.2025.1752

(Rakuasa & Pakniany, 2022). The serious impact is that the land available for agriculture, forests and other natural resources is decreasing (Somae et al., 2023).

Based on observations from the Intergovernmental Panel on Climate Change (IPCC) in the IPCC Fifth Assessment Report (AR5) at the Paris Agreement in 2015, it shows that the impact of global warming has led to an increase of 1.5°C above pre-industrial levels and global greenhouse gas emission pathways (Arvidson, 2002). Human-induced warming reached about 1°C above pre-industrial levels in 2017, increasing by 0.2°C per decade, while in the decade 2006-2015 it was estimated at 0.87°C (likely between 0.75°C and 0.99°C) (BPS, 2014). The phenomenon of changes in surface air temperature is closely influenced by changes in land cover (BPS, 2019). The land cover change is caused by the factor of changing the vegetation area into non-vegetation (Mallick et al., 2008; Pal & Ziaul, 2017). Land cover change shows a direct correlation with the increase in LST (Desfandi & Ruliani, 2022). Conversion of land cover to built-up land and open land has led to a significant increase in ESG (BPS, 2024). Spatiotemporal changes in land cover classes, along with factors such as urbanization and global warming, have a significant impact on ESG, emphasizing the importance of understanding these dynamics for effective land use policies (Damayanti et al., 2023). It is important to consider the distribution of heat radiation between the atmosphere and the Earth's surface (Tan et al., 2010). There is a need to monitor land cover changes and their impacts, as these are related to temperature changes that affect the comfort of humans living in the region (Ermida et al., 2020).

Satellite imagery is helpful in monitoring land cover change (Saurabh & Shwetank, 2023). Models utilizing satellite imagery and advanced algorithms have been developed to accurately detect land cover change over two time periods, thus helping in understanding the dynamics of land cover transformation (Pavan et al., 2023). This enables observation of spatial and temporal changes on the Earth's surface, helping in the identification of modifications such as urbanization, environmental changes, water bodies, and forest cover (Karandikar & Agrawal, 2023). Through the integration of remote sensing technology and geographic information system tools, monitoring changes from the past to the present becomes more efficient (Ghozali, 2018).

The method of measuring heat radiation between the atmosphere and the Earth's surface can use the Landsat 8 satellite (Guntara, 2016). Landsat 8 utilizes Digital Number (DN) as a calculation method for imaging multispectral images, which depends on two sensor parameters, the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) (Handayani, 2007). Land Surface Temperature (LST) values are obtained from thermal bands found in satellite imagery, unmanned aerial vehicles (UAVs), drones, and other platforms with thermal sensors (Nugroho et al., 2016). LST has a spatial resolution of 100m (Arvidson, 2002). The satellite image data obtained must go through a conversion process to get the surface temperature value in centigrade units (Hooijer & Vernimmen, 2021).

This study examines massive land cover change in Cibadak and Cikidang sub-districts, Sukabumi district, West Java province. The difference in orientation between the urbanized Cibadak sub-district, which is close to the BOCIMI (Bogor-Ciawi-Sukabumi) toll exit and the Bogor-Sukabumi junction, and the rural Cikidang sub-district will result in different LST distributions and land cover changes. Land cover change will affect the level of land surface temperature. The relationship between land cover change and LST in Cibadak and Cikidang sub-districts needs to be mapped so that prevention and anticipation efforts can be made, especially on changes in LST in Cibadak and Cikidang sub-districts which can have a direct impact on the comfort of the people of Cibadak and Cikidang sub-districts.

2. Methods

The research method used quantitative method with spatial analysis. This research was conducted in Cibadak and Cikidang sub-districts, Sukabumi district, West Java. Land cover data used were from 2013, 2018 and 2023. The variables used were land surface temperature and land cover (Sugiyono, 2008). The results were analyzed based on the land cover unit of analysis. The flow of thought of this research can be seen in figure 1.

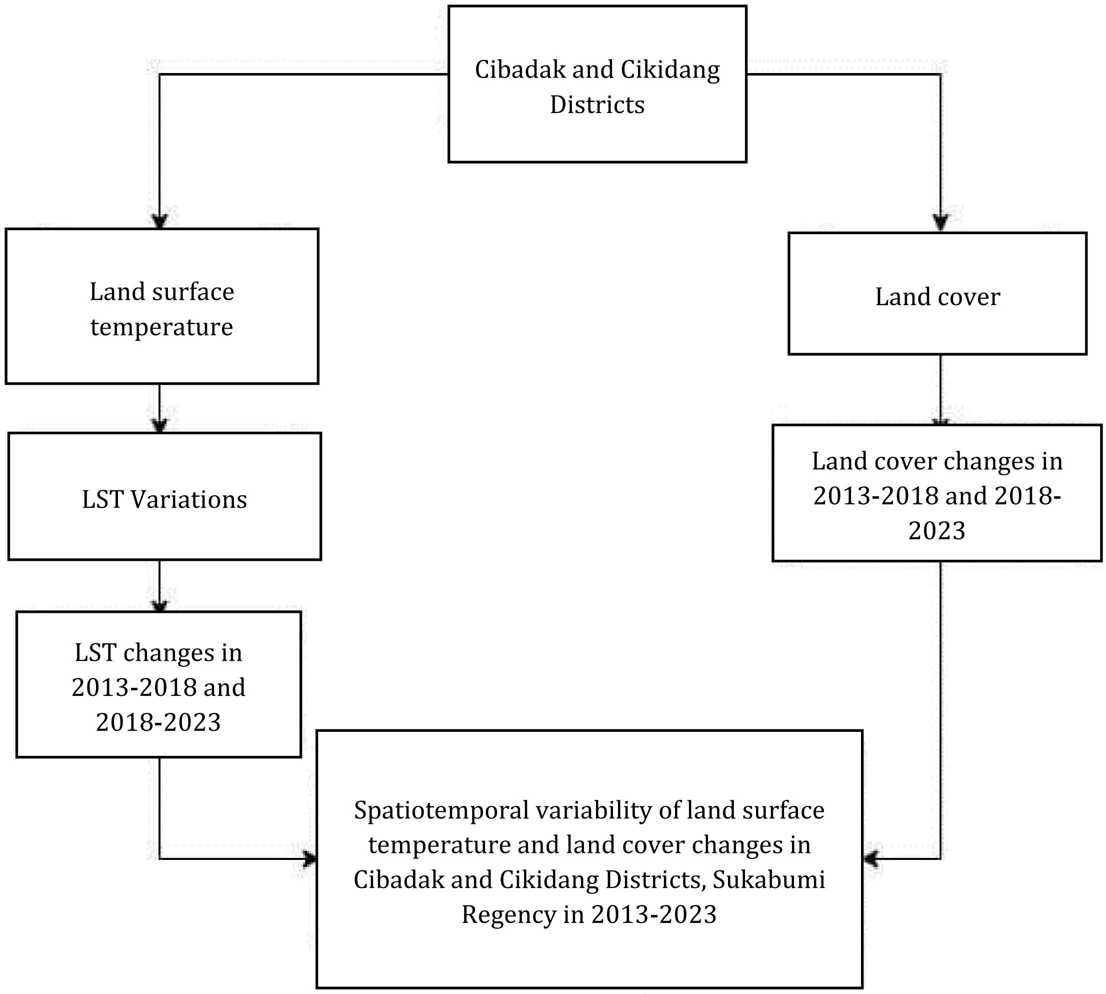

Fig. 1. Research train of thought

3. Results and Discussion

3.1 Land cover in 2013, 2018, and 2023

The land cover of Cibadak Sub-district and Cikidang Sub-district in 2013 was dominated by forest covering 91.11 km2 or 41.78% of the study area. In Cibadak Subdistrict, it is dominated by gardens covering an area of 23.89 km2 or equivalent to 39.1% of the Cibadak Subdistrict area, while in Cikidang Subdistrict, it is dominated by forest cover covering an area of 71.5 km2 or equivalent to 45.5% of the Cikidang Subdistrict area (Ibochi & Richard, 2020). Forests dominate in the northeast area of Cikidang Sub-district which is still included in the Gunung Halimun Salak National Park area. In Cibadak Sub-district, it is dominated by garden cover which dominates in the east which borders Cikidang Sub-district. The area of garden cover in the two sub-districts in 2013 had an area of 85.71 km2 or 39.3% of the total area of the study area (Julianto et al., 2020). The area of rice field cover in 2013 was 17.2 km2 or 7.89% of the total study area. The built-up area in Kecamatan Cibadak and Kecamatan Cikidang in 2013 reached 7.4 km^2 or 3.4% of the total area (Kunz, 2017). The built-up area of Kecamatan Cibadak and Kecamatan Cikidang in 2013 was mostly located in Kecamatan Cibadak. This is because Cibadak Subdistrict is closer to Sukabumi City area and as a connector from Bogor to Sukabumi. Land cover of open land in Cibadak and Cikidang Subdistrict in 2013 has an area of 14.4 km^2 or 6.6% of the study area which dominates the border between Cibadak and Cikidang Subdistrict. While water is the land cover with the smallest area, which is 2.3 km^2 or 1.1% of the total area of the study area in 2013 see figure 2.

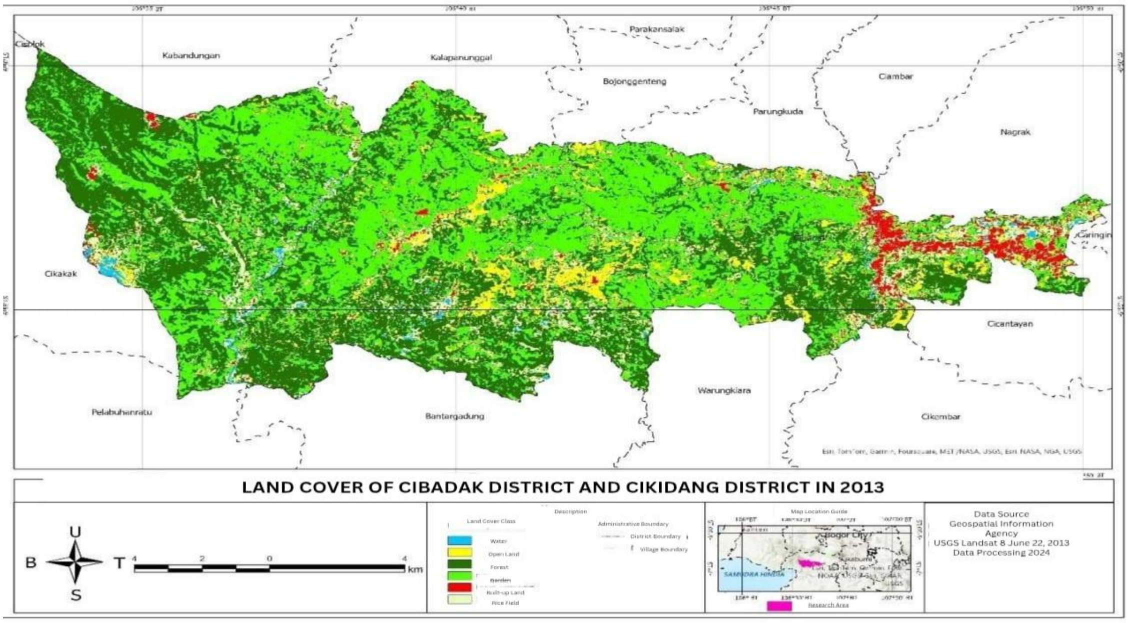

Fig. 2. Land cover map of Cibadak Sub-District and Cikidang Sub-District in 2013

The accuracy test of land cover data of Cibadak Subdistrict and Cikidang Subdistrict in 2013 was carried out with the training data based confusion matrix method, using 60 data samples. The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient (Latue, 2023). Land cover data for Cibadak and Cikidang sub-districts obtained from Landsat 8 image processing has an Overall Accuracy of 75% with a Kappa Coefficient of 0.7. It is included in the good category. The land cover of Kecamatan Cibadak and Kecamatan Cikidang in 2018 was dominated by forest covering an area of 68.97 km2 or 36.93% of the total area of Kecamatan Cibadak and Kecamatan Cikidang, a decrease of 4.85% from 2013. In Cibadak Sub-district, it is dominated by gardens covering an area of 17.82 km2 or equivalent to 29.18% of the Cibadak Sub-district area, a decrease of 9.92% from 2013, while in Cikidang Sub-district, it is dominated by forest cover covering an area of 68.98 km2 or equivalent to 43.94% of the Cikidang Sub-district area, a decrease of 1.56% from 2013 (Madakarah et al., 2019). In Kecamatan Cibadak, it is dominated by garden cover which dominates in the east bordering Kecamatan Cikidang. The built-up area in Kecamatan Cibadak and Kecamatan Cikidang in 2018 reached 8.7 km^2 or 4% of the total area of Kecamatan Cibadak and Kecamatan Cikidang, an increase of 0.6% from 2013 (Mansour et al., 2020). The built-up area of Kecamatan Cibadak and Kecamatan Cikidang is mostly located in Kecamatan Cibadak.

Table 1. Land cover accuracy test of Cibadak Sub-District and Cikidang Sub-District in 2013

		Field data						Total	User accuracy
		Water bodies	Forest	Open land	Built-up area	Rice fields	Plantation		
Classification results	Water bodies	8				1	1	10	80
	Forest		7				3	10	70
	Open land		2	8				10	80
	Built-up area				10			10	100
	Rice fields	1				8	1	10	80
	Plantation		4	2			4	10	40
Total		9	9	13	10	10	9	60	
Producer Accuracy		88.89	53.85	80	100	88.89	44.44		
Overall accuracy: 75%									
Kappa coefficient: 0.7									

The expansion of built-up areas from 2013 to 2018 is partly due to the fact that areas that were open land in 2013 in 2018 turned into built-up areas. The increase in built-up area occurred around the center of Cibadak Sub-district. The land cover of open land in Cibadak Sub-district and Cikidang Sub-district in 2018 has an area of 50.55 km^2 or 23.18% of the total area of Cibadak Sub-district and Cikidang Sub-district spread across Cibadak Sub-district and Cikidang Sub-district, this figure has increased dramatically by 16.58% from 2013 which was only 6.6% (Mebankerlang, 2023). Meanwhile, water is the land cover with the smallest area, which is 1.7 km^2 or 0.81% of the total area of Cibadak District and Cikidang District in 2018, this figure has decreased by 0.6 km2 (Nawangwulan et al., 2013). The area of plantation cover in Cibadak Sub-district and Cikidang Sub-district in 2018 reached 61.8 km^2 or 28.34% of the study area spread across the two sub-districts, a decrease of 23.9 km2 or 11% of the study area (Narulita et al., 2016). The area of rice field cover in 2018 was 14.73 km^2 or 6.75% of the total study area, a decrease of 2.47 km^2 or 1.14% from the area of rice fields in 2013. Land cover of rice fields, waters, forests, and gardens in 2018 decreased while open land cover and built-up land increased, especially open land which increased dramatically, due to the ongoing dry season, with imagery taken in September see figure 3.

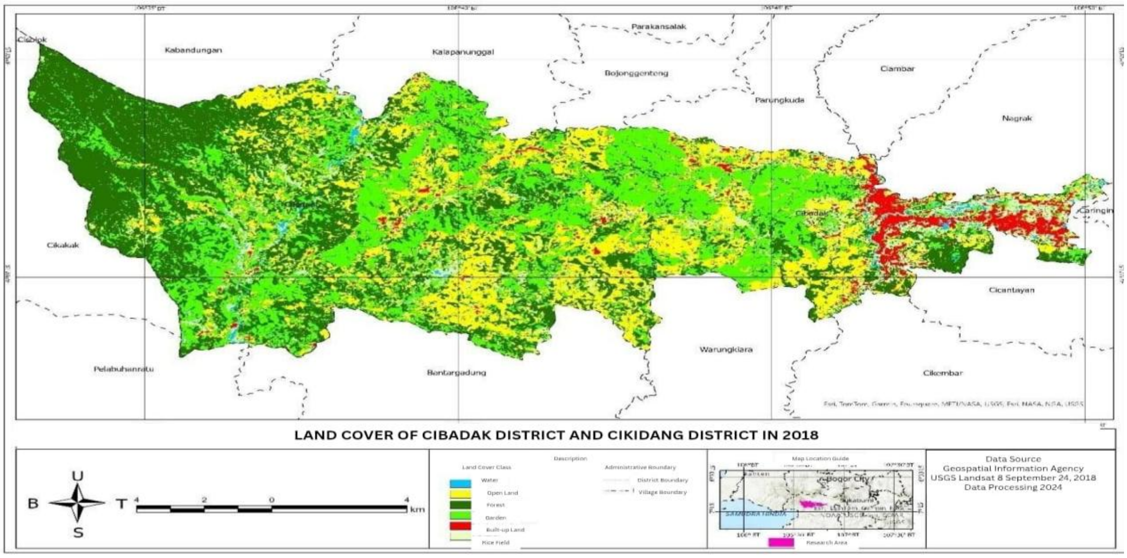

Fig. 3. Land cover map of Cibadak Sub-District and Cikidang Sub-District in 2018

The accuracy test of land cover data for Cibadak Sub-district and Cikidang Sub-district in 2018 was carried out using the confusion matrix method, using 60 data samples. The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient. Land cover data for Cibadak District and Cikidang District obtained from Landsat 8 image processing has an Overall Accuracy of 76.67% with a Kappa Coefficient of 0.72. For User Accuracy and Producer Accuracy can be seen in Table 2.

Table 2. Land cover accuracy test of Cibadak Sub-District and Cikidang Sub-District in 2018

		Field data						Total	User accuracy
		Water bodies	Forest	Open land	Built-up area	Rice fields	Plantation		
Classification result	Water bodies	7		1		2		10	70
	Forest		7				3	10	70
	Open land			7	1	2		10	70
	Built-up area				10			10	100
	Rice fields	1				8	1	10	80
	Plantation		1	2			7	10	70
Total		8	8	10	11	12	11	60	

Producer Accuracy	87.5	87.50	70.00	90.90909	66.67	63.64
Overall accuracy: 76.67						
Kappa coefficient: 0.72						

The accuracy test of land cover data for Cibadak Sub-district and Cikidang Sub-district in 2018 was carried out using the confusion matrix method, using 60 data samples. The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient (Pratama & Riana, 2022). Land cover data for Cibadak District and Cikidang District obtained from Landsat 8 image processing has an Overall Accuracy of 76.67% with a Kappa Coefficient of 0.72. The land cover of Kecamatan Cibadak and Kecamatan Cikidang in 2023 is dominated by forests, covering an area of 75.94 km^2 or 34.82% of the total area of the study area, forest cover dominates the northeast area of Kecamatan Cikidang. In Cibadak Subdistrict, the dominating land cover is gardens with an area of 22.64 km^2 or 32.91% of the area of Cibadak Subdistrict, while the dominating land cover in Cikidang Subdistrict is forest with an area of 66.4 km^2 or as wide as 44.47 of the total area of Cikidang Subdistrict. The area of open land cover in Cibadak District and Cikidang District in 2023 reached 60.71 km^2 or 27.84 of the total area of the study area (Ramakrishnan et al., 2023). The land cover area of built-up land in Cibadak Sub-district and Cikidang Sub-district in 2023 reached 9.63 km^2 or 4.42% of the total study area. The area of forest cover in Cibadak Sub-district and Cikidang Sub-district in 2023 reached 75.94 km^2 or 34.82% of the total study area. The area of plantation land cover in Cibadak and Cikidang sub-districts in 2023 reached 50.75 km^2 or 23.27% of the study area. Meanwhile, water is the land cover with the smallest area, which is 2.46 km^2 or 1.13% of the total research area (Rwanga & Ndambuki, 2017). The land cover of built-up areas in 2018 has increased, especially in the southern part of Cikidang District.

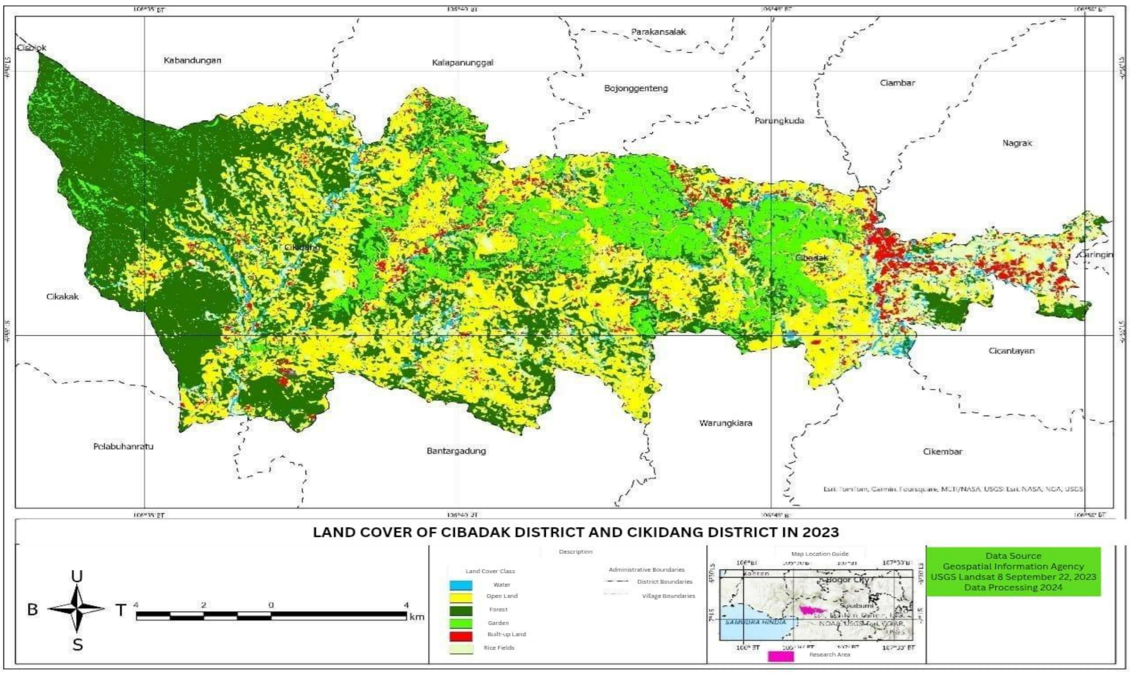

Fig. 4. Land cover map of Cibadak Sub-District and Cikidang Sub-District in 2023

The accuracy test of land cover data for Cibadak Sub-district and Cikidang Sub-district in 2023 was carried out using the confusion matrix method, using 60 data samples. The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient. Land cover data for Cibadak District and Cikidang District obtained from Landsat 8 image processing has an Overall Accuracy of 78.3% with a Kappa Coefficient of 0.74, in Table 3.5 included in the good category. For User Accuracy and Producer Accuracy can be seen in Table 3.

Table 3. Land cover accuracy test of Cibadak Sub-district and Cikidang Sub-district in 2023

Classification result	Field data: Water bodies	Forest	Open land	Built-up area	Rice fields	Plantation	Total water bodies	User accuracy forest
Water bodies	8		1	1			10	80
Forest		9	1				10	90
Open land			8			2	10	80
Built-up Area				9		1	10	90
Rice fields					10		10	100
Plantation		2	4		1	3	10	30
Total		8	11	14	10	11	60	
Producer Accuracy		81.82	57.14	90	90.91	50		
Overall accuracy: 78.3%								
Kappa coefficient: 0.74								

The accuracy test of land cover data for Cibadak Sub-district and Cikidang Sub-district in 2018 was carried out using the confusion matrix method, using 60 data samples (Sasky et al., 2017). The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient. Land cover data for Cibadak District and Cikidang District obtained from Landsat 8 image processing has an Overall Accuracy of 76.67% with a Kappa Coefficient of 0.72 (Taorui & Shibin, 2022). The land cover of Kecamatan Cibadak and Kecamatan Cikidang in 2023 is dominated by forests, covering an area of 75.94 km^2 or 34.82% of the total area of the study area, forest cover dominates the northeast area of Kecamatan Cikidang. In Cibadak Subdistrict, the dominating land cover is gardens with an area of 22.64 km^2 or 32.91% of the area of Cibadak Subdistrict, while the dominating land cover in Cikidang Subdistrict is forest with an area of 66.4 km^2 or as wide as 44.47 of the total area of Cikidang Subdistrict. The area of open land cover in Cibadak District and Cikidang District in 2023 reached 60.71 km^2 or 27.84 of the total area of the study area. The land cover area of built-up land in Cibadak Sub-district and Cikidang Sub-district in 2023 reached 9.63 km^2 or 4.42% of the total study area (Utomo et al., 2017). The area of forest cover in Cibadak Sub-district and Cikidang Sub-district in 2023 reached 75.94 km^2 or 34.82% of the total study area. The area of plantation land cover in Cibadak and Cikidang sub-districts in 2023 reached 50.75 km^2 or 23.27% of the study area. Meanwhile, water is the land cover with the smallest area, which is 2.46 km^2 or 1.13% of the total research area. The land cover of built-up areas in 2018 has increased, especially in the southern part of Cikidang District.

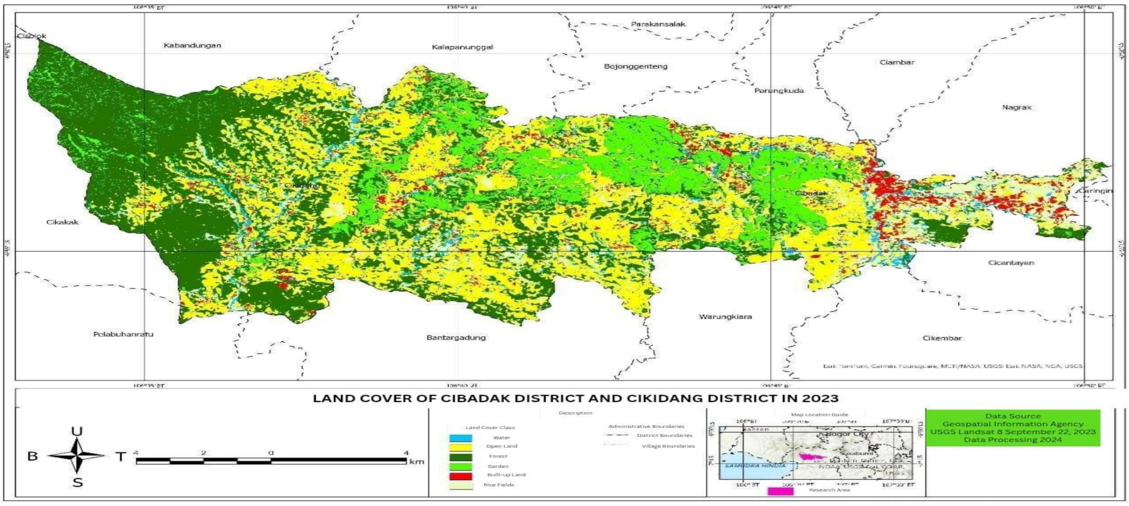

Fig. 5. Land cover map of Cibadak Sub-District and Cikidang Sub-District in 2023

The accuracy test of land cover data for Cibadak Sub-district and Cikidang Sub-district in 2023 was carried out using the confusion matrix method, using 60 data samples. The resulting accuracy values are User Accuracy, Producer Accuracy, Overall Accuracy and Kappa Coeficient. Land cover data for Cibadak District and Cikidang District obtained from Landsat 8 image processing has an Overall Accuracy of 78.3% with a Kappa Coefficient of 0.74, included in the good category (Wahyunto et al., 2006). Based on the results of Landsat 8 image processing, the land cover of Cibadak Sub-district and Cikidang Sub-district from 2013, 2018, and 2023 continues to change (Wang et al., 2020). The area of open land in Cibadak Sub-district and Cikidang Sub-district continues to increase followed by a decrease in other land cover classes, especially forest and garden classes (Wang et al., 2020). The percentage and area of land cover in Cibadak Sub-district and Cikidang Sub-district from 2013-2023 can be seen in table 4.

Table 4. Land cover area of Cibadak Sub-District and Cikidang Sub-District 2013-2023

Land cover	2013 Area (km^2)		2018 Area (km^2)		2023 Area (km^2)	
	Cibadak	Cikidang	Cibadak	Cikidang	Cibadak	Cikidang
Water bodies	0.64	1.63	0.88	0.87	1.43	1.03
Open land	5.10	9.30	15.64	34.96	18.58	42.13
Forest	19.62	71.49	11.55	68.98	9.54	66.40
Plantation	23.89	61.82	17.82	43.98	12.65	38.12
Built-up area	5.34	2.07	6.94	1.75	7.52	2.10
Rice fields	6.51	10.69	8.26	6.46	11.38	7.22
Total	61.10	157.00	61.10	157.00	61.10	157.00

In 2013, 91.11 km^2 or 41.78% of the land cover in these two sub-districts was forest and decreased to 36.93% in 2018. The decrease in forest area was accompanied by a drastic increase in the area of open land cover class in 2018. In 2018, gardens in Cibadak and Cikidang sub-districts were mostly classified as open areas because the gardens were not in a vegetated condition. The increase in the area of open land is also influenced by the conversion of land use functions that previously had a high vegetation density such as forests into garden land use which has a lower vegetation density than in previous years, in the process of becoming garden land cover, forest land cover is deforested and becomes open land cover first before becoming garden land cover (Wang et al., 2021).

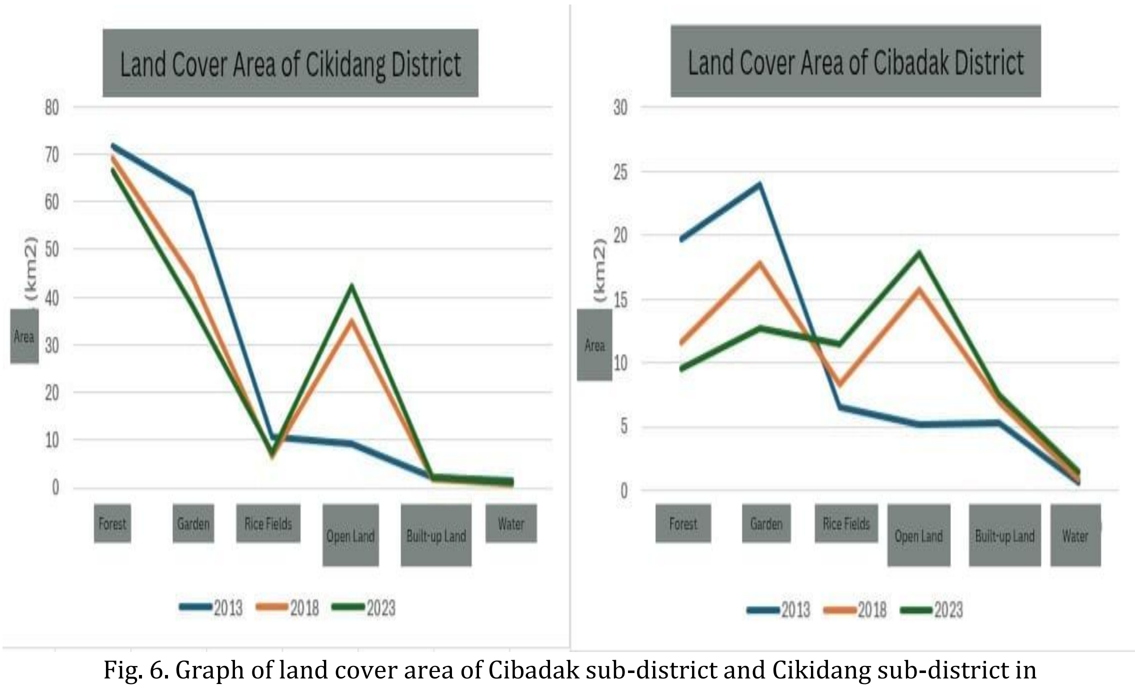

Fig. 6. Graph of land cover area of Cibadak sub-district and Cikidang sub-district in 2013, 2018, and 2023

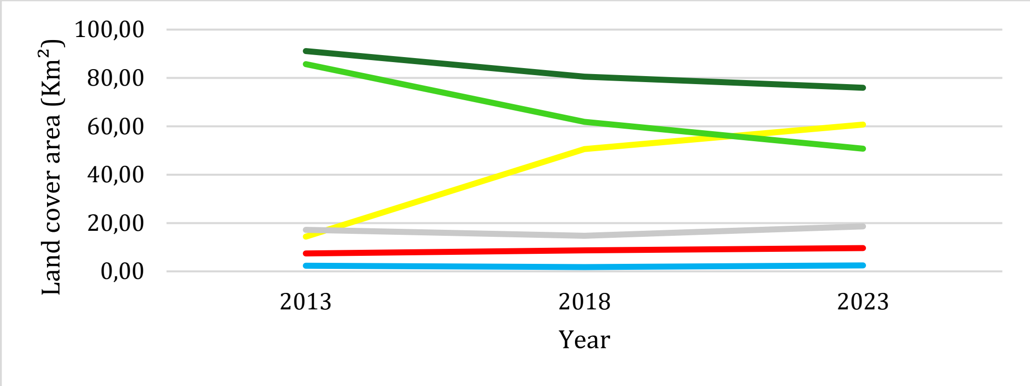

Fig. 7. Percentage of land cover area of Cibadak Sub-District and Cikidang Sub-District in 2013, 2018, and 2023

The area of forest and garden land cover in Cibadak Sub-district and Cikidang Sub-district from 2013 to 2023 decreased. This occurred in tandem with an increase in the area of open land in Cibadak Sub-district and Cikidang Sub-district. Land cover of water bodies in Cibadak Sub-district and Cikidang Sub-district tended to be stable from 2013-2023. Land cover of built-up areas in Cibadak Sub-district and Cikidang Sub-district continued to increase from 2013 to 2023. The graphical changes in land cover area of Cibadak Sub-district and Cikidang Sub-district in 2013-2023 can be seen in Figure 5 and the percentage of land cover area of Cibadak Sub-district and Cikidang Sub-district in 2013-2023 can be seen in figure 6 and 7.

3.2 Land surface temperature (LST) in 2013, 2018, and 2023

Based on data processing of Landsat 8 images recorded on September 10, 2013, the Land Surface Temperature of Cibadak and Cikidang sub-districts ranged from 16.86-45.95°C. The LST of Cibadak District and Cikidang District in 2013 was dominated by the medium LST class with an area of 98.21 km^2 or 43.52% of the area of Cibadak District and Cikidang District, high LST class (30°C-35°C) covering 69.36 km^2 or 32.76% of the total area of the study area. The area included in the very low LST class has an area of 0.01 km^2, the low class has an area of 18.88 km^2. While the very high class has an area of 31.63 km^2. The spatial pattern of LST in Cibadak Sub-district and Cikidang Sub-district in 2013 can be related to the land cover. Areas with low and very low LST classes are in water and forest land cover. The medium class LST pattern is occupied by the garden and rice field land cover classes, and the high and very high LST classes are occupied by open land land cover and built-up areas.

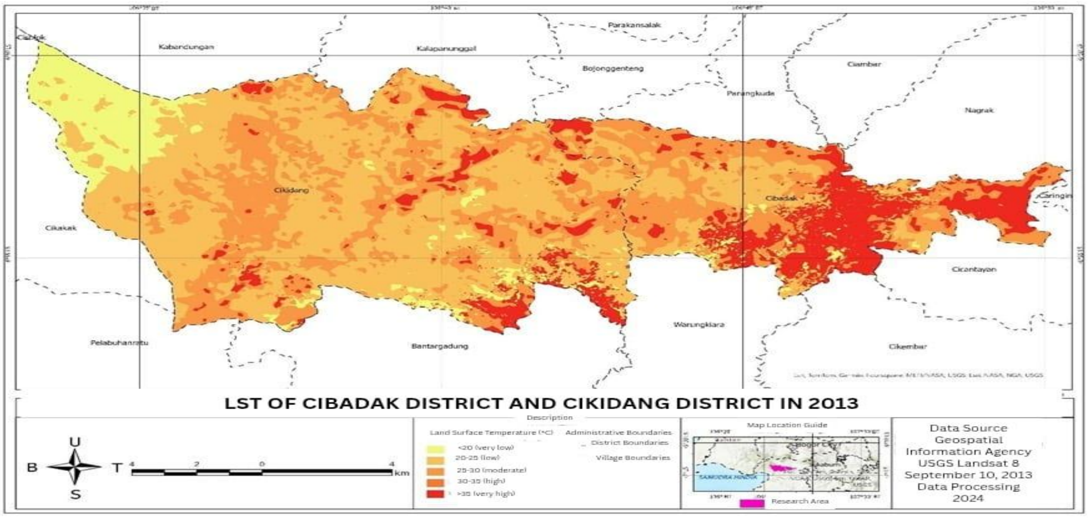

Fig. 8. Land surface temperature map of Cibadak Sub-District and Cikidang Sub-District in 2013

Based on data processing of Landsat 8 images recorded on September 24, 2018, the Land Surface Temperature of Cibadak District and Cikidang District ranged from 20.63-48.38°C, the lower limit of temperature increased by 3.77°C from 2013 which was only 16.86°C. The LST of Cibadak District and Cikidang District in 2018 was dominated by the very high LST class with an area of 123.66 km² or 56.71% of the area of Cibadak District and Cikidang District. In 2018, the medium LST class experienced a decrease in area because some rose to the high class. The high LST class (30-35°C) increased from 69.36 km² to 77.51 km² in 2018, because most of it rose to the very high class, the very high LST class experienced a drastic increase from 31.63 km² in 2013 to 123.66 km² in 2018. No area belonging to the very low ESG class was found in 2018. The increase in the area of high and very high LST classes in 2018 was in the land cover classes of built-up land, open land, and gardens which dominated the area of Cibadak Subdistrict and Cikidang Subdistrict, while waters and rice fields were dominated by the medium LST class and the low LST class was dominated by the forest land cover class (Wibisono et al., 2023).

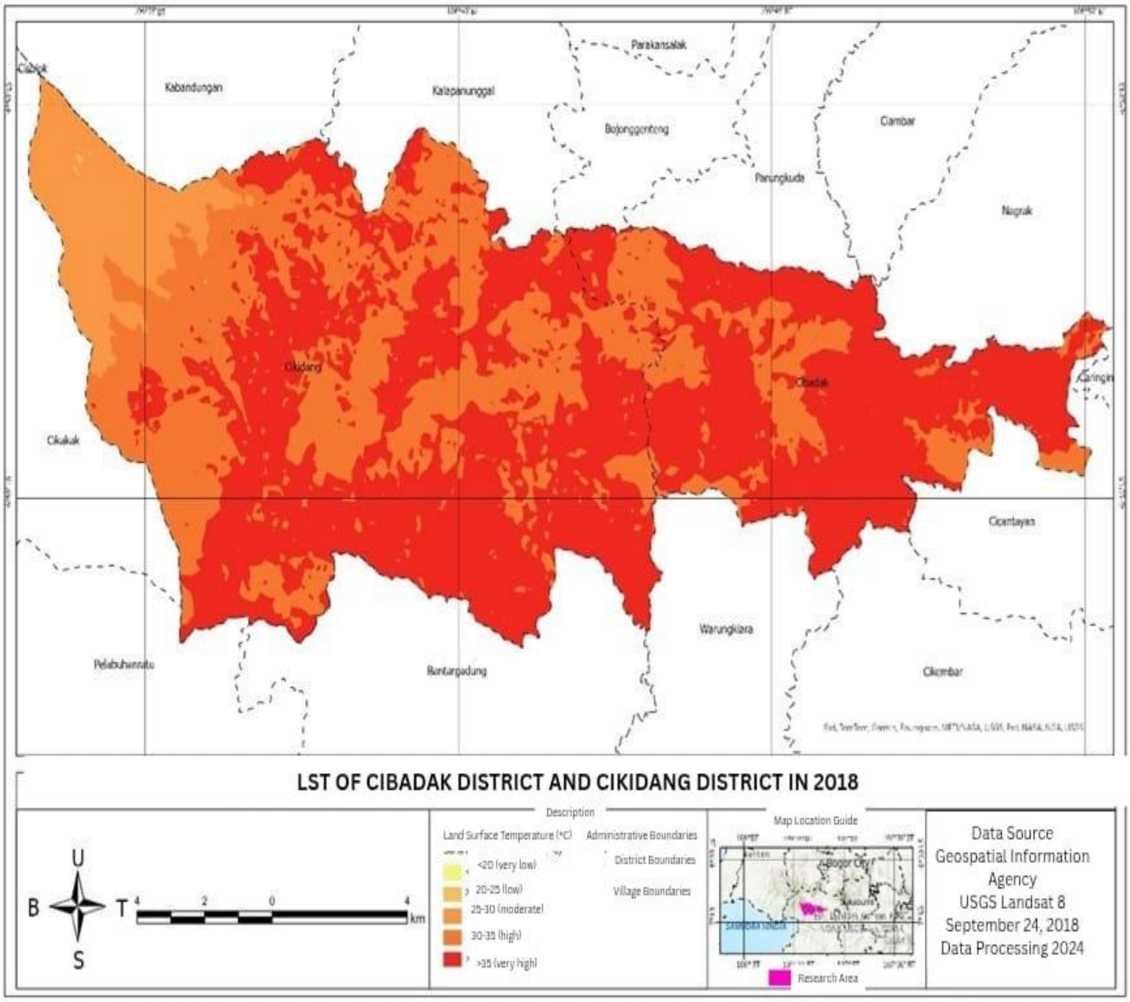

Fig. 9. Land surface temperature map of Cibadak Sub-District and Cikidang Sub-District in 2018

Based on data processing of Landsat 8 images recorded on September 6, 2023, the Land Surface Temperature of Cibadak District and Cikidang District ranges from 20.82-51.47°C. The LST of Cibadak District and Cikidang District in 2023 is dominated by very high LST with an area of 144.32 km² or 66.2% of the area of Cibadak District and Cikidang District. In 2023 the high LST class experienced a decrease in area because some rose to the very high class. The high LST class (30- 35°C) decreased from 77.51 km² in 2018, to 55.81 km² in 2023, because some of it rose to the very high LST class (>35°C). The very high ESG class (>35°C) increased from 123.66 km² to 144.32 km².

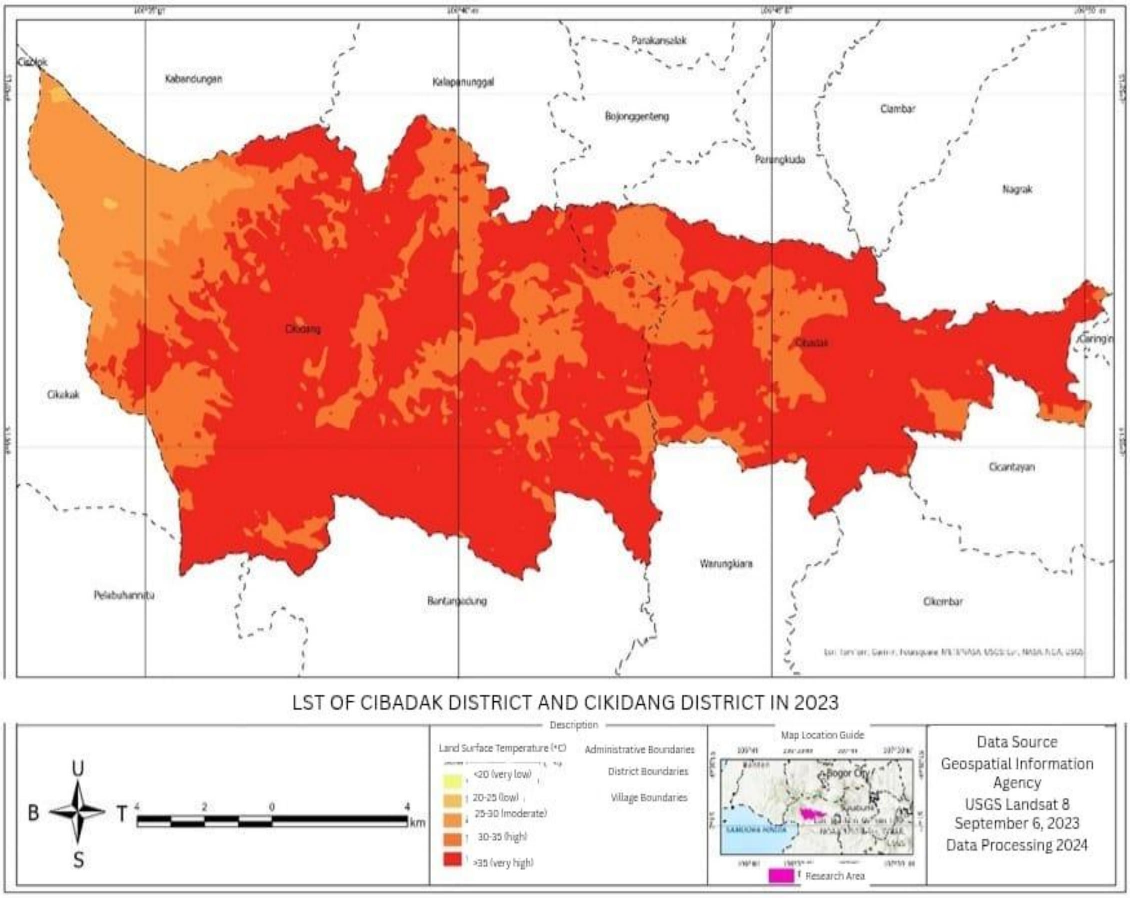

Fig. 10. Land surface temperature map of Cibadak Sub-District and Cikidang Sub-District in 2023

The area included in the medium LST class is 17.65 km^2 and the low LST class is 0.31 km^2, while the very low LST class is not found in 2023 (Zha et al., 2003). The increase in the area of high and very high LST classes in 2023 is in the land cover classes of built-up land, open land, and gardens which dominate the area of Cibadak Sub-district and Cikidang Sub-district. The medium and low LST classes follow the land cover pattern of forests, waters, and rice fields. While the high class LST pattern follows the land cover pattern of built-up areas and open land.

Table 5. The area of very high LST class increases every year reaching the highest area in 2023

LST (°C)	2013 Area (km^2)		2018 Area (km^2)		2023 Area (km^2)	
	Cibadak	Cikidang	Cibadak	Cikidang	Cibadak	Cikidang
<20	0.00	0.01	0.00	0.00	0.00	0.00
20-25	1.08	17.80	0.00	0.08	0.00	0.31
25-30	15.27	82.94	0.02	16.83	0.14	17.51
30-35	23.17	46.19	15.41	62.17	15.16	40.65
>35	21.57	10.06	45.67	77.92	45.80	98.52
Total (km^2)	61.10	157.00	61.10	157.00	61.10	157.00

Land Surface Temperature data from Landsat 8 image processing in 2023 and direct measurement data were tested and obtained an R value of 0.4485 and R2 0.2011. These results show that the variation of LST data can be explained by direct measurement data by 20.11%. Between LST data and measurements there is a difference of 0.14-19.21°C. Very low-grade ESG was only found in 2013 and was not found in 2018 and 2023. Low-grade ESG continued to decrease from 2013-2023. Low-grade ESG in 2013 had the largest area compared to other years. The medium class LST experienced the same thing, namely a decrease in area in the following year. The area of a high class LST increased from 2013 to 2018 and decreased in 2023 because some of it shifted to the very high LST class.

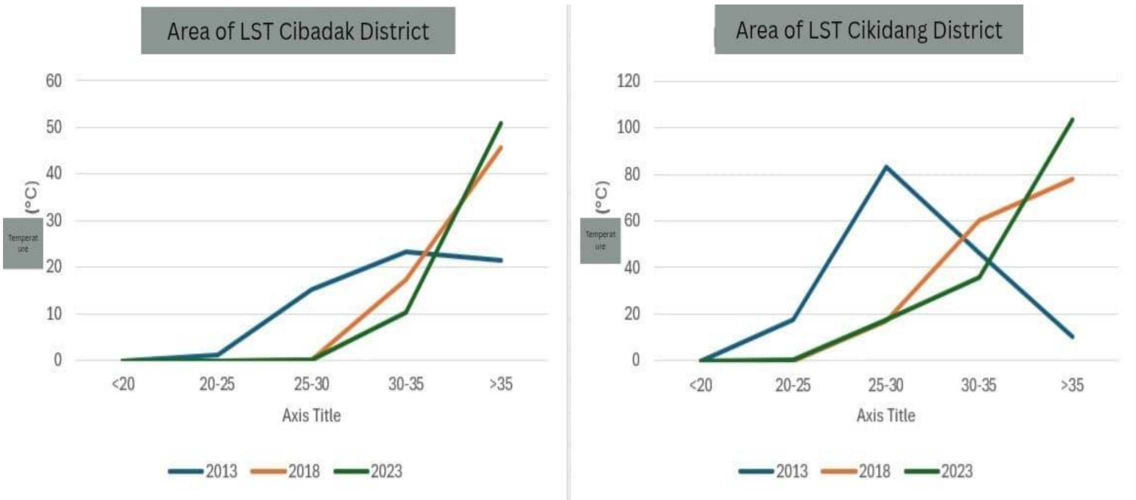

Fig. 11. Graph of LST area of Cibadak Sub-district and Cikidang Sub-district 2013-2023

The increase in open land area in Cibadak Sub-district and Cikidang Sub-district in 2013-2023 was followed by an increase in the average LST of Cibadak Sub-district and Cikidang Sub-district by 7.76°C. Each year the built-up land cover has the highest average LST compared to other land covers. For other land cover types, the average LST of each land cover also increased. The increase in the average LST value of built-up land cover is 6.27°C. Garden land cover in Cibadak Sub-district and Cikidang Sub-district experienced an increase in average LST of 5.58°C. Rice field land cover in Cibadak District and Cikidang District experienced an average increase in LST of 9.75°C. Forest land cover in Cibadak District and Cikidang District became the land cover with the smallest average LST among other land covers and experienced an average increase in a LST of 5.92°C. Waters experienced an average increase in LST of 8.44°C, when compared to the average LST on other land cover types, waters experienced the highest average increase in LST.

3.3 Relationship between land cover change and land surface temperature

Land cover change in Cibadak and Cikidang sub-districts from 2013 to 2023 has had an impact on the average LST increase of 7.76°C in that time period. In general, the LST of Cibadak District and Cikidang District from 2013 to 2023 continues to increase in area. The relationship between land cover change and LST can be seen through cross-sections (Zhang et al., 2023). Figure 5.17 shows the 2013, 2018, and 2023 land cover maps traversed by cross-section A-B.

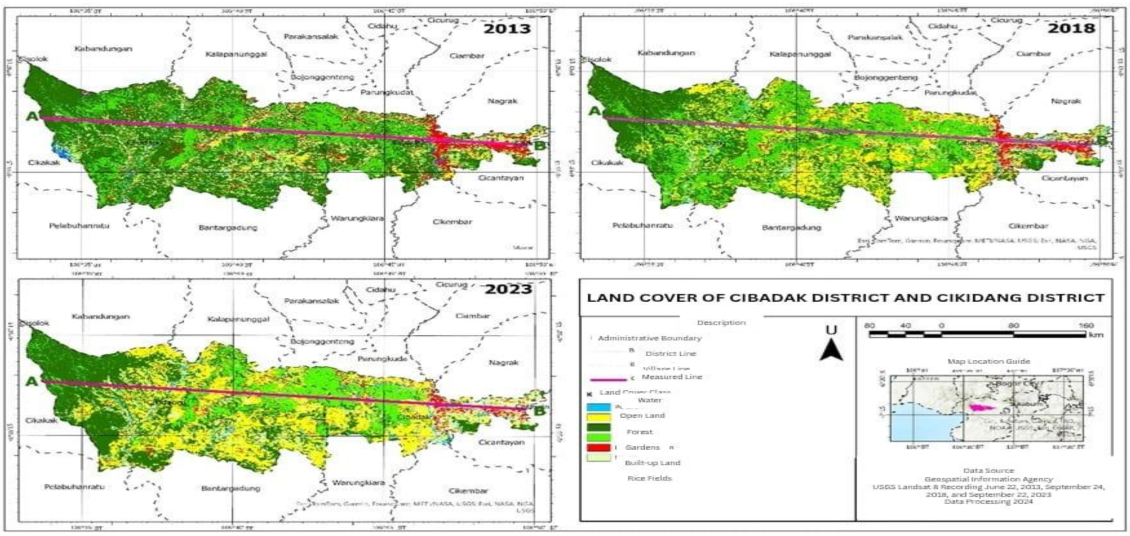

Fig. 12. Transect map on land cover in Cibadak Sub-District and Cikidang Sub-District

The reason for selecting these cross-sections is to represent each type of land cover that also experienced changes from 2013-2023. The cross-section illustrates some of the land cover types that are also changing, for example vegetation turning into open land and built-up land. The cross section also shows variations in the temperature crossed by the track line from year to year, indicating a change or upward trend in surface temperature in the area crossed by the cross section. From the extraction of the cross-section, a graph of surface temperature variation along the line was produced.

In the cross section, it can be seen that there are fluctuations in land surface temperature based on the type of land cover. Basically, the cross-section patterns in 2013, 2018 and 2023 are relatively the same, there are only some significant changes at certain distances. The temperature will decrease in vegetated land cover areas consisting of forests and gardens with intervals between 24-32°C and increase to open land with interval values between 32-36°C in 2013, 2018 and 2023, and open land at temperatures above 40°C. So it can be seen the variation of surface temperature of land cover in Cibadak District and Cikidang District. Based on these cross-sections, it can be seen that changes in land surface temperature are related to changes in land cover. Land cover in the form of built-up land and open land has a high temperature. Meanwhile, land cover in the form of forests and gardens has a low temperature.

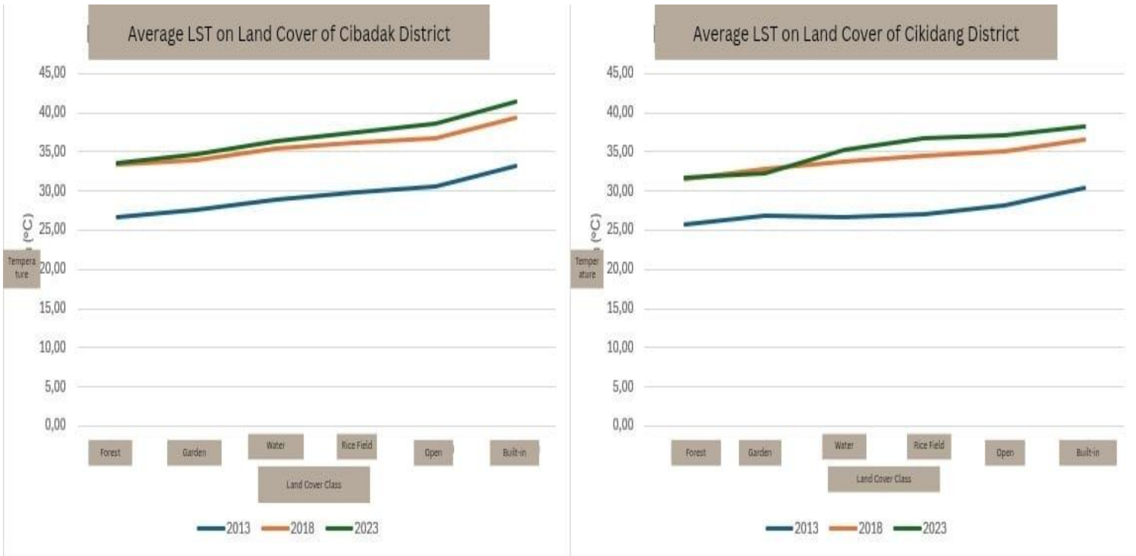

Fig. 13. Average land surface temperature graph based on land cover Cibadak Sub-district and Cikidang Sub-district 2013-2023

The increase in open land area in Cibadak Sub-district and Cikidang Sub-district in 2013-2023 was followed by an increase in the average LST of Cibadak Sub-district and Cikidang Sub-district by 7.76°C. Each year the built-up land cover has the highest average LST compared to other land covers. For other land cover types, the average LST of each land cover also increased. The increase in the average LST value of built-up land cover is 6.27°C. Garden land cover in Cibadak Sub-district and Cikidang Sub-district experienced an increase in average LST of 5.58°C. Rice field land cover in Cibadak District and Cikidang District experienced an average increase in LST of 9.75°C. Forest land cover in Cibadak District and Cikidang District became the land cover with the smallest average LST among other land covers and experienced an average increase in a LST of 5.92°C. Waters experienced an average increase in LST of 8.44°C, when compared to the average LST on other land cover types, waters experienced the highest average increase in LST.

4. Conclusions

Land cover change in Cibadak sub-district in the 2013-2018 period reached an area of 17.49 km² and Cikidang sub-district was 38.31 km². Land cover change in Cibadak Sub-district in the 2018-2023 period reached an area of 12.23 km^2, while land cover change in Cikidang in the 2018-2023 period reached an area of 24.97 km^2. Land cover change in Cibadak Sub-district, which is more urban in nature, is wider than Cikidang Sub-district, which is more rural in the 2013-2023 period.

Land Surface Temperature (LST) changes in a Cibadak Sub-district in 2013-2018 reached an area of 33.73 km^2, while in Cikidang Sub-district 134.82 km^2. Land Surface Temperature (LST) changes in Cibadak sub-district in 2018-2023 reached an area of 5.35 km^2, while in Cikidang sub-district it was 29.24 km^2. The lower LST class decreased and the higher LST class increased in area in the 2013-2023 period. The very low ESG class was only found in 2013 and was not found in 2018 and 2023. The low ESG class in 2013 had the largest area compared to the other years. The area of medium and high class ESG increased in the period 2013-2018 and decreased in 2023. The area of a very high class LST increased every year, reaching the highest area in 2023.

Land cover change has a high influence on the variation and increase of land surface temperature in 2013-2023. From the cross-sectional interpretation, it can be seen that land cover change has an impact on the increase of land surface temperature. From the statistical test results, it can be seen that land cover change has a strong to very strong relationship with LST change. Both variables have a positive correlation value. This means that the more the land cover area changes, the higher the LST value in that place.

Acknowledgement
The author would like to thank BMKG and Google Earth Engine for providing essential data and tools that supported the spatial and statistical analysis in this research.

Author Contribution
The author conducted the data collection, analysis, interpretation, and writing of the manuscript independently throughout the research process.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The author declares no conflict of interest.

Open Access

References

Achmadi, P. N., Dimyati, M., Manesa, M. D. M., & Rakuasa, H. (2023). Model Perubahan Tutupan Lahan Berbasis CA-Markov: Studi Kasus Kecamatan Ternate Utara, Kota Ternate. *Jurnal Tanah Dan Sumberdaya Lahan*, *10*(2), 451–460. https://doi.org/10.21776/ub.jtsl.2023.010.2.28

Afasel, D., Purnamasari, R., & Edwar, E. (2023). Klasifikasi Tutupan Lahan Menggunakan Supervised Machine Learning Pada Citra Satelit Menggunakan Google Earth Engine. *eProceedings of Engineering*, *9*(6). https://openlibrarypublications.telkomuniversity.ac.id/index.php/engineering/article/view/18996

Arvidson, T. (2002). *Personal correspondence, landsat 7 senior systems engineer*. Landsat Project Science Office, Goddard Space Flight Center.

BPS. (2014). *Kabupaten Sukabumi Dalam Angka Tahun 2014.* Badan Pusat Statistik Indonesia.

BPS. (2019). *Kabupaten Sukabumi Dalam Angka Tahun 2019*. Badan Pusat Statistik Indonesia.

BPS. (2024). *Kabupaten Sukabumi Dalam Angka Tahun 2024*. Badan Pusat Statistik Indonesia.

Damayanti, A., Khairunisa, F. I., & Maulidina, K. (2023). Impacts of Land Cover Changes on Land Surface Temperature using Landsat Imagery with the Supervised Classification Method. *Aceh International Journal of Science and Technology*, *12*(1), 116–125. https://doi.org/10.13170/aijst.12.1.30834

Desfandi, M., & Ruliani, R. (2022). Identifikasi Perubahan Lahan Hutan Menjadi Lahan Pertanian Di Desa Paya Dedep Kecamatan Jagong Jeget Kabupaten Aceh Tengah. *Jurnal Pendidikan Geosfer*, *7*(2), 168-179. https://doi.org/10.24815/jpg.v7i2.23722

Ermida, S. L., Soares, P., Mantas, V., Göttsche, F. M., & Trigo, I. F. (2020). Google earth engine open-source code for land surface temperature estimation from the landsat series. *Remote Sensing*, *12*(9), 1471. https://doi.org/10.3390/rs12091471

Ghozali, I. (2018). *Aplikasi Analisis Multivariate dengan Program IBM SPSS 25*. Badan Penerbit Universitas Diponegoro.

Guntara, I. (2016). *Analisis Urban Heat Island untuk Pengendalian Pemanasan Global di Kota Yogyakarta Menggunakan Penginderaan Jauh*. Fakultas Geografi UMS.

Handayani, H. (2007). *Identifikasi Perubahan Kapasitas Panas Kawasan Perkotaan Dengan Menggunakan Citra Landsat TM/ETM (Studi Kasus :Kodya Bogor)*. FMIPA IPB.

Healey, N. C., Taylor, J. L., & Auch, R. F. (2023). Assessment of public and private land cover change in the United States from 1985–2018. *Environmental Research Communications*, *5*(6). https://iopscience.iop.org/article/10.1088/2515-7620/acd3d8/meta

Hooijer, A., & Vernimmen, R. (2021). Global LiDAR land elevation data reveal greatest sea-level rise vulnerability in the tropics. *Nature communications*, *12*(1). https://www.nature.com/articles/s41467-021-23810-9

Ibochi, A. A., & Richard, J. U. (2020). Assessing the Accuracy of Different Supervised Classification Methods of Satellite Image*. Engineering & Technology Review, 1*(1), 1-10. http://dx.doi.org/10.47285/etr.v1i1.34

Julianto, F. D., Putri, D. P. D., & Safi'i, H. H. (2020). Analisis Perubahan Vegetasi dengan Data Sentinel-2 menggunakan Google Earth Engine (Studi Kasus Provinsi Daerah Istimewa Yogyakarta). *Jurnal Penginderaan Jauh Indonesia*, *2*(2), 13-18. https://journal.its.ac.id/index.php/jpji/article/view/262

Karandikar, A., & Agrawal, A. (2023). Performance analysis of change detection techniques for land use land cover. *International Journal of Electrical and Computer Engineering (IJECE)*, *13*(4), 4339. https://doi.org/10.11591/ijece.v13i4.pp4339-4346

Kunz, A. (2017). *Misclassification and kappa-statistic: theoretical relationship and consequences in application*. Ludwig-Maximilians-Universitat Munchen Institut fur Statistik.

Latue, P. C. (2023). Analisis Spasial Temporal Perubahan Tutupan Lahan di Pulau Ternate Provinsi Maluku Utara Citra Satelit Resolusi Tinggi. *Buana Jurnal Geografi, Ekologi dan Kebencanaan*, *1*(1), 31–38. https://doi.org/10.56211/buana.v1i1.339

Madakarah, N. Y., Wibowo, A., Manessa, M. D. M., & Ristya, Y. (2019). Variations of Land Surface Temperature and Its Relationship with Land Cover and Changes in IPB Campus, Dramaga Bogor 2013-2018. *In E3S Web Of Conferences*, *125*, 01004. https://doi.org/10.1051/e3sconf/201912501004

Mallick, J., Kant, Y., & Bharath, B. D. (2008). Estimation of land surface temperature over Delhi using Landsat-7 ETM+. *J. Ind. Geophys. Union*, *12*(3), 131-140. https://iguonline.in/journal/Volume_12-3.html

Mansour, S., Al-Belushi, M., & Al-Awadhi, T. (2020). Monitoring land use and land cover changes in the mountainous cities of Oman using GIS and CA-Markov modelling techniques. *Land Use Policy*, *91*. https://doi.org/10.1016/j.landusepol.2019.104414

Mebankerlang, N. (2023). Impact of land use land cover change on the land surface temperature: A case study of Shillong. *Indian Scientific Journal Of Research In Engineering And Management*. https://ijsrem.com/download/impact-of-land-use-land-cover-change-on-the-land-surface-temperature-a-case-study-of-shillong/

Narulita, S., Zain, A. F. M., & Prasetyo, L. B. (2016). Geographic Information System (GIS) application on urban forest development in Bandung City. *Procedia Environmental Sciences*, *33*, 279-289. https://doi.org/10.1016/j.proenv.2016.03.079

Nawangwulan, N. H., Sudarsono, B., & Sasmito, B. (2013). Analisis pengaruh perubahan lahan pertanian terhadap hasil produksi tanaman pangan di Kabupaten Pati tahun 2001–2011. *Jurnal Geodesi UNDIP*, *2*(2). https://doi.org/10.14710/jgundip.2013.2444

Nugroho, S. A., Wijaya, A. P., & Sukmono, A. (2016). Analisis Pengaruh Perubahan Vegetasi Terhadap Suhu Permukaan Di Wilayah Kabupaten Semarang Menggunakan Metode Penginderaan Jauh. *Jurnal Geodesi UNDIP*, *5*(1), 253–263. https://doi.org/10.14710/jgundip.2016.10597

Pal, S., & Ziaul, S. K. (2017). Detection of land use and land cover change and land surface temperature in English Bazar urban centre. *The Egyptian Journal of Remote Sensing and Space Science*, *20*(1), 125–145. https://doi.org/10.1016/j.ejrs.2016.11.003

Pavan, P., Varma, B. S. S., Asish, K., & Suneetha, M. (2023). Detection of Land Cover Changes using Satellite Image Classification Technique. *2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT)*, 1499–1505. https://doi.org/10.1109/ICSSIT55814.2023.10060992

Pratama, M. R., & Riana, D. (2022). Klasifikasi Penutupan Lahan Menggunakan Google Earth Engine dengan Metode Klasifikasi Terbimbing pada Wilayah Penajam Paser Utara. *JUPITER: Jurnal Penelitian Ilmu Dan Teknologi Komputer*, *14*(2), 637-650. https://doi.org/10.5281./5927/5.jupiter.2022.10

Rakuasa, H., & Pakniany, Y. (2022). Spatial Dynamics of Land Cover Change in Ternate Tengah District, Ternate City. *In Forum Geografi*, *36*(2). https://doi.org/10.23917/forgeo.v36i2.19978

Ramakrishnan, R., Rejuwan, S., Shaik, V. A., Lalit, T., Biju, G., Pillai, R., & Ponnusamy, P. (2023). *Classification and Contrast of Supervised Machine Learning Algorithms*. https://doi.org/10.1109/AISC56616.2023.10085338

Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. *International Journal of Geosciences*, *8*(4), 611. https://doi.org/10.4236//ijg.2017.84033

Sasky, P., Sobirin, S., & Wibowo, A. (2017). Pengaruh Perubahan Penggunaan Tanah Terhadap Suhu Permukaan Daratan Metropolitan Bandung Raya Tahun 2000–2016. *Prosiding Industrial Research Workshop and National Seminar*, *8*, 354-361. https://doi.org/10.35313/irwns.v8i3.767

Somae, G., Supriatna, S., Rakuasa, H., & Lubis, A. R. (2023). Pemodelan Spasial Perubahan Tutupan Lahan dan Prediksi Tutupan Lahan Kecamatan Teluk Ambon Baguala Menggunakan CA-Markov. *Jurnal Sains Informasi Geografi*, *6*(1), 10. https://doi.org/http://dx.doi.org/10.31314/jsig.v6i1.1832

Saurabh, K., & Shwetank, S. (2023). Change Detection Analysis of Land Cover Features using Support Vector Machine Classifier. *International Journal of Next-Generation Computing*, https://doi.org/10.47164/ijngc.v14i2.384

Sugiyono, S. (2008). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif dan Kualitatif R&D (6th ed.)*. Alfabeta.

Tan, K. C., Lim, H. S., MatJafri, M. Z., & Abdullah, K. (2010). Landsat data to evaluate urban expansion and determine land use/land cover changes in Penang Island, Malaysia. *Environmental Earth Sciences*, *60*(7), 1509-1521. https://doi.org/10.1007/s12665-009-0286-z

Taorui, T., & Shibin, Z. (2022). Land cover change evaluation based on eco-economic balance modeling. *Water Science & Technology: Water Supply*. https://doi.org/10.2166/ws.2022.419

Utomo, A. W., Suprayogi, A., & Sasmito, B. (2017). Análisis Hubungan Variasi Land Surface Temperature dengan Kelas Tutupan Lahan Menggunakan Data Citra Satelit Landsat (Studi Kasus: Kabupaten Pati). *Jurnal Geodesi Undip*, *6*(2), 71-80. https://doi.org/10.14710/jgundip.2017.16258

Wahyunto, A., Zainal, M., Priyono, Adi., & Sunaryo, S. (2006). Studi Perubahan Penggunaan Lahan di Sub Das Citarik, Jawa Barat dan Das Kaligarang, Jawa Tengah. *Prosiding Seminar Nasional Multifungsi Lahan Sawah*, *4*. https://doi.org/10.20961/region.v17i2.38660

Wang, L., Diao, C., Xian, G., Yin, D., Lu, Y., Zou, S., & Erickson, T. A. (2020). A summary of the special issue on remote sensing of land change science with Google earth engine. *Remote Sensing of Environment*, *248*, 112002. https://doi.org/10.1016/j.rse.2020.112002

Wang, S. W., Munkhnasan, L., & Lee, W. K. (2021). Land use and land cover change detection and prediction in Bhutan's high altitude city of Thimphu, using cellular automata and Markov chain. *Environmental Challenges*, *2*, 100017. https://doi.org/10.1016/j.envc.2020.100017

Wibisono, P., Miladan, N., & Utomo, R. P. (2023). Hubungan Perubahan Kerapatan Vegetasi dan Bangunan terhadap Suhu Permukaan Lahan: Studi Kasus di Aglomerasi Perkotaan Surakarta. *Desa-Kota: Jurnal Perencanaan Wilayah, Kota, dan Permukiman*, *5*(1), 148-162. https://jurnal.uns.ac.id/jdk/article/view/63639

Zha, Y., Gao, J., & Ni, S. (2003). Use of Normalized Difference Built-Up Index in Automatically Mapping Urban Areas from TM Imagery. *International Journal of Remote Sensing*, *24*(3), 583-594. https://doi.org/10.1080/01431160304987

Zhang, Y., Li, X., Zhang, K., Wang, L., Cheng, S., & Song, P. (2023). A Simple Real LST Reconstruction Method Combining Thermal Infrared and Microwave Remote Sensing Based on Temperature Conservation. *Remote Sensing*, *15*(12), 3033. https://doi.org/10.3390/rs15123033

Biography of Author

Muhammad Annas Fathoni, Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, West Java 16424, Indonesia.

- Email: muhammad.annas@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A