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# Changes in land use impacted air temperature in Bekasi Regency

Okta Nindita Priambodo[a], Ade Wachjar[a], Anugerah Rafi Pratama[b], Muhammad Sahfitri[b]

[a] Lecturer in the Palm Oil Processing Technology Study Program, Vocational Faculty, Institut Teknologi Sains Bandung, Kota Deltamas, 17530, Indonesia
[b] Palm Oil Processing Technology Study Program, Institut Teknologi Sains Bandung, Kota Deltamas, 17530, Indonesia

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**Corresponding Author:**
Okta Nindita Priambodo
Lecturer in the Palm Oil Processing Technology Study Program, Vocational Faculty, Institut Teknologi Sains Bandung;
Phone: +6285159299291
Email: oktaninditapriambodo@gmail.com

***Abstract****. Indonesia is experiencing dynamic land change. One area in Indonesia that has experienced high land use change is Central Cikarang District. Landsat 9 image sensing and land cover data from the Ministry of Environment and Forestry show the increased temperature in the Central Cikarang District area since 2004. Based on the NDVI analysis, the residential area has increased, and the area of green vegetation has decreased. Analysis of temperature changes using satellite imagery also shows a wider distribution of hot temperatures in the 2004–2022 range. From the two data analyses that were carried out, a regression test was carried out to determine the correlation between air temperature and vegetation density. The results of the regression test obtained an R2 value of 7.2%. It is also known that the value of the regression coefficient is negative, which means that the correlation of the two data is inversely proportional. So this research analyzes changes in land cover to changes in temperature.*

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## INTRODUCTION

Changes in land cover can occur due to large developments in cities or districts in Indonesia. Changes in land cover can be caused by converting vegetation land to non-vegetation (Zaitunah et al. 2021). Bekasi Regency is an area that has experienced significant changes in land cover due to a very high population increase and continues to develop as an industrial and office area. The population of Bekasi Regency in 2003 was 1,877,414 people; in 2018, it jumped to 3,500,023 people (BPS 2018).

Population growth and urbanization rates are generally in line with increasing air temperatures (Dede et al. 2019). The trend of global surface temperatures in the last 50 years (1956–2006) has increased 2-fold, namely 0.013 °C/year and also predicts that in 2,100 there will be an increase in the earth's surface temperature on average between 1.8–4.0 °C (IPCC 2007). As one of the regions of Bekasi Regency, Central Cikarang District is also experiencing rapid development. It resulted in land conversion in Central Cikarang District. The land, originally a green open area, was converted into a residential and industrial area. In addition, the increasing air temperature in Central Cikarang District is further exacerbated by the pollution produced by industry.

Land cover change is a significant source of atmospheric carbon dioxide ($CO_2$) (Jiao et al. 2010). The increase in carbon dioxide gas is due to the loss of green open areas that absorb carbon dioxide gas. Increasing Carbon Dioxide ($CO_2$) cause global warming (Jatnika and Zuhair 2019). The impact of global warming is an increase in temperature or air temperature (Pramudiysari et al. 2021). Weng et al. (2004), estimated changes in surface temperature due to the expansion of urban areas by combining GIS (Geographic Information System) data with Landsat imagery.

Nadira et al. (2019) researched land cover changes to the urban heat island phenomenon in Cikarang Utara district, Bekasi district from 2007–2018 using Landsat 8 and 5 satellite imagery. This research discusses changes in land cover to air temperature in Central Cikarang District from June 2004–July 2013–July 2022 using Landsat 9 satellite imagery and Geospatial Information Agency data. Changes in land cover were obtained through NDVI, while air temperature estimates were obtained through data analysis. Therefore, this research aims to analyze changes in land cover in Central Cikarang District and to analyze changes in air temperature caused by changes in vegetation land cover in Central Cikarang District.

## METHOD

### Location and Time of Research

The research will be conducted at the Bekasi Regency government office, ITSB Campus, and Agricultural land in Cikarang Pusat District in September to December 2022. The types of variable data that will be used in this study are primary data and secondary data. Primary data is obtained directly from the field, while secondary data is obtained indirectly from the field. The primary data used is the coordinate data of the sample points in Cikarang Pusat Sub-District, totaling 15 coordinate points (Figure 1). The secondary data used is the administrative map of Bekasi Regency for 2020 which comes from data from the Geospatial Information Agency, Landsat 9 (9 July 2022) imagery data with path-row 122/64 in Bekasi Regency and land cover data from the Ministry of Environment and forestry for 2004 and 2013.

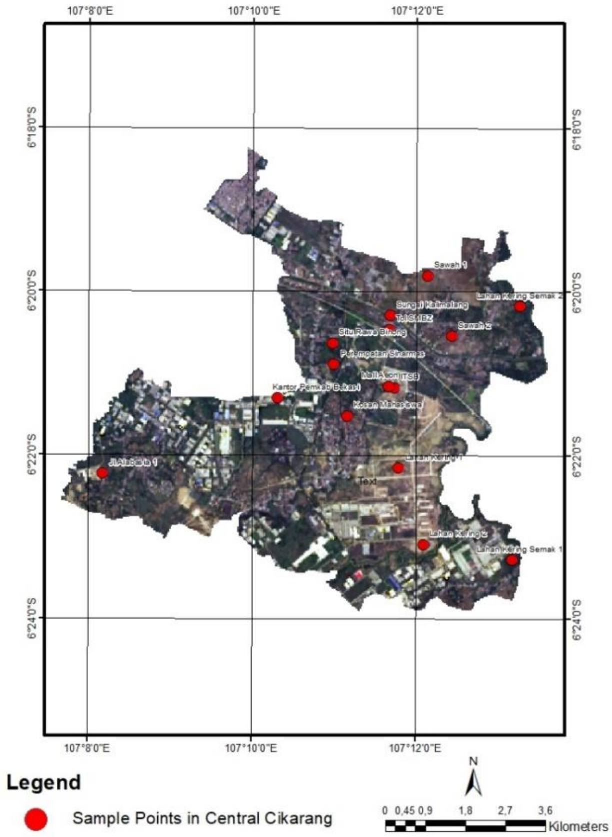


Figure 1 Selection of sample point coordinates

## Data Analysis

### *Guided Classification of Land Cover*

Guided classification is a classification carried out under the direction of an analyst (supervised), in which class grouping criteria are determined based on class signatures obtained through the creation of a sample area (training area). The training area digitizes several pixels with the same characteristics as the sample area (sample) to make specifications for certain areas that will be classified as land cover.

The combination of bands 6-5-4 on Landsat 9 is used to map NDVI (USGS 2013). NDVI with a value of 0.2–0.4 indicates mixed vegetation areas, values 0–0.2 indicate areas with minimal vegetation or built-up areas, and values below 0 represent bodies of water (Dede et al. 2019). From this value, it will be used in the guided classification of the study area into five classes: settlement, water, paddy fields, dry land, and dry bushland. The raster data resulting from the guided classification into polygon form is converted using the raster to polygon function in ArcMap 10.3 Software. The area can be known through the attribute table of several land class polygons.

### *Calculating Emissivity*

Normalized Difference Vegetation Index (NDVI) is a non-linear function that varies between –1 to 1. NDVI is the difference between the reflectance of the near-infrared and visible channels and is normalized by the sum of the two reflectance values. The NDVI value can be expressed in the form of the following equation (USGS 2013).

$$NDVI = (NIR - RED) / (RED + NIR)$$

where NIR is the digital number value on the near-infrared channel, and RED is the digital number value on the red channel. Furthermore, the value of the proportion of vegetation can be obtained using the following formula (USGS 2013).

$$Pv = [(NDVI - NDVImin) / (NDVImax - NDVImin)]^2$$

where the maximum and minimum values of NDVI can be obtained from statistical data on the distribution of NDVI in Bekasi Regency. NDVI and Pv parameters are used to calculate the emissivity value (ε). The formula for calculating the emissivity value is as follows (USGS 2013):

$$\varepsilon = 0.004\ Pv + 0.986$$

### *Calculating Surface Temperature*

Calculating surface temperature is the temperature emitted by an object and was the first element identified by a thermal satellite. The following are the steps for determining the surface temperature. According to the USGS (2013), the spectral radians value can be calculated using the following formula:

$$L\lambda = G_{rescale} \times Q_{cal} + B_{rescale}$$

where Lλ is the spectral radians value (W $m^{-2}$ $sr^{-1}$ ʒ$m^{-1}$), $G_{rescale}$ is the radiance multiplicative scaling factor, and $Q_{cal}$ is the digital number value for a particular channel, while $B_{rescale}$ is the radiance additive scaling factor. The brightness temperature value can be calculated by the following formula (USGS 2013):

$$Tb = K2 / \ln (K1 / L\lambda + 1) - 273.15$$

Tb is the brightness temperature in ˚C, K1, and K2 are the thermal conversion constants for a particular channel, and Lλ is the spectral radians value (W $m^{-2}$ $sr^{-1}$ ʒ$m^{-1}$). Surface temperature value (Ts) can be calculated by the following formula (USGS 2013):

$$Ts = Tb + (\lambda T / b\partial) \ln \varepsilon$$

Surface temperature (Ts) has several parameters, namely brightness temperature, emitted wavelength or λ of 11.5 µm, ∂ which is 0.01438 mK, and ε (surface emissivity value).

***Calculating Radiation Balance Components***

Estimating the net radiation value is the main objective in the calculation of the energy balance components. According to the USGS (2013), the radiation balance can be found by the equation:

$$qn = (RSin + RLin) - (RSout + RLout)$$

where Qn is net radiation ($Wm^{-2}$), RSin is shortwave radiation entering the earth ($Wm^{-2}$), RLin is long wave radiation entering the earth ($Wm^{-2}$), RSout is shortwave radiation coming out of the earth ($Wm^{-2}$), and RLout is long-wave radiation that comes out of the earth's surface ($Wm^{-2}$). The following are the steps in determining the components of the radiation balance. The short-wave radiation that escapes into the atmosphere and albedo can be calculated through the following equation using the imagery of channel 4, channel 3, and channel 2 (USGS 2013).

$$RSout = 3.14 \text{ x } L\lambda \text{ x } d^2 \text{ x } \lambda$$

$$\alpha = \frac{3.14 \; x \; L_\lambda \; x \; d^2}{ESUN_\lambda \; x \; Cos \; \Theta_s}$$

where d is the Earth-sun distance on a certain Julian date, Esun is a certain exoatmospheric solar irradiance channel ($Wm^{-2}\mu m^{-1}$), and θs is the zenith angle of the sun. The albedo and outgoing shortwave radiation are used to calculate the incoming shortwave radiation to the earth's surface. Here is the equation of incoming shortwave radiation (USGS 2013):

$$RSin = ROut / \alpha$$

Rlin has a very small value, so in the calculation of the radiation balance, the value of long-wave radiation entering the earth can be assumed to be zero. Furthermore, the long-wave radiation that comes out of the earth's surface is calculated based on the Stefan-Boltzmann law (USGS 2013):

$$RLout = \varepsilon \sigma Ts^4$$

where σ is the Stefan-Boltzmann constant with a value of $5.67 \times 10^{-8}$ $Wm^{-2}K^{-4}$, and Ts is the surface temperature (K).

***Calculating Sensible Heat***

Sensible heat (H) is felt the heat, namely the net radiant energy used in the process of heating air in the atmosphere by convection. The calculation of sensible heat uses the Bowen Ratio method as follows (USGS 2013).

$$H = (Qn - G) / (\beta + 1)$$

Bowen's ratio is the ratio between felt heat and latent heat. This ratio is relatively constant for each specific land cover so that the β value for water bodies is 0.1, the β value for vegetation is 0.5, and for built-up land is 4. The G value is the amount of soil heat flux (G) whose value can be calculated by the following formula (USGS 2013):

$$G = (T /s\alpha)\ (0.0038 + 0.0074\ \alpha 2)\ (1 - NDVI4)$$

### *Calculating Air Temperature*

Air temperature is a measure of the average kinetic energy of the movement of air molecules in the atmosphere. The air temperature value is influenced by surface temperature and sensible heat parameters. Here is the formula for calculating the air temperature value (USGS 2013):

$$Ta = Ts - [(ra.H)/(\rho a.Cp)]$$

where Ts is surface temperature ($^oC$), ra is aerodynamic density for each land cover, H is sensible heat ($W/m^2$), ρa is air density of 1.27 $kg/m^3$, and Cp is heat capacity of 1,004.

## RESULTS AND DISCUSSION

Cikarang Pusat is a sub-district located in Bekasi Regency, West Java Province. The area of Cikarang Pusat District is 47.6 $km^2$. The population growth rate in Cikarang Pusat District in 2010–2020 reached 1.67% (BPS 2021), requiring the government to carry out development. An increase in population can lead to increased development, especially development in the settlement sector (Laka et al. 2017). Rapid development in big cities can cause changes in land cover. Land cover is the physical surface of the land (Juniyanti et al. 2020). Changes in land cover in the Cikarang Pusat area in 2004, 2013, and 2022 can be seen in Figure 2 below.

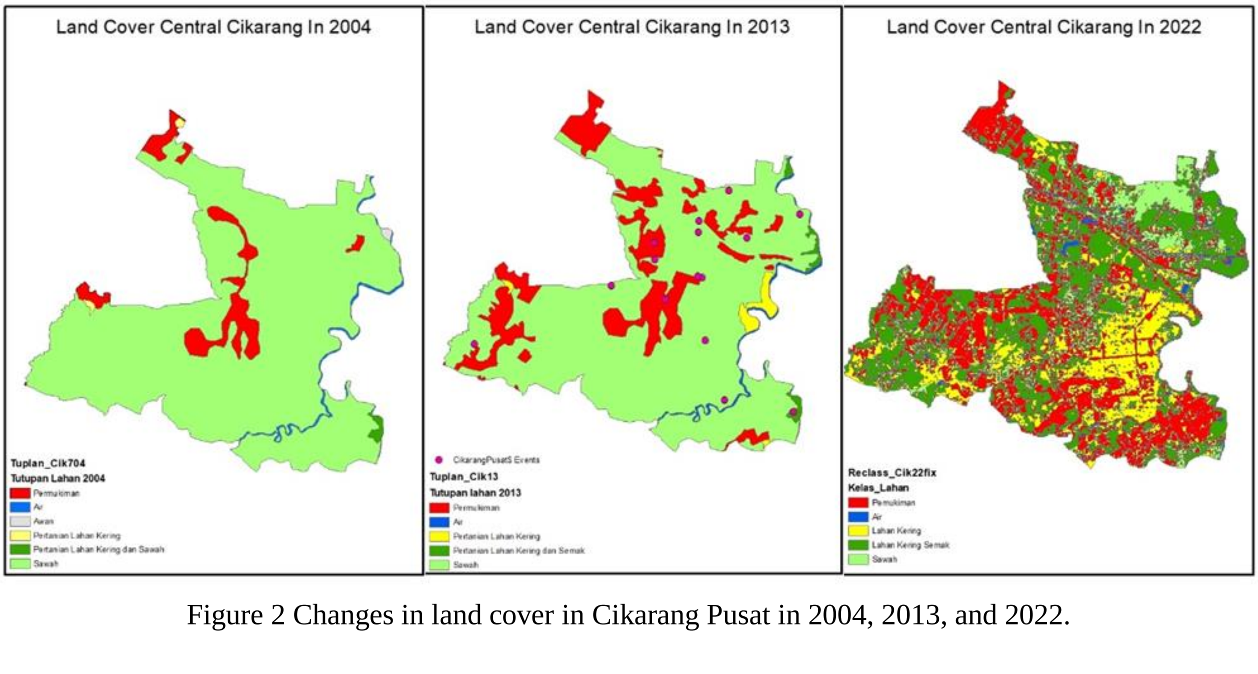


Figure 2 Changes in land cover in Cikarang Pusat in 2004, 2013, and 2022.

Changes in land cover in 2022 are due to the expansion of residential land cover areas. This expansion can be seen in Figure 2, where this expansion removes the paddy field cover. Whereas in 2004 and 2013, the ratio of paddy field land cover was greater than the residential land cover. Residential land cover is shown in red areas, water land cover is shown in blue areas, cloud land cover is shown in white areas, dry land agricultural land cover is shown in yellow areas, dry land agricultural land cover, and shrubs are shown in dark green areas, and paddy field land cover is shown in areas light green. Residential in question are not only residences but also industrial and non-industrial buildings. In 2013 and 2022, indicate an increase in the area of the red residential area. This is because economic development has begun to focus on non-agricultural sectors, such as investment in the industrial sector, infrastructure, hotels, restaurants, and other buildings (Putri 2015). Changes in land cover in Cikarang Pusat District related to changes in land use are shown in Table 1.

Land cover in Central Cikarang Subdistrict showed that in 2004 it was dominated by paddy field land cover of 4,902.70 ha and then dry shrub land cover of 355.80 ha. In 2013, some paddy fields were converted into residential land cover. Thus, land cover in 2013 was dominated by paddy field land cover of 4,250.10 ha followed by a residential land cover of 921.07 ha. Meanwhile, in 2022, paddy field cover will be less than in 2013 due to the conversion of paddy field cover to residential land cover. The conversion of paddy fields into settlements in Central Cikarang District was due to the sub-urbanization process (Sitorus et al. 2012). This land cover change can result in temperature changes in Central Cikarang District which can be seen in Figure 3.

Table 1 Land cover area (ha) in Cikarang Pusat in 2004, 2013, and 2022

| **Land cover** | **2004** | **2013** | **2022** |
|---|---|---|---|
| Water | 66.07 | 66.07 | 78.15 |
| Cloud | 8.16 | 0 | 0 |
| Paddy field | 4,902.70 | 4,250.10 | 669.37 |
| Dryland | 11.77 | 78.08 | 1,165.50 |
| Bush dry land | 355.80 | 49.90 | 1,641.28 |
| Residential | 20.75 | 921.07 | 1,794.63 |

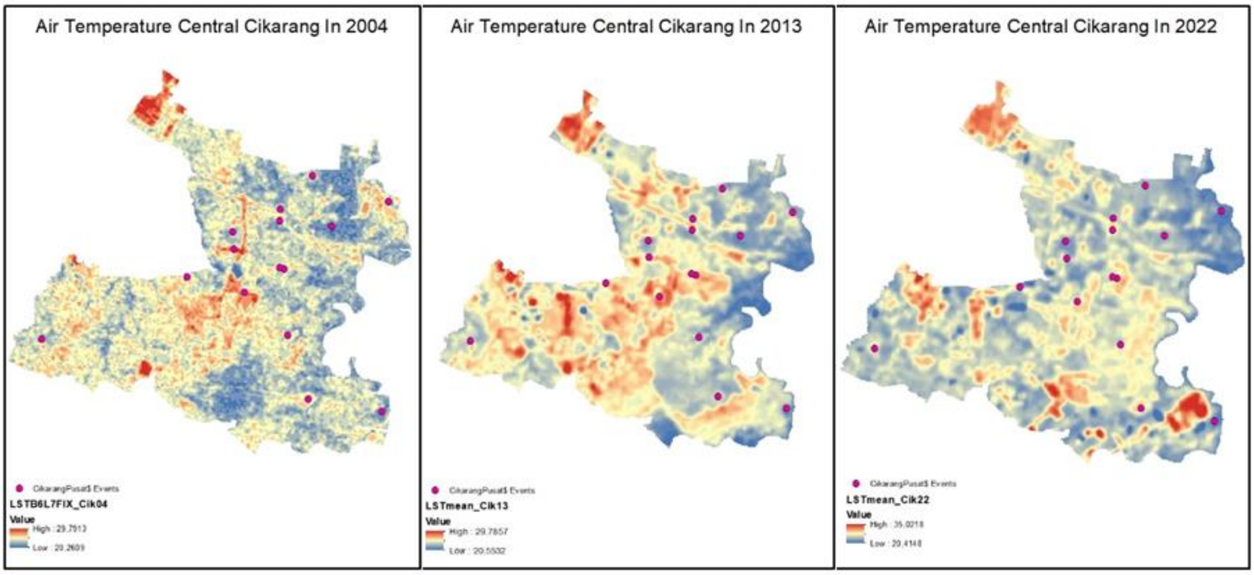


Figure 3 Changes in air temperature in Cikarang Pusat in 2004, 2013 and 2022

In the image above, temperature changes can be seen from the color differences. A bluish color indicates cool air temperature, a yellowish color represents normal air temperature, and a reddish color indicates hot air temperature. In 2004, the air temperature was dominated by cool and normal temperatures. This can be seen in the color map of the Central Cikarang area, which shows a lot of bluish and yellowish intensity. Whereas in 2013, the air temperature experienced a change where the air temperature was getting hotter. This can be seen from the increasing intensity of the reddish color and the decrease in the intensity of the bluish color. Built-up land has changed its type to built-up land or open land, causing temperatures to rise (Mukmin et al. 2016). In 2022, the air temperature will decrease again, which is marked by a reduced intensity of reddish color from 2013. Changes in temperature in Central Cikarang District can be seen in Table 2.

Table 2 Temperature changes in Cikarang Pusat in 2004, 2013, and 2022

| Location | Temperature change (ºC) | | |
|---|---|---|---|
| | **2004** | **2013** | **2022** |
| ITSB | 23.35 | 24.97 | 28.36 |
| Sinar Mas Quarter | 25.86 | 25.06 | 27.06 |
| Jl. Alabasia 1 | 23.35 | 24.05 | 27.29 |
| Aeon Mall | 24.30 | 25.02 | 27.17 |
| Student boarding house | 24.36 | 25.07 | 27.89 |
| SMBZ toll | 24.36 | 25.13 | 27.75 |
| Bekasi Regency Government Office | 24.36 | 24.81 | 26.52 |
| Dry Land 1 | 23.86 | 24.10 | 28.03 |
| Dry Land 2 | 23.35 | 24.05 | 27.94 |
| Shrub Dry Land 1 | 22.33 | 22.92 | 24.57 |
| Shrub Dry Land 2 | 22.84 | 23.26 | 24.83 |
| Situ Rawa Binong | 22.84 | 23.57 | 25.25 |
| Kalimalang River | 23.35 | 23.85 | 26.23 |
| Paddy field 1 | 22.84 | 23.45 | 25.88 |
| Paddy field 2 | 22.33 | 23.31 | 25.72 |
| Average | 23.58 | 24.17 | 26.70 |

Table 3 Changes in vegetation in Central Cikarang in 2004, 2013, and 2022

| Location | NDVI | | |
|---|---|---|---|
| | **2004** | **2013** | **2022** |
| ITSB | 0.102 | 0.289 | 0.142 |
| Sinar Mas Quarter | 0.149 | 0.130 | 0.130 |
| Jl. Alabasia 1 | 0.203 | 0.276 | 0.294 |
| Aeon Mall | 0.106 | 0.327 | 0.333 |
| Student boarding house | 0.240 | 0.225 | 0.218 |
| SMBZ toll | 0.019 | 0.132 | 0.063 |
| Bekasi Regency Government Office | 0.118 | 0.110 | 0.047 |
| Dry Land 1 | 0.197 | 0.381 | 0.161 |
| Dry Land 2 | 0.157 | 0.315 | 0.089 |
| Shrub Dry Land 1 | 0.304 | 0.300 | 0.466 |
| Shrub Dry Land 2 | 0.311 | 0.451 | 0.443 |
| Situ Rawa Binong | 0.359 | 0.071 | 0.001 |
| Kalimalang River | 0.080 | 0.067 | 0.056 |
| Paddy field 1 | 0.027 | 0.332 | 0.101 |
| Paddy field 2 | 0.259 | 0.368 | 0.163 |
| Average | 0.175 | 0.252 | 0.180 |

Changes in temperature from the 15 sample coordinates above show that there has been an increase in average temperature from 23.58 ºC in 2004, to 24.17 ºC in 2013, and 26.70 ºC in 2022. The temperature in residential areas is higher than in paddy fields. The process of photosynthesis absorbs $CO_2$ and evaporates water vapor $H_2O$, resulting in increasing latent heat fluxes (LE) and reduced sensible heat fluxes (H), hence reducing temperature (June 2022). While from 2013 to 2022, there will be a high increase in air temperature of 2.53 ºC. This happens because residential areas absorb and store radiation or have a higher albedo than paddy fields (Kontryana et al. 2021). If the wider the residential area, the more heat is stored, causing the air temperature to increase. Changes in vegetation area can be seen in Table 3.

From the two data above, then a correlation analysis was carried out between the NDVI values in Table 3 and the air temperature in Table 2 in Central Cikarang District. The analysis was carried out by means of a regression test. From the results of the analysis, the regression equation temperature = 25.5–3.57 NDVI value. Also obtained was a coefficient of determination of 7.2%. The regression coefficient value is negative, which means the correlation between the NDVI value and air temperature is inversely proportional. Where, the higher the NDVI value, the lower the air temperature and vice versa.

## CONCLUSION

The increase in air temperature in Central Cikarang District is evidenced by changes in land cover. The regression test results between the NDVI value and air temperature produce an equation temperature 25.5–3.57 NDVI value. This equation shows that the correlation between NDVI values and air temperature is inversely proportional. There has been a significant change in land cover from 2004 to 2022. It can be seen from the area covered by paddy fields from 4,902.70 ha to 669.37 ha and other land cover areas. This change in land cover causes a significant temperature rise. It can be seen from the average temperature 2004 of 23.58 ºC to 26.70 ºC in 2022. Therefore, there is a correlation between land cover changes and air temperature changes in Central Cikatrang District.

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