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Analysis of Changes in Vegetation Density and Its Effect on Surface Temperature in Kotamobagu City

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ABSTRACT

This study investigates the relationship between vegetation density change and its effect on surface temperature in Kotamobagu City during the period 2002–2022. Rapid urban development has led to land cover changes that potentially influence microclimatic conditions, especially land surface temperature (LST). This research employed a quantitative approach using remote sensing data by calculating the Normalized Difference Vegetation Index (NDVI) and LST. Data processing involved classification, correlation analysis using the R-table method, and was supported by field surveys for land validation. Results indicated that vegetation cover in 2002 was relatively low, covering 4,246.78 hectares. A slight increase occurred in 2012 (4,247.09 hectares), followed by a minor decline in 2022 (4,246.93 hectares). Meanwhile, surface temperatures showed a decreasing trend: from 17.4°C in 2002, to 9.4°C in 2012, and 8.7°C in 2022. The analysis also found a significant negative correlation between NDVI values and LST, indicating that areas with lower vegetation density tend to have higher surface temperatures. This correlation was supported by graphical analyses conducted for each year of observation. These findings highlight the impact of vegetation dynamics on urban temperature variation, emphasizing the importance of vegetation in regulating microclimates within rapidly developing urban areas such as Kotamobagu.

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1. INTRODUCTION

Kotamobagu City is one of the areas of North Sulawesi Province with an area of ± 68.06 km^2 or about 0.49% of the area of North Sulawesi Province. The pace of development today is an indicator that shows the progress of an area so that the government seeks to support development in all aspects, on the other hand, development opens up the possibility of changing environmental conditions from vegetated to open spaces or artificial materials such as concrete and asphalt. The abundance of artificial materials can increase the trapped solar radiation so that the temperature around it is higher. Changes in climate elements that occur are temperature, wind speed, radiation and clouds. Of the four elements that can be felt directly by living beings, temperature changes (Duka, 2018). The urbanization process can be seen not only as influenced by increasing population (Ayuni et al., 2023). Urban Heat Island is a phenomenon of increasing temperature that occurs in the city area compared to the surrounding area. Urban Heat Island is caused by reduced vegetation due to changes in rural land use to urban areas (Putra et al., 2022).

The development of a city can be seen physically from the increase in its population, the existence of increasingly dense buildings, and the increase in the population population, especially in settlements that tend to be more extensive, as well as the more complete city facilities that support urban social and economic activities (Uchrowi & Tjitropranoto, 2019). Although higher density can improve efficiency, there is a link between the increased risk of urban heat effects and higher density. This needs to be understood because the surface of the city is closed and heat-absorbing materials make urban areas warmer than inland areas (Giofandi & Sekarjati, 2020; Hilmy et al., 2021).

Kotamobagu City is one of the cities that is experiencing rapid development dynamics, the city is a place that has a function as a center of human activities. The development of various fields in urban areas is very rapid compared to other areas. This is closely related to the characteristics of urban areas that have a function as a center of government, economic activities, tourism and a vehicle for improving the quality of life. The great opportunity to improve the quality of life makes urban areas increasingly dense by people from suburban areas and people from villages who are trying their luck in the city. The increase in the population will cause an increasing need for housing which will consequently have an impact on changes in various fields. The change is very much felt like the change of a garden or city park into high-rise buildings, housing, highways and so on. The pace of development in the present is an indicator of the progress of a region so that the government seeks to support development in all aspects, on the other hand, development opens up the possibility of changing environmental conditions from vegetated to open spaces or artificial materials such as concrete and asphalt. The abundance of artificial materials can increase the trapped solar radiation so that the temperature around it is higher. Changes in climate elements that occur are temperature, wind speed, radiation and clouds (Bibi et al., 2018). Of the four elements that can be felt directly by living beings, it is a change in temperature.

The condition of vegetation in urban areas is generally much less than in suburban areas so that urban temperatures are higher than in the surrounding areas (Nofrizal & Hanif, 2018). The higher the density of vegetation in an area, the lower the temperature in that area, and vice versa. If the land surface temperature in urban areas is high, usually the area has a low vegetation density (Huda, 2018). Normalized Difference Vegetation Index (NDVI) is a method of obtaining images using vegetation greenness index or photosynthesis activity. NDVI is an index that displays the difference between the visible vegetation cover reflexes (Ariani et al., 2020; Hapsari et al., 2022). The use of the Normalized Difference Vegetation Index (NDVI)

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percentage obtained from the infrared and red channels is very relevant in providing information about the vegetation index. Peters in (Puspita & Luthfiya, 2023), the numerical equation between the infrared channel image and the red channel is processed to produce the vegetation index value.

Urbanization, which correlates with population and economic growth, affects land cover change. The redistribution of solar radiation, the contrast of surface radiation, and the air temperature in urban areas to the surrounding areas have been affected by the replacement of natural vegetation by surfaces that are difficult to experience evaporation and transpiration such as concrete, asphalt, and metal as a result of urban development (Suyadi et al., 2019). This is likely to happen in tandem with regional infrastructure improvements and increased human activity. Significant problems that arise in urban areas are directly correlated with the rapid expansion of urban areas (Nurzafira & Pisyam, 2024).

Changes in vegetation density are often associated with microclimate change and the urban heat island (UHI) phenomenon in urban areas. Several studies have shown that a decrease in vegetation density due to land-use change and urbanization can significantly increase surface temperatures. One study conducted by (Yin et al., 2019) in the city of Beijing found that the reduction of green areas leads to an increase in surface temperatures, especially in areas with high rates of urbanization. In Indonesia, a similar study has been conducted by (Maheng et al., 2024) analyzing changes in Temperature and Urban Rainfall Patterns in Jakarta: A Comprehensive Historical Analysis which shows that changes in land cover have a significant impact on the increase in temperature and rainfall intensity in urban areas.

Remote sensing methods can be used to analyze changes in surface temperature. Remote sensing is a technique to obtain information about an object, area, or phenomenon with the help of tools without direct contact with the object, area, or phenomenon (Kurniadin et al., 2022). With the help of remote sensing technology, the observation of current surface temperatures can cover more areas. One of the technologies based on remote sensing is the Landsat 8 OLI/TIRS satellite. Surface temperature treatment utilizes canals 10 and 11 in Landsat 8, and considers the results of analysis from the Normalized Difference Vegetation Index (NDVI) to obtain accurate results (Kevin et al., 2019).

Land surface temperature is an earth's surface phenomenon that can be observed by satellite remote sensing sensors (thermal channels). In contrast, the advantage of remote sensing lies in the temporal resolution, which allows satellites to record the same area at different times. This advantage can be used to observe changing phenomena of the earth's surface, such as changes in land cover, areas affected by disasters, changes in vegetation density, and changes in the earth's surface temperature (Himayah, 2019; Fahmi et al., 2023). Land function change can impact on decreasing green open space and land surface temperature (LST), which is one of the important parameters in environmental change (Aginta et al., 2021).

The focus of this research is Kotamobagu City, which is one of the regions in North Sulawesi Province. This region was chosen because it has experienced significant changes in land use, which has the potential to affect vegetation density and surface temperature. The analysis of changes in vegetation density was carried out using satellite image data covering several time periods, namely in the period 2002-2022. The purpose of this study is to analyze the vegetation density that occurred in Kotamobagu City in the period 2002-2022, analyze the temperature changes that occurred in Kotamobagu City in the period 2002-2022 and analyze

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the effect of changes in vegetation density on the surface temperature distribution that occurred in Kotamobagu City in the period 2002-2022.

Based on literature reviews, most of the research on the relationship between vegetation density and surface temperature focuses on large cities that have high rates of urbanization. Research in small or medium-sized urban areas with different demographic and developmental characteristics, such as Kotamobagu City, is still very rare. This creates a knowledge gap on how changes in vegetation density affect surface temperatures in cities with smaller development scales but experiencing rapid urbanization. The scope of this research is the entire administrative area of Kotamobagu City, which consists of various types of land cover such as settlements, open land, agriculture, and forests. This study uses data from several time periods 2002-2022 to analyze temporal changes in vegetation density and surface temperature.

The research uses the Land Surface Temperature (LST) method by utilizing Landsat 8 thermal band images. This LST method is a method used to determine and map the surface temperature distribution of a land cover or land use by utilizing the temperature and vegetation density (NDVI) parameters as a reference for the influence of the land use whether it is still vegetated or includes non-vegetation land (Fitriana et al., 2021).

2. METHODS

This research was conducted in the Kotamobagu City area, North Sulawesi. Based on the geographical location, Kotamobagu City is located between 124°15' 9.56" – 124° 21' 1.93"East Longitude and 0° 41' 16.29" - 0° 46' 14.8" North Latitude (Sakip, 2017) as shown in Figure 1.

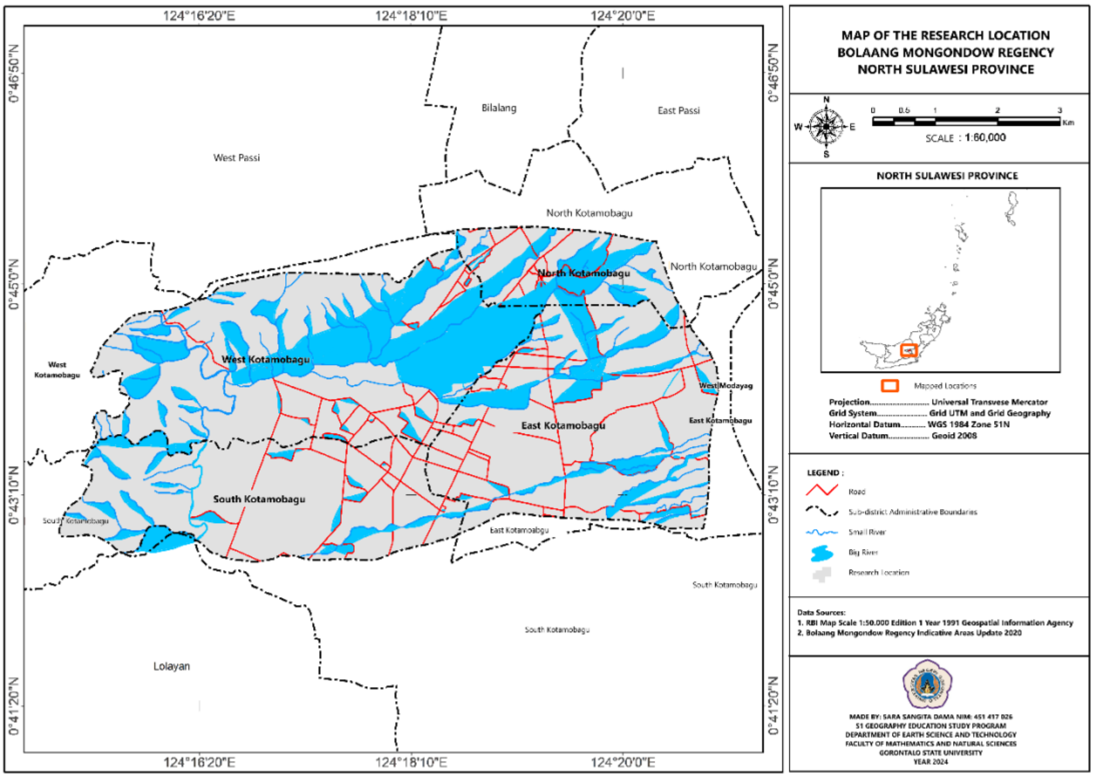

Figure 1. Map Research Location

This study uses a quantitative approach and then analyzed descriptively. The method used is a quantitative data analysis method carried out by calculating the NDVI formula, LST formula, classification and choreography of the R table with digital data processing and

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analysis techniques. A quantitative approach is used to interpret textual data and image data resulting from the data collection and processing process (Taherdoost et al., 2022). Descriptive analysis seeks to describe a model of relationships between variables by providing logical interpretation and analysis between these relationships (Fariz et al., 2020).

The subject of this study is the entire area of Kotamobagu City, which includes various types of land use such as settlements, urban, agricultural land, and forests. The characteristics of the research subjects include: Kotamobagu City Area: Covers the entire administrative area of Kotamobagu City, including sub-districts and sub-districts that differ in terms of vegetation density and land use. Variation in Vegetation Density: The study subjects had variations in vegetation density measured using the vegetation index (NDVI) of satellite imagery. Surface Temperature: The research subjects cover a variety of locations with varying surface temperatures, which are influenced by vegetation density as well as other factors such as land use and human activities.

The data collection technique in this study uses Landsat satellite image media path-row 121-65. The materials used are visible, near-infrared and medium-infrared wavelengths as well as thermal wavelengths in Landsat TM and OLI TIRS 2002-2022 satellite images for the Kotamobagu City area, North Sulawesi. Landsat satellite imagery data is obtained through the process of downloading image data through the glovis.usgs.gov website (Fahad et al., 2020). Landsat satellite imagery data has not been able to provide the information needed related to this research, so it requires further processes to obtain data through the image classification process. The classification process based on the technique is differentiated into manual/qualitative classification and quantitative classification. In qualitative classification, the grouping of pixels into a class is done manually by the interpreter based on basic elements that include color, shape, size, pattern, texture, shadow, location and association. The data used in this study consisted of primary and secondary data, where primary data was obtained based on primary surveys and field observations to validate land use maps and get an overview of field conditions.

Data Analysis Using Image Pre-Processing Before processing, improvements were made to the satellite image data, namely in the form of radiometric corrections and geometric corrections. Radiometric correction is carried out by a contrast sharpening process for image interpretation (Yilmaz et al., 2022). Geometric correction is carried out by the process of providing map coordinates on the image according to the projection system used (Pi et al., 2022). Subsequently, the conversion of OLI-TIRS landsat imagery to thermal data for the acquisition of surface temperature data, the conversion of spectral radiance (L to temperature. Conversion from satellite temperature to ground surface temperature (Landsat OLI/TIRS 2012, 2022) and Quantitative Classification to Obtain Vegetation Density Data (NDVI).

The analysis technique used in this study is Descriptive Analysis: Analyzing and visualizing the distribution of vegetation density and surface temperature in Kotamobagu City in the form of a thematic map. Correlation and Regression Analysis: Uses correlation analysis to measure the relationship between NDVI and surface temperature.

3. RESULTS AND DISCUSSION

3.1 Results of Analysis of Surface Temperature Data Acquisition

Land Surface Temperature (LST) data processing is produced by classification with 6 classes, namely, hot, slightly humid, normal, slightly cold or humid, cold and very cold or

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humid. In the 2002 LST competition, the lowest average temperature was obtained at 24.34°C and the highest value was at 34.53°C. Meanwhile, in 2012, the lowest temperature was obtained at 31.79°C and the highest value was at 34.93°C. In 2022, the lowest temperature was obtained at 22.66°C and the highest temperature was at 30.04°C.

Based on the results of the surface temperature comparison above, it can be seen in Figure 2 that in Kotamobagu City there was an increase in temperature from 2002 to 2012 by 12.49%, while from 2012 to 2022 there was a significant decrease in temperature by 8.58% due to reforestation efforts carried out by the government.

In accordance with the results of research conducted by Duka (2020), the pattern of surface temperature distribution in 1990, 2003 and 2017 is generally relatively different. In general, it can be concluded that changes in the pattern of surface temperature distribution in Gorontalo City are influenced by changes in land cover. The pattern of change in the distribution of surface temperature almost resembles the pattern of change in land cover. In addition to changes in land cover, planting patterns on agricultural lands of annual crops that can change at any time depending on the planting season or growth phase also affect vegetation characteristics which ultimately affect the surface temperature distribution pattern (Duka et al., 2020).

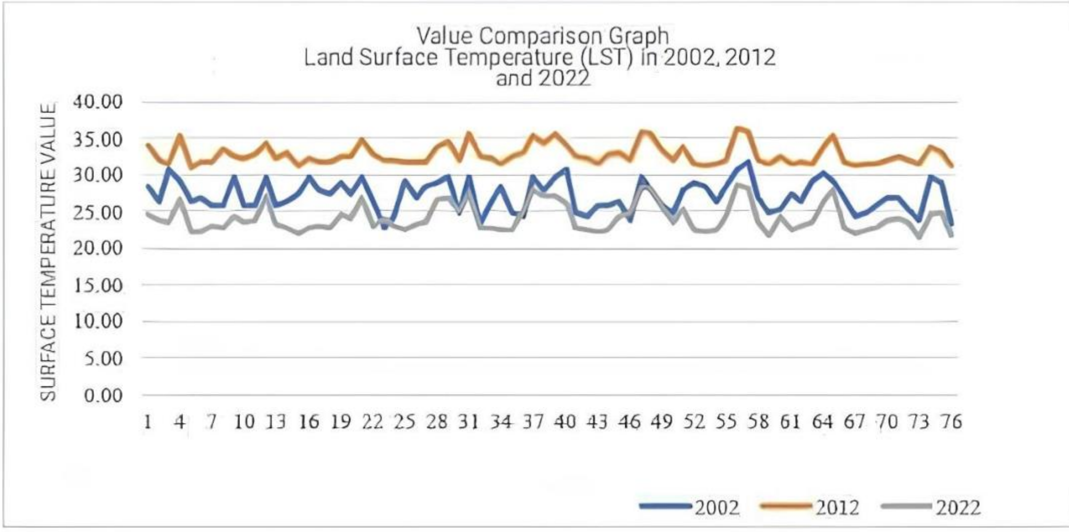

Figure 2. Comparison Chart of ESG Values in 2002, 2012 and 2022

In line with the results of research conducted by (Rinnanda, 2020) that vegetation density has changed in the last 20 years, the density of the vegetation index has changed from 0.75 to 0.60. The highest temperatures are found around areas with dense buildings and low vegetation, while the lowest temperatures are found in areas around hills and forests with dense vegetation. The correlation between vegetation density and vegetation temperature in Padang City has a negative relationship and the degree of relationship is low to strong, while the influence value varies. The results of research conducted by (Liu et al., 2024) produced spatially, wind farms are mainly clustered in three aggregation areas in the center. Further, wind farms increased nighttime LST, with a mean value of 0.23 °C, but had minor impacts on the daytime LST. Moreover, wind farms caused a decline in NPP, especially over forest areas, with an average reduction of 12.37 GC/m^2.

3.2 Results of Analysis of Vegetation Density Data

The Normalized Difference Vegetation Index (NDVI) data processing is classified into five

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classes, namely, non-vegetation, sparse vegetation, medium vegetation, dense vegetation and very dense vegetation. Based on the calculation of NDVI, the results varied in 2002 with the lowest vegetation density value of around -0.12 to 0.19 with a percentage of 11.29% and the highest value of around 0.48 to 0.62 with a percentage of 20.88%. Land use in that year showed a lot of land clearing or plantations around the city and settlement development.

In 2012, the vegetation density increased considerably, with the lowest NDVI value of around -0.12 to 0.19 with a percentage of 9.58% and the highest NDVI value of around 0.48 to 0.62 with a percentage of 27.49%. In 2022, the lowest NDVI value was around -0.12 to 0.19 with a percentage of 12.92% and a value of 0.48 to 0.62 with a percentage of 27.26%. Land cover in Kotamobagu that year was used for residential land use in urban areas which had begun to increase rapidly and land use for monthly crop plantations and annual crops also increased.

Changes in the area that occur are not always caused by the conversion of land from forests or mixed gardens, but are also influenced by planting patterns that can change at any time depending on the planting season or growth phase at the time of the date of coverage of the image data used. The area that is not fixed but relatively decreases from year to year is the area of forest land cover, although it is not possible to accurately estimate the change in area that occurs due to cloud cover around the area (Duka et al., 2020).

Based on the results of the comparison of vegetation density above, it can be seen in Figure 3 that there was a significant decrease in vegetation density in 2002, while in 2012 to 2022 there has begun to be an increase in vegetation density due to greening or efforts to increase vegetation density in Kotamobagu City.

Table 1. Minimum and Maximum Surface Temperatures in 2002, 2012 and 2022

LST	Suhu Permukaan (˚C)		
	Min	**Maks**	**Rata -rata**
2002	24.34	34.53	29.44
2012	31.79	38.06	34.93
2022	22.66	30.04	26.35

Source : Data analysis (2023)

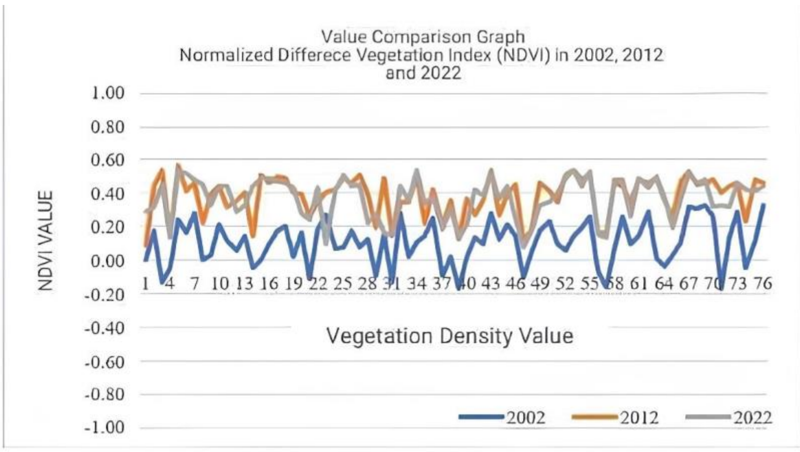

Figure 3. Comparison Chart of NDVI Values in 2002, 2012 and 2022

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In line with the research that has been conducted by (Ekawati, 2020) with the results of image processing which shows that the dominant land cover is agricultural areas spread across all sub-districts. The relationship between land surface temperature and land cover can be obtained through temperature correlation and NDVI. NDVI is used because from this NDVI value can indicate a certain land cover. The larger the NDVI, the greater the land cover will have a large vegetation density.

The correlation coefficient is 0.99 and is marked negative. This means that land cover with large vegetation cover (non-agricultural areas in the form of forests) has a lower temperature than land cover in the form of built-up land which has little vegetation cover and has an inverse relationship. Differences in vegetation value classification classes cannot be separated from vegetation canopy or land cover which then influences spectral reflections and then differences in infrared wave reflections, resulting in differences in classification class levels. Land cover in the form of residential areas will of course have different spectral reflections from land cover in the form of agricultural land or plantations (Rachmasya & Susilawati, 2024).

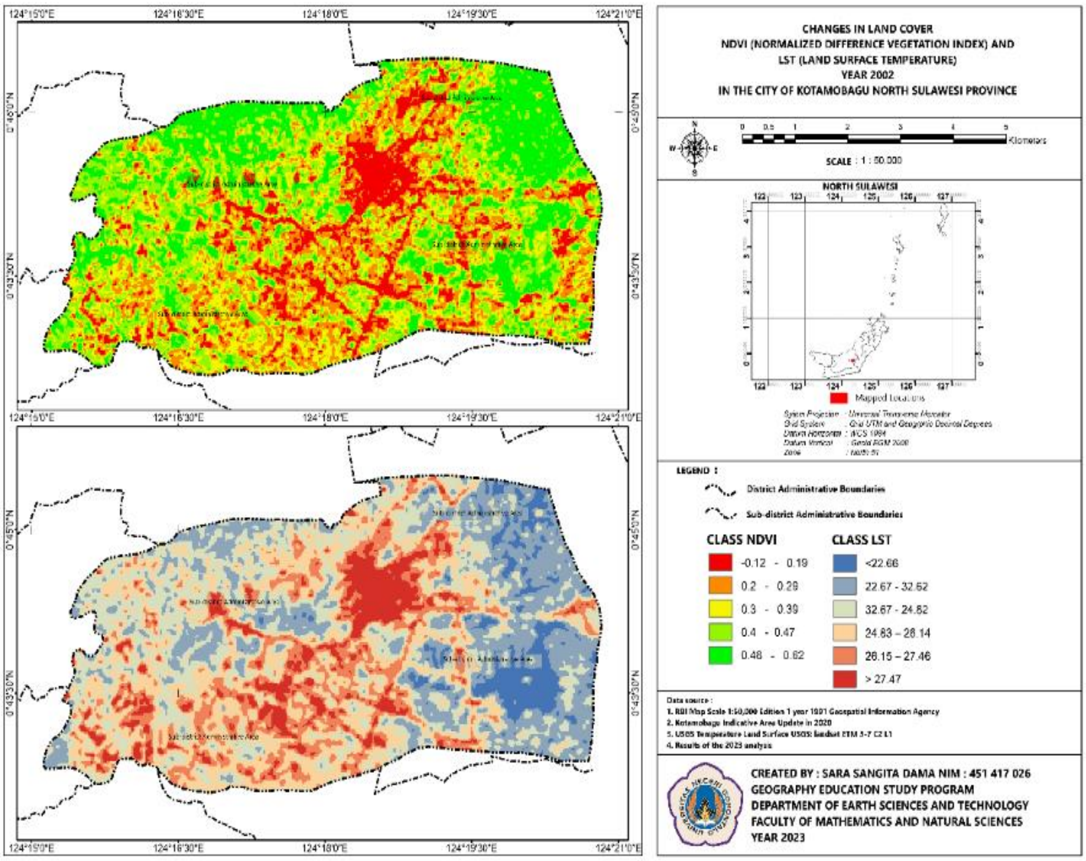

Figure 4. *Land Surface Temperature (LST) Maps and Normalized Difference Vegetation Index (NDVI) maps on year 2002*

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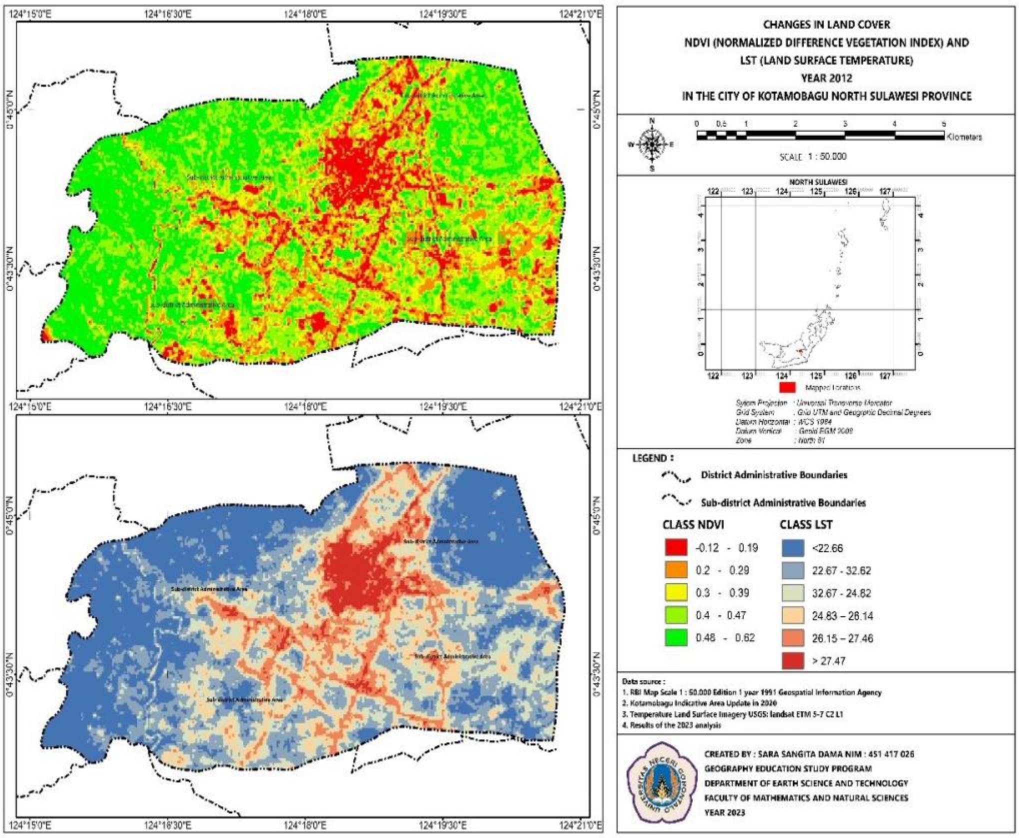

Figure 5. *Land Surface Temperature (LST) Maps and Normalized Difference Vegetation Index (NDVI) maps on year 2012*

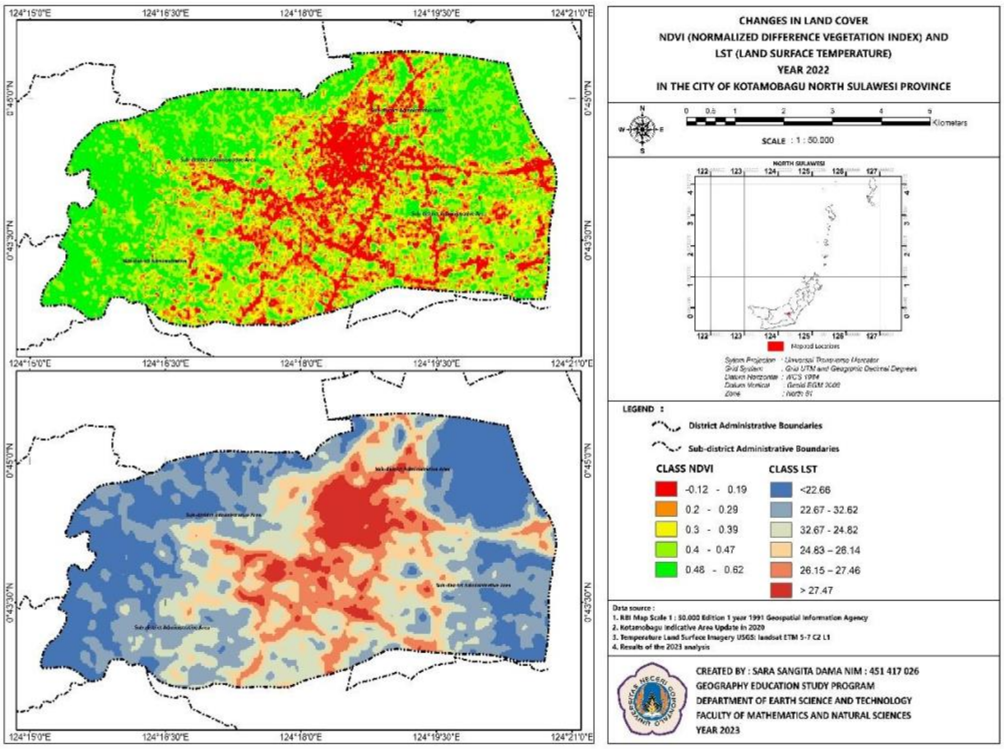

Figure 6. *Land Surface Temperature (LST) Maps and Normalized Difference Vegetation Index (NDVI) maps on year 2022*

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3.3 Results of Correlation Analysis of Vegetation Density to Surface Temperature

Changes in land cover can affect the earth's surface temperature through the mechanism of the albedo effect, the effect of greenhouse clearing and the effect of hot air. Therefore, it is necessary to have good and responsible land management to reduce the negative influence of land cover changes on the earth's surface temperature.

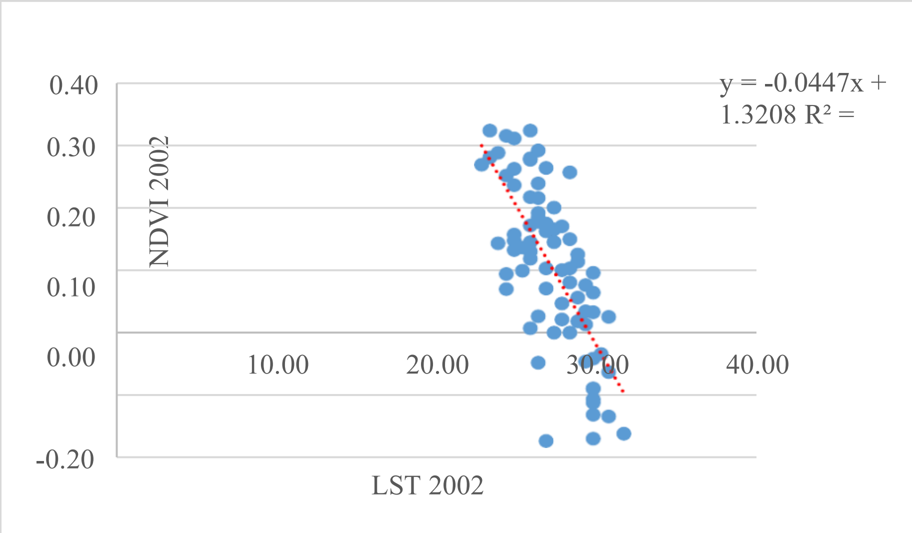

Figure 7. Correlation test of vegetation density (NDVI) surface temperature (LST) in 2002

Based on the results of the calculation of the correlation of NDVI values or land cover and surface temperature in Kotamobagu in 2002. The correlation shows that the change in land cover to the surface temperature of Kotamobagu has a negative correlation or only slightly affected with a correlation value of y = -11.596 x + 28.409 and the coefficient of determination is $R^2 = 0.5185$ this correlation shows that the value found in this correlation has a relationship between land cover and surface temperature or called a weak correlation. The linear line on this correlation also shows positive.

Based on the results of the calculation of vegetation density values (NDVI) and surface temperature (LST) in 2012 in Kotamobagu. The results of the calculation show that the correlation of vegetation density and surface temperature correlates positively, the results of R analysis table show y= 9.7317 x + 36.487, with the determination coefficient is $R^2 = 0.738$ which shows this correlation is positive. This correlation shows that the influence of land cover on surface temperature changes in Kotamobagu is very influential which is shown by a correlation value of more than 0.5.

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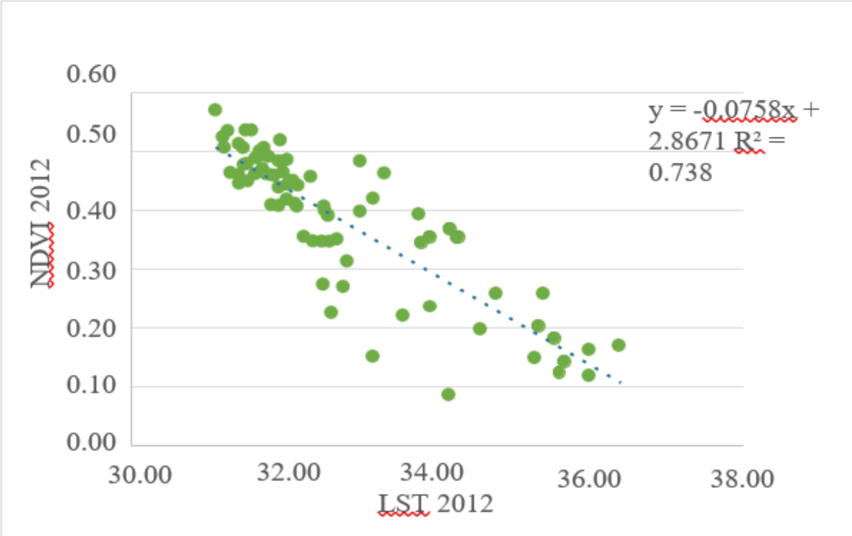

Figure 8. Correlation test of vegetation density (NDVI) surface temperature (LST) in 2012

Based on the results of the calculation of surface temperature values and vegetation density values, it shows that the correlation of surface temperature and land use in Kotamobagu is positively correlated with the calculation value of y = 12,402x + 28,714, and the determination coefficient is R^2 = 0.6532. Based on the analysis in the correlation, the variable X has quite an effect on the variable Y.

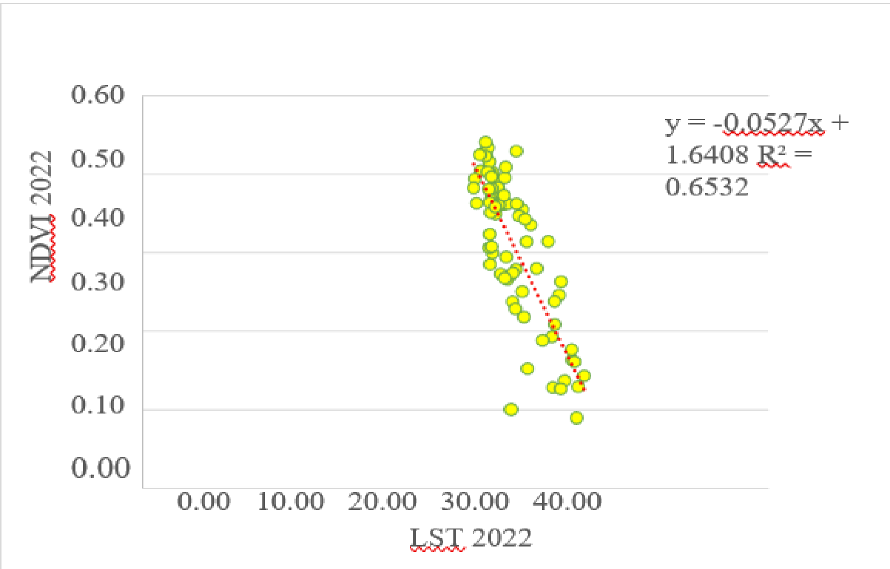

Figure 9. Correlation test of vegetation density (NDVI) surface temperature (LST) in 2022

In line with the research that has been conducted by (Indrawati et al., 2020) that based on the range of correlation values that have been obtained with Pearson analysis, there is a negative relationship between the Normalized Difference Vegetation Index (NDVI) variable and the surface temperature variable. The value of the negative correlation coefficient means that the two variables have an inversely proportional relationship marked by a negative sign in front of the correlation result which means that if the value of the variable x, namely the density of vegetation, is high, then the value of the variable y, namely the Land Surface

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Temperature (LST) will be low. And vice versa, if the vegetation density value is low, the Land Surface Temperature (LST) value will be high. Based on the values obtained, the two variables, namely vegetation density and surface temperature, have a relationship and are interrelated. This is also in line with research conducted by (Achmad & Muryunika, 2021) The higher the NDVI value, the higher the vegetation density. LST with a low temperature value of 18-25 ° C, where low temperatures have land cover classes in the form of secondary forest and other vegetated areas such as plantations and agriculture.

4. CONCLUSIONS

Based on the analysis that has been carried out, it can be concluded, The increasing development of the city causes the density of vegetation and buildings to change. Based on a comparison graph of surface temperature values, Kotamobagu City experienced a temperature increase from 2002 to 2012 by 12.49%, while from 2012 to 2022 there was a significant decrease in temperature by 8.58%. Based on the graph of the comparison of vegetation density values, there was a significant decrease in vegetation density in 2002, while in 2012 to 2022 there has begun to be an increase in vegetation frequency due to greening or efforts to increase vegetation density in Kotamobagu City. So that in the result research can be find, The relationship between surface temperature and vegetation density shows a very strong correlation so that it can be concluded that there is a linear relationship between vegetation density and surface temperature.

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