

Spatio Temporal Characteristics of LST to NDBI and NDVI in Lake Tondano Based on Landsat Imagery

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Abstract. Rapid development of building growth resulted in the decline of green area around Tondano Lake. Tondano lake as a conservation area also act as a tourist area and watershed. The reduction of green land with the increasing number of buildings causes the ground surface to absorb more hot temperatures from the sun, this will cause an increase in surface temperature on land. This research was conducted with spatiotemporal to analyze land cover in Tondano lake using Landsat-8 Imagery with TIRS (Thermal Infrared Red Sensor) and OLI (Operation Land Imager) bands in the period 2015, 2019, and 2021. The model is based on LST (Land Surface Temperature), NDVI (Normalized Difference Vegetation Index) and NDBI (Normalized Difference Built-up Index) algorithms. Variations in the vegetation greenness index ranged from -0.30 – 0.86 in 2015, -0.21 – 0.86 in 2019 and -0.06 – 0.84 in 2021. Meanwhile, the highest building density index ranged from 0.22 in 2015, 0.29 in 2019, and 0.18 in 2021. Pearson Product Moment correlation is used to determine the relationship between land surface temperature or LST affects greenish levels or NDVI and building density levels or NDBI. The results of the correlation test showed the relationship between LST and NDVI is that the higher the land surface temperature in one region, the lower the level of vegetation in the region, in contrast to the relationship between LST and NDBI.

Keywords: Lake Tondano, Landsat-8 Imagery, LST, NDVI, NDBI.

INTRODUCTION

Tondano Lake is a lake that is included in the national strategic area listed in government regulation or PP No.26 of 2008 on National Regional Spatial Plan (RTRWN), Conservation Area and Tourism area. Lake Tondano is designated as a National Strategic Area with an environmental interest angle. Tondano Lake plays an important role as a powerhouse for the Tanggari hydropower plant, as a source of food in the form of fish, drinking water sources (PDAM Manado), irrigation of rice fields, gardens, household needs of residents around the lake, water sources for industry, etc. Ironically, during the prolonged dry season resulted in an electricity crisis in a number of areas in North Sulawesi province and water will flood settlements in the area around the Tondano watershed during the rainy season. The settlement area around Lake Tondano is growing and the use of land that is not directed is a factor that affects the decline in the quality of Lake Tondano [1].

Land Surface Temperature (LST) is defined as the temperature at interface between the Earth's surface and its atmosphere [2]. LST is the temperature emitted by the surface and measured in kelvin. The increase in LST affects climatic conditions in a region, vegetation across the earth's surface will be affected by LST conditions. Land Use / Land Cover (LU / LC) an area can be used to estimate the amount of LST, natural activities also affect the amount of LST [3].

Multi-temporal and multi-resolution remote sensing images can provide basic data for analyzing urban spatial information and thermal environment effectively. Landsat-8 that launched in 2013 have TIRS and OLI instruments, the advantage from the OLI and TIRS instruments is observed Earth's surface with resolution from 15 meters to 100 meters. According to the technical specification, the LANDSAT-8 are very suitable for retrieving LST [4]. The Landsat-8 imagery is also used as a medium to detect land surface temperature by looking at the greenery density index of vegetation and density building [5]. The quality of the image can affect the results of analysis [6]. Previous studies suggest that there exists a strong negative correlation between Normalized Difference Vegetation Index (NDVI) and land surface temperature, while NDVI changes greatly with season. [7].

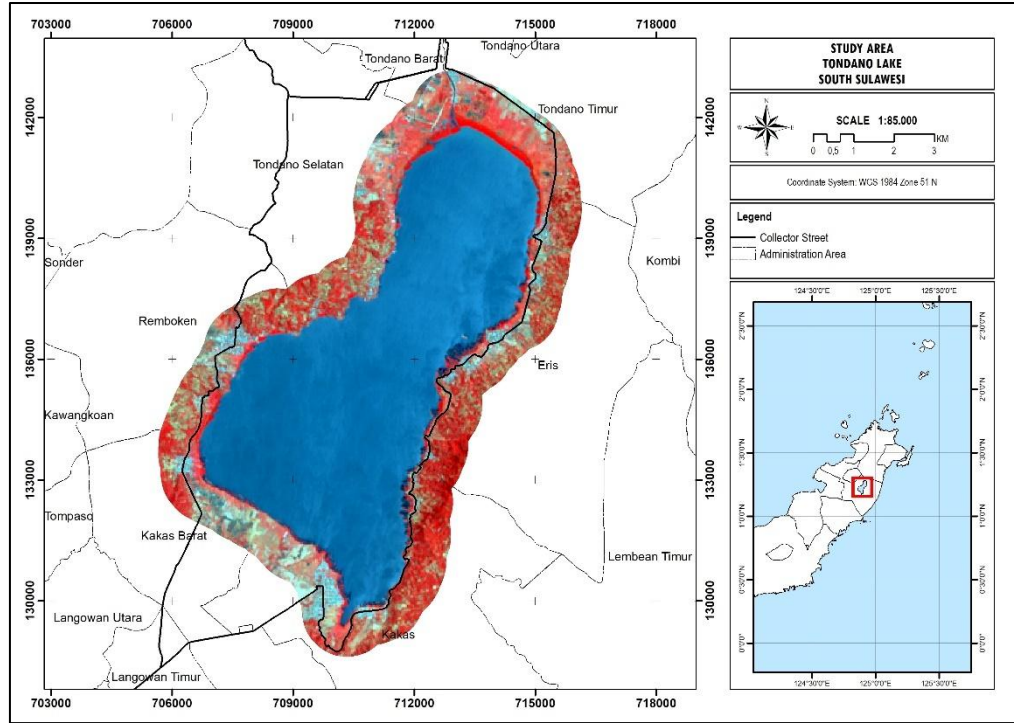


FIGURE 1. Study area map.

MATERIALS AND METHODS

2.1 Materials

Geographically, the study area extends from 01°13'25" N latitude and 124°53'43" E longitude. The study period covered from year 2015, 2019, and 2021 were selected to analyze LST relationship to NDVI and NDBI. Images acquired by Landsat 8 OLI/TIRS. These imageries were collected free of charge from the United States Geological Survey website (<https://earthexplorer.usgs.gov/>)

2.2 Methods

Data processing is done by processing primary data from Landsat 8 OLI / TIRS images to obtain LST, NDVI and NDBI values. Processing to obtain the value of land surface temperature is obtained from thermal waves in the image. In Landsat 8 OLI/TIRS imagery, Band 6 and Band 5 are used to obtain NDBI values, while Band 4 and Band 5 are used to obtain NDVI values [8]. Thermal Band TIRS or Band 10 is used to obtain LST values [2].

Radiometric correction is done to convert the digital number value into a reflecting value that serves as an improvement in pixel values to match the original [5]. Radiometric correction is done by converting pixel values or digital numbers in the image into spectral radiance. [9].

$$L\lambda = M_p \times Q_{cal} + A_L$$

Description: $L\lambda$ is the spectral radiance, M_p is the scale factor (Band-specific multiplicative rescaling factor), Q_{cal} is the pixel value (Digital Number) and A_L is the enhancer factor.

After obtaining spectral values, the process of converting spectral values into temperature values is carried out.

$$T = k2 / \ln \left(\left(\frac{K1}{L\lambda} \right) + 1 \right)$$

Description: T Is the temperature obtained from satellite sensors. (Kelvin), $K1$ is the calibration constant 1 for Landsat OLI (774.853 K), $K2$ is the calibration constant 2 for Landsat OLI (1321.0789), $L\lambda$ is the spectral radiance of

Band 10. The resulting temperature data in the form of Kelvin will be changed to the form of degrees Celsius, following the formula used:

$$Temp - ^\circ C = Temp - K - 273,15 = T - 273,15$$

NDVI (Normalized Difference Vegetation Index) is used to obtain the value of density index and the presence of plants on the earth's surface [10]. The vegetation index is based on the observation that different surfaces will reflect different types of light waves [5]. NDVI value will be carried out classification process into four levels of greenery vegetation [11].

$$NDVI = \frac{NIR - RED}{NIR + RED} = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4}$$

Description: NIR is the near infrared and RED is the red reflectance or red-light reflection.

TABLE 1. Classification of NDVI level on Landsat-8 imagery

No.	NDVI Index Value	Class
1	<0,3	Non-vegetation
2	0,3-0,4	Low
3	0,4-0,6	Medium
4	>0,6	High

Meanwhile, NDBI (Normalized Difference Built Index) used to obtain building density index values using mid-infrared waves (SWIR) and near infrared (NIR). The value of the density of the building to be obtained is between -1 to 1 [11].

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR} = \frac{Band\ 6 - Band\ 5}{Band\ 6 + Band\ 5}$$

Description: SWIR Is the band 6 on Landsat-8.

TABLE 2. Classification of NDBI level on Landsat-8 imagery

No.	NDVI Index Value	Class
1	NDBI Index Value	Class
2	<-0,15	Non-vegetation
3	-0,15 - -0,1	Low
4	-0,1 - 0,1	Medium

RESULTS AND DISCUSSION

3.1 Land Surface Temperatures of Lake Tondano

The distribution of Land Surface Temperatures in Tondano Lake varies greatly. This is because the distribution of the number of buildings in the area around Tondano Lake varies. In addition, the distribution of different community activities also affects the distribution of LST.

Variations of Land Surface Temperatures Tondano in 2015 are in the range of 20.1 °C - 32°C. Areas that have high enough temperatures are in residential areas. This is due to the amount of land that is built and the lack of vegetation that can absorb the reflection of sunlight radiation.

In 2019 the land surface temperatures variation is in the range of 18.1°C - 32.4°C. Areas with high enough temperatures are in residential areas and in the Tondano watershed. It can be seen in **Figure 3** in 2019 the occurrence of an increase in temperature in the lake body area, which means an increase in activity in the lake body area.

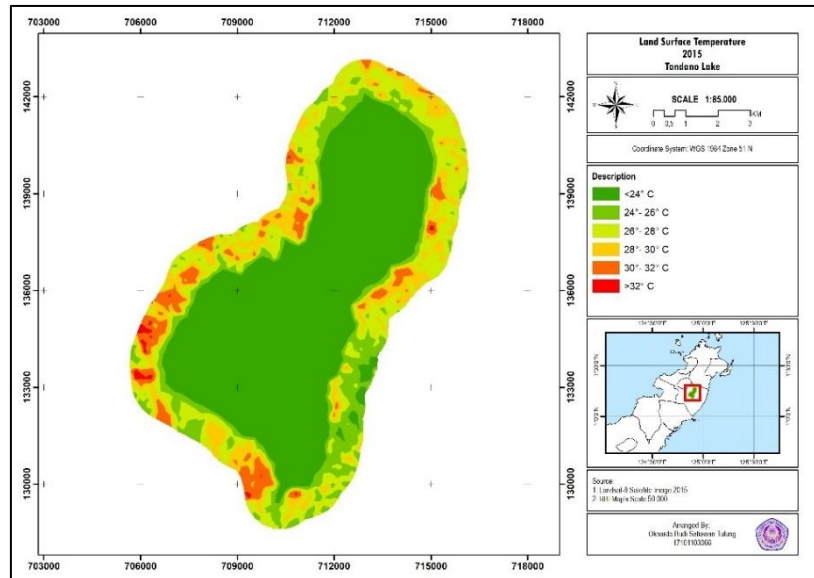


FIGURE 2. Land Surface Temperature map of Lake Tondano in 2015

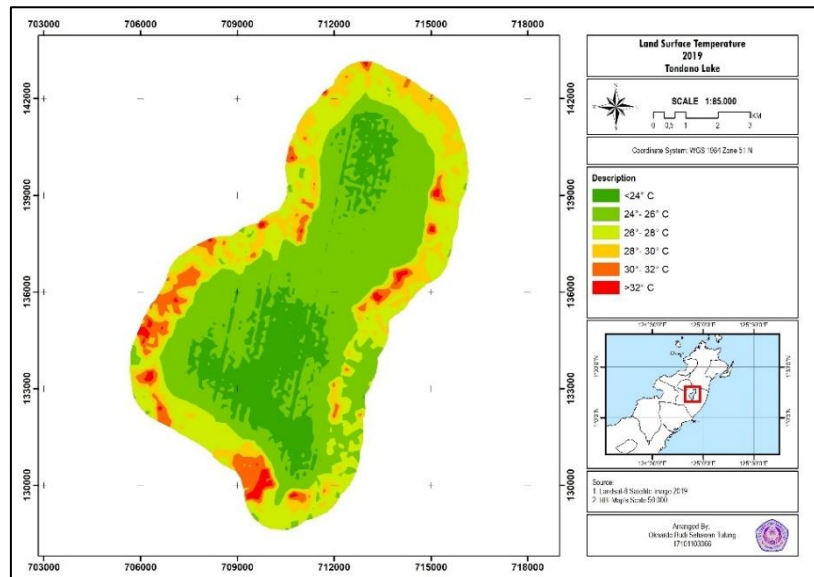


FIGURE 3. Land Surface Temperature map of Lake Tondano in 2019

In 2021 the land surface temperatures variation is in the range of 17°C – 28,8°C. Areas with high enough temperatures are in residential areas and in the Tondano watershed. It can be seen in **Figure 4** in 2019 the occurrence of an increase in temperature in the lake body area, which means an increase in activity in the lake body area. Meanwhile, there is an increase in temperature in the land area around Tondano Lake which means increasing the activity of people outside and inside area of Tondano.

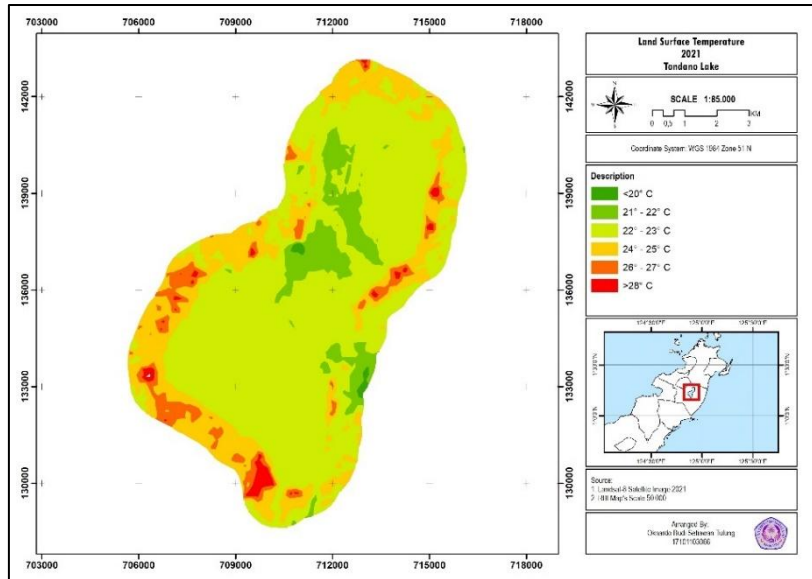


FIGURE 4. Land Surface Temperature map of Lake Tondano in 2021

3.2 NDVI of Lake Tondano

The distribution of the greenish index in Tondano Lake is quite varied. This is due to changes in land use in the area around the Lake that are centered on changing community activities. Overall, areas outside the residential area did not experience significant changes.

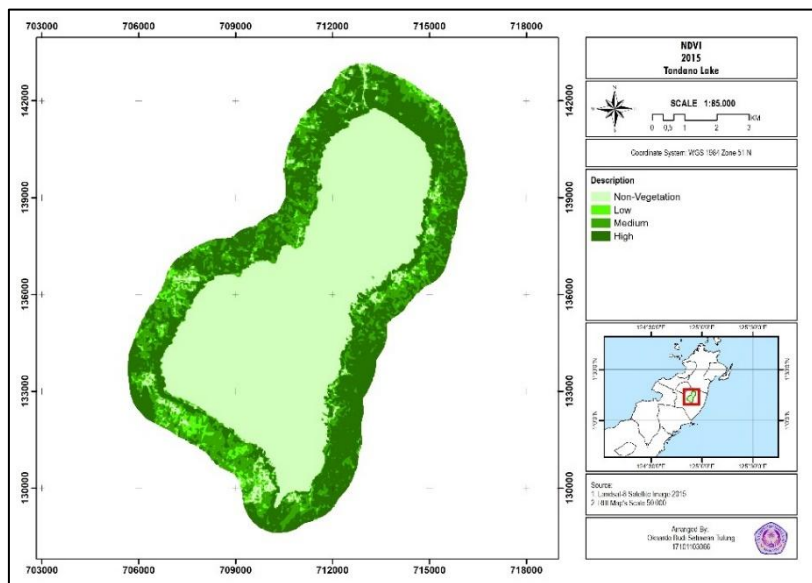


FIGURE 5. NDVI map of Lake Tondano in 2015

In 2015 the NDVI variation was in the range of -0.30 – 0.86. The index value range shows a considerable difference in the Tondano Lake region. The large range of difference values in a region means that the area is not entirely an urban area where most of the area is built-up land [5].

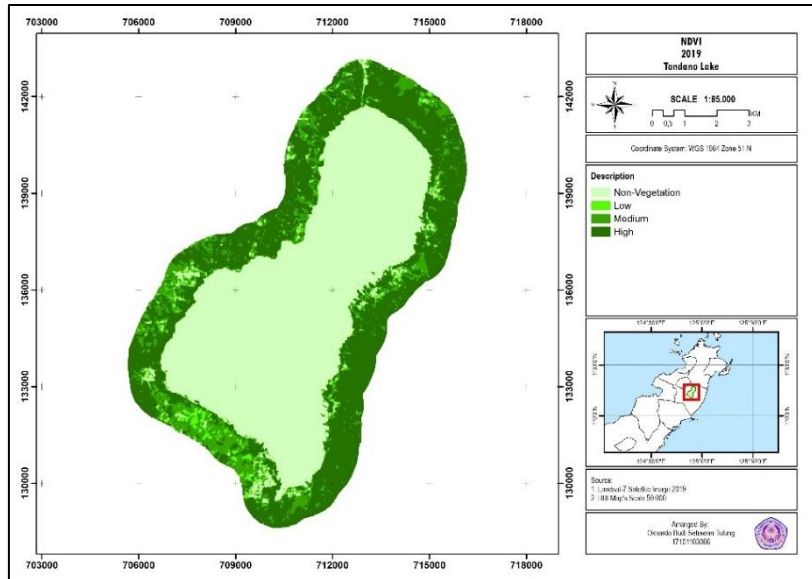


FIGURE 6. NDVI map of Lake Tondano in 2019

In 2019 the NDVI variation was in the range of $-0.21 - 0.86$. When compared to the variation in NDVI in 2015, this year's NDVI index did not change very significantly. It can also be known that there is also a change in the range of the smallest index that increases. The increase in the value of the smallest greenish index indicates the change of land built into green land. [5]. One of the factors that cause this to happen is the reduction of plantation land, agricultural land, and the reduction of fish ponds in the body of the lake.

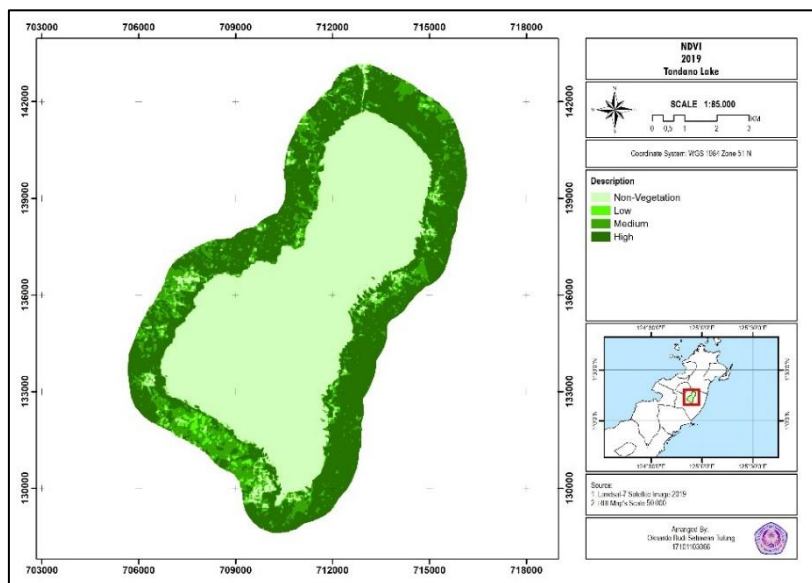


FIGURE 7. NDVI map of Lake Tondano in 2021

In 2021 the NDVI variation was in the range of $-0.06 - 0.84$. This year there has been a significant decline in the lowest index values. With the reduced amount of land built, this indicates a decrease in community activities in the area around the lake.

3.3 NDBI of Lake Tondano

Variations in the distribution of NDBI in Tondano Lake 2015 have the highest index value of 0.22 with the lowest index at -0.62. This shows that the distribution of the NDBI index in Tondano Lake is not evenly spread, this happens because there are still many green areas around the built-up area.

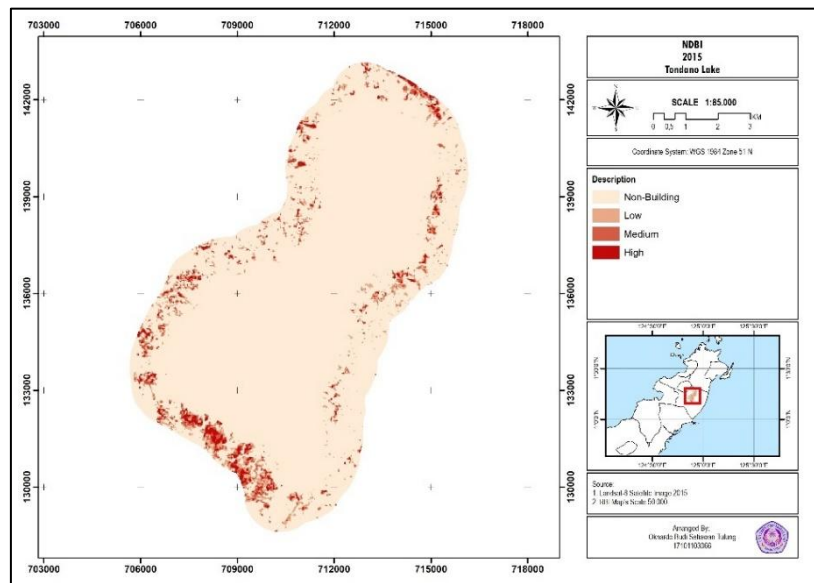


FIGURE 8. NDBI map of Lake Tondano in 2015

Variations in the distribution of NDBI in Tondano Lake 2019 have the highest index in value of 0.29 with the lowest index at -0.65. From the index there was an increase in the NDBI index from the previous year. The difference between the NDBI index in 2015 and 2019 was insignificant.

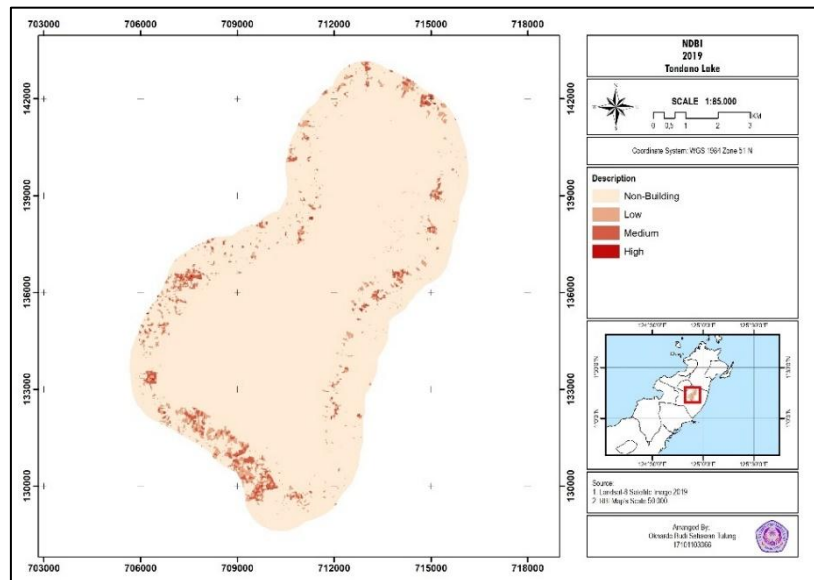


FIGURE 9. NDBI map of Lake Tondano in 2019

Meanwhile, variations in the distribution of NDBI in Tondano Lake 2021 have the highest index value of 0.18 with the lowest index at -0.57. From the NDBI index in 2021, there is a significant decrease in the amount of built land. This can be due to reduced community activity around the lake area.

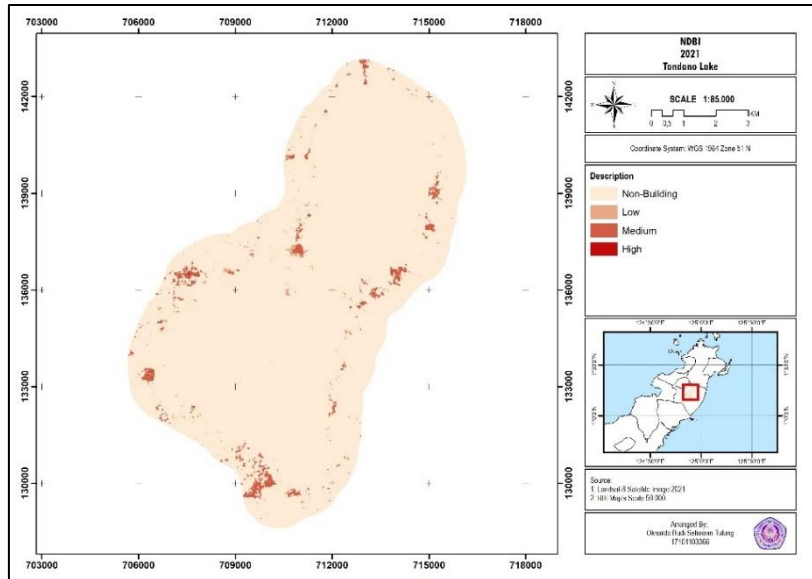


FIGURE 10. NDBI map of Lake Tondano in 2021

3.4 Correlation Between LST to NDVI and NDBI

The correlation between LST and NDVI and NDBI was done with Pearson Product Moment statistical testing. The results of correlation testing between LST and NDVI in Lake Tondano showed correlation values of -11.91 in 2015, -17.73 in 2019 and -16.93 in 2021. Meanwhile, the coefficient of determination or R^2 amounted to 0.99 in 2015, 0.97 in 2019 and 0.98 in 2021. The results of correlation testing showed that the higher the LST value, the lower the NDVI value.

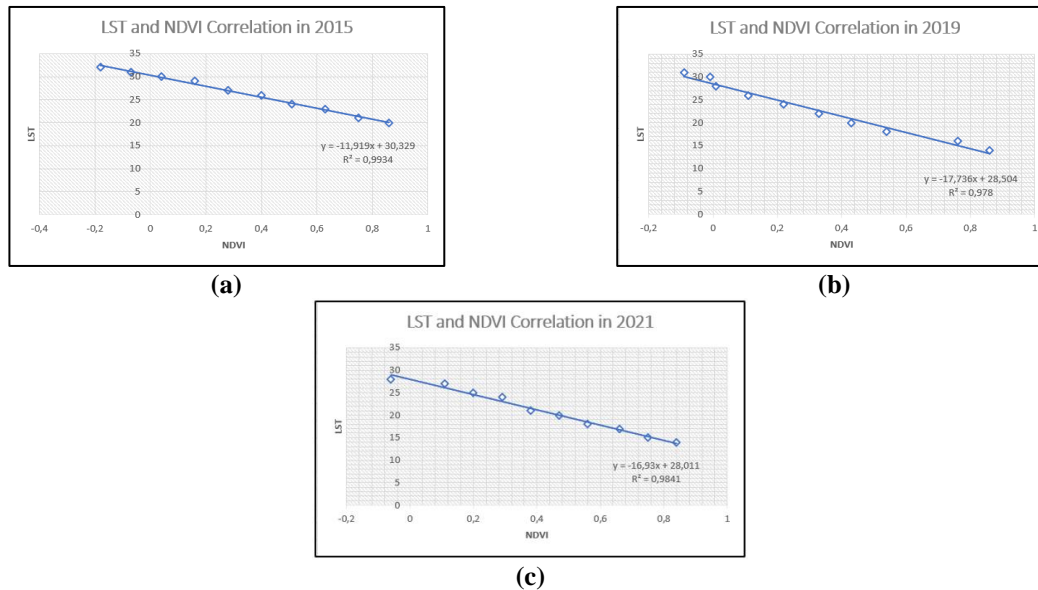


FIGURE 11. (a). Correlation of LST and NDVI in 2015, (b). Correlation of LST and NDVI in 2019, (c). Correlation of LST and NDVI in 2021.

The results of correlation testing between LST and NDVI in Lake Tondano showed correlation values of 14.99 in 2015, 18.57 in 2019 and 19.77 in 2021. Meanwhile, the coefficient of determination or R^2 amounted to 0.99 in 2015, 0.99 in 2019 and 0.98 in 2021. The results of correlation testing showed that the higher the LST value, the higher the NDBI value.

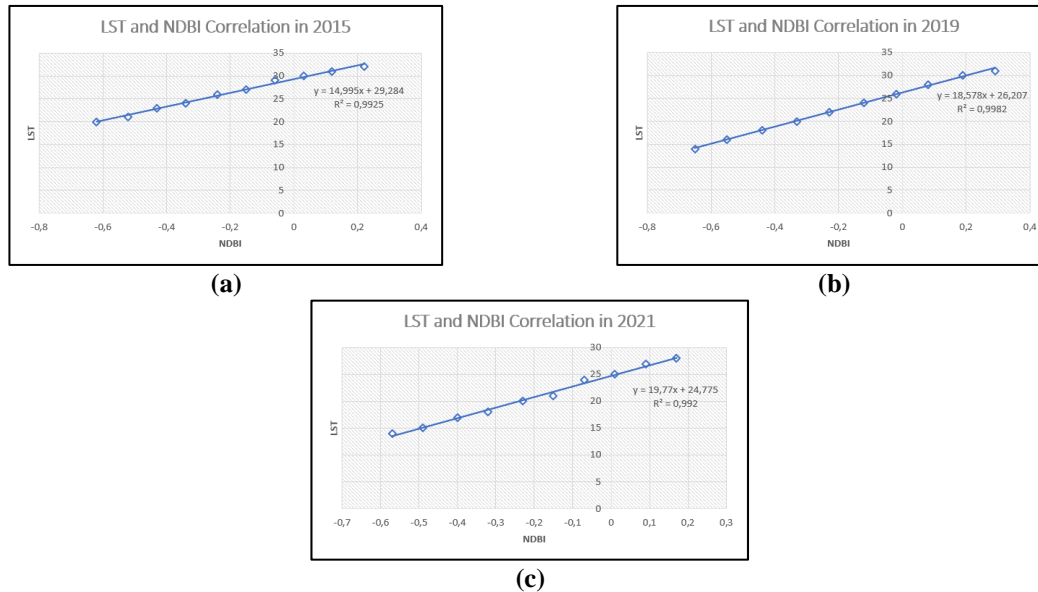


FIGURE 12. (a). Correlation of LST and NDBI in 2015, (b). Correlation of LST and NDBI in 2019, (c). Correlation of LST and NDBI in 2021.

CONCLUSION

Land use changes that occur in Lake Tondano affect the absorption of the reflection of sunlight radiation into the earth, with reduced levels of greenness in a region and increasing the built-up area will cause rising temperatures on the land surface in the area around Tondano Lake. Variations of Land Surface Temperatures Tondano are in the range of 20.1 °C - 32°C in 2015, 18.1°C - 32.4°C in 2019 and 17°C – 28,8°C in 2021. The NDVI variation was in the range of -0.30 – 0.86 in 2015, -0.21 – 0.86 in 2019 and -0.06 – 0.84 in 2021. The distribution of NDBI in Tondano Lake have the highest index value of 0.22 with the lowest index at -0.62 in 2015, the highest index in the range of 0.29 with the lowest index at -0.65 in 2019 and the highest index in the range of 0.18 with the lowest index at -0.57 in 2021. Korelation between LST and NDVI shows an inversely proportional correlation between land surface temperature with NDVI or vegetation greenness index. This means that the higher the land surface temperature value, the lower the greenness index of vegetation. Meanwhile, the relationship of LST with NDBI shows the direction of correlation towards positive values, this means that the value of the building density index is directly proportional to the surface temperature of the land. This means that the higher the land surface temperature value, the higher the density value of the building.

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