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To cite this article: Ridwan *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **802** 012042

IOP Conf. Series: Earth and Environmental Science **802** (2021) 012042 doi:10.1088/1755-1315/802/1/012042

Assessment of the relationship between building density and urban heat island using Landsat images in Makassar City

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Abstract. Increasing temperatures in urban areas provide many adverse effects, and such is the potential for fires, air pollution up to the comfort of life in the state capital, and the other problems, with the global warming which occurred in the world, such as the melting of ice on most of the north pole, unpredictable Global warming and the number of flora and fauna habitat damaged. The need for facilities and infrastructure is the main factor that triggers settlements' development; in general, urban areas often experience densely populated settlements. Therefore, researchers feel the need to monitor the relationship between Urban Heat Island (UHI) in Makassar City. Monitoring of Urban Heat Island needed surface temperature data from Landsat 8 OLI/TIRS with a thermal band resolution of 100m, building density needed NDBI models for data building density. This study analyses the relationship between building density and urban Heat Island using Landsat Imagery Data in Makassar city. The Landsat 8 OLI/TIRS imagery provides to be used to show the Urban Heat Island (UHI) phenomenon in Makassar City. In addition to UHI analysis, Landsat 8, Oil/TIRS imagery provides building density information using the NDBI spectral transformation. The results of the two result models' determination tests show that Urban Heat Island and Building Density have a very high relationship.

1. Introduction

The rapid growth in Makassar City has an impact on the total need for land use for living. The development of Makassar City has also resulted in the rapid conversion of undeveloped land into built-up land where new activity centers' growth will be the main attraction for land-use changes [1–3]. Land use results from any form of human intervention of land on the earth's surface, which is dynamic and functions to meet life's needs, both material and spiritual [2,4,5]. The more the population, the greater the probability level of land change.

The increase in the earth's surface temperature generally occurs due to changes in land cover changes. The land cover that can control heat is vegetated land with a high density, but this land cover tends to change its function to support human activities [6,7]. The development of infrastructure, facilities, and infrastructure, clearing forest land into agricultural land is also one of the causes of increasing surface temperature from the surface temperature from receiving solar radiation and air temperature influenced by surface temperature from land cover and climatic conditions. The temperature is also a part or component of nature that is highly influenced by and influences living things and environmental conditions [8].

This occurs in Makassar city, where the dense development seen from building density indicates the city's high development. The building's density is considered because of the need for facilities and infrastructure to support the economy and accommodate the resident population. High-density results in land changes not being developed to become developed, the risk of increasing climate and becoming an urban heat island (UHI) phenomenon [9].

The Changes in surface temperature and building density were observed with multispectral and multitemporal data by taking data extensively. one of the available data is remote sensing data in the form of satellite image data. The remote sensing data are Landsat TM images with a thermal band resolution of 120 m, Landsat UTM + of 60, and Landsat OLI of 100 m [10–12]. This research about the relationship between UHI and build density requires a spectral transformation model that correlates between building density data and the UHI. The spectral transformation used in this study is Normalize Difference Built-up Index (NDBI).

2. Methodology

2.1. Study Area

This research's location is in Makassar City, South Sulawesi Province, Indonesia (figure 1). Geographically, the city of Makassar located between 199 ° 24'17'38 "East Longitude and 5 ° 8'6'19" South Latitude, with an area of Makassar City covering an area of 175.77 km² which includes 15 congestion and a population of 1,526,677 souls in 2019.

The use of land in Makassar City (figure 1) consists of residential areas with an area of 6,674.44 ha or 37.69% of the total area of the city of Makassar, then Sawah with 4732.42 ha (26.93%), Wetlands 2,352.32 ha (13.39%), vacant land 1,186.52 ha (6.75%), Industry 635.35 ha (3.61%), Commercial 590.15 (3.36%), River 550.86 ha (3, 13%), Mangroves 471.68 ha (2.68%), City Forests 293.17 ha (1.67%) and, Lake 88.02 ha (0.50%).

2.2. Materials

Thermal imagery displays radiant temperature data on the earth's surface. Landsat OLI has a TIRS (thermal infrared system) sensor designed to show the thermal infrared channel and obtain temperature data on the earth's surface in the multispectral image. The thermal channel on the Landsat OLI/TIRS imagery has a spatial resolution of 100 cm with flight missions from 2013- to now, where it can be accessed and used via the U.S. Geological Survey (USGS).

This study aims to find the relationship between the urban heat island and buildings' density previously using the Landsat 8 OLI/TIRS thermal channel data. In spatial image modeling, building density can analyze using the urban index spectral transformation method. Several urban indices can use; Urban Index (UI) [13], Visible green-based built-up index (VgNIR-BI) [14], Normalize Difference Built-up Index (NDBI) and Built-up Area [15]. In this study, researchers used the NDBI spectral transformation by utilizing the middle infrared channel one and near-infrared on the Landsat 8 OLI/TIRS satellite imagery, considering that all data was available Landsat 8 OLI/TIRS satellite imagery, so in this study using Landsat data. 8 OLI/TIRS recording date 20th August 2020 path/row; 114/064.

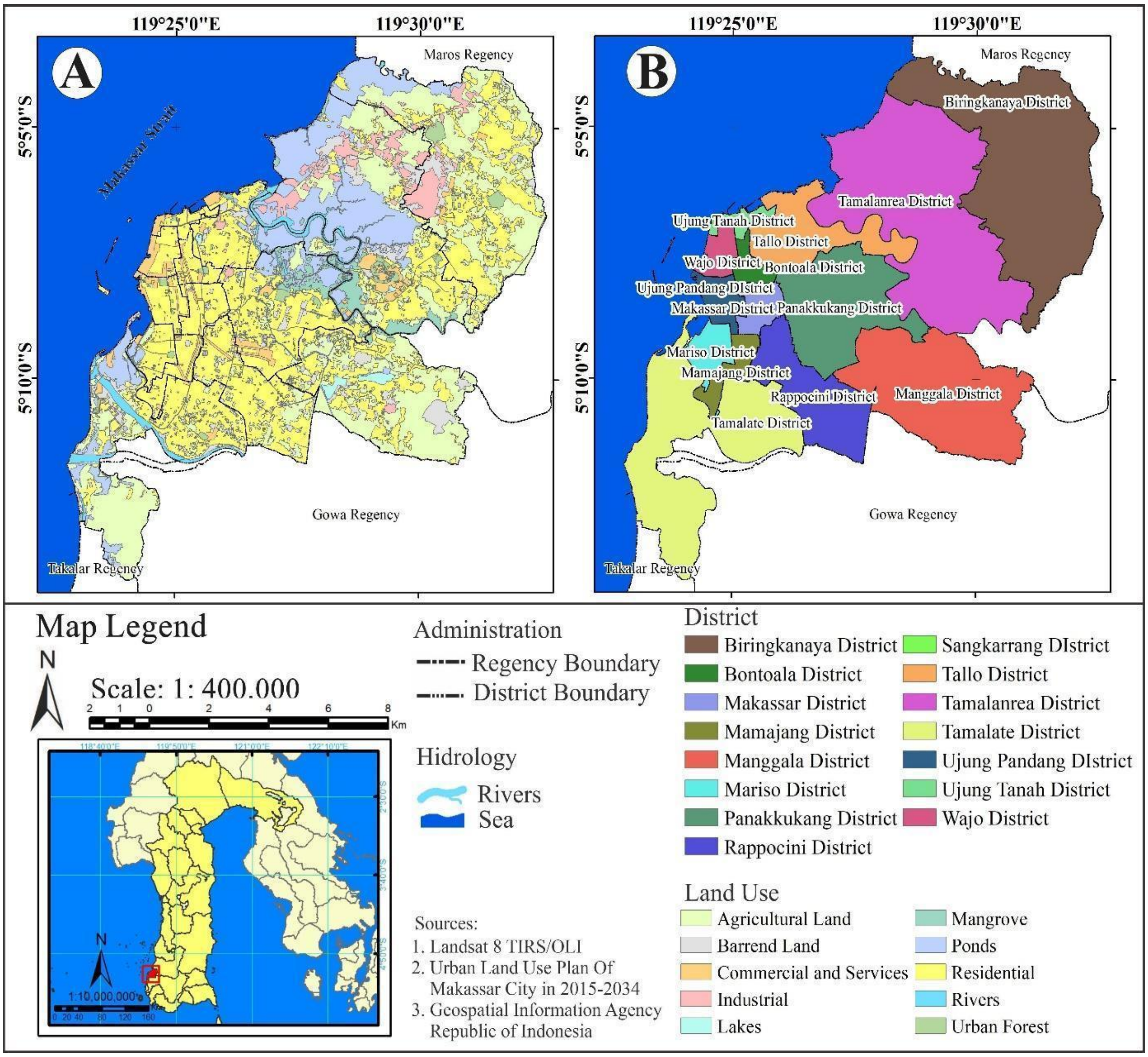

Figure 1. (A) Land use of Makassar City, (B) district in Makassar City.

2.3. Methodology

The TIRS sensor has a spectral waveform error value due to atmospheric interference received by the sensor. This error occurs due to changes in the value of the spectral electromagnetic waves received by the sensor when recording with the emitted spectral value. As with aerial photographs, the influence of the atmosphere significant to the intensity and composition of the energy spectrum recorded by the thermal system, the process used to obtain the temperature/object value of the earth's surface temperature by converting the unit temperature in kelvin to ° C is to change the DN channel into a radiation value. , then change the DN value assessed by radiance to a Kelvin value, and the last process is to convert the brightness temperature value from °Kelvin to °Celsius.

Furthermore, to analyze the urban heat island, the temperature data of Makassar city will be analyzed using data land cover and temperature distribution for each district in Makassar City. Data between land cover with temperature values and land cover with sub-district topology and then overlay to obtain an urban heat island analysis. The specific transformations are used for various studies, starting from observing vegetation growth stages (phenology) and their development. Specific transformations can also use for various urban studies with the character of building land cover objects. Spectrally, the roofs of buildings in Indonesia's cities are dominated by roof tiles, clay, and concrete. So middle infrared spectral reflection is sensitive to these objects and has differences in natural objects such as vegetation and water bodies.

This research uses the Normalized Difference Built-up Index (NDBI) spectral transformation, an image transformation, to provide built-up area information. Zha, et al. (2003) carried out the NDBI transformation to map China's Nanjing city's built-up [15].

3. Results and discussion

3.1. Urban heat island Makassar City

The temperature analysis results of the city of Makassar using the Landsat 8 OLI/TIRS thermal channels recording on 20th August 2020 path/row; 114/064. This indicates the lowest temperature has a surface heat as high as 16.09 ° C, and the warmest surface shows a temperature of 28.87 ° C (figure 2). The Sub-districts of Makassar city with the highest average temperature and the tallest land cover showing in table 1.

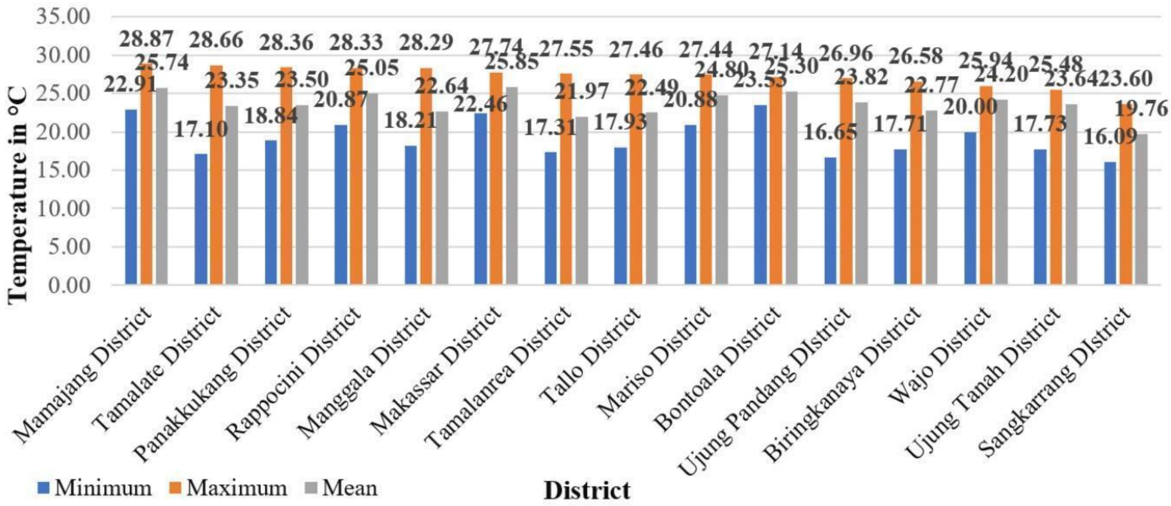

Figure 2. The temperature in °C of district in Makassar City.

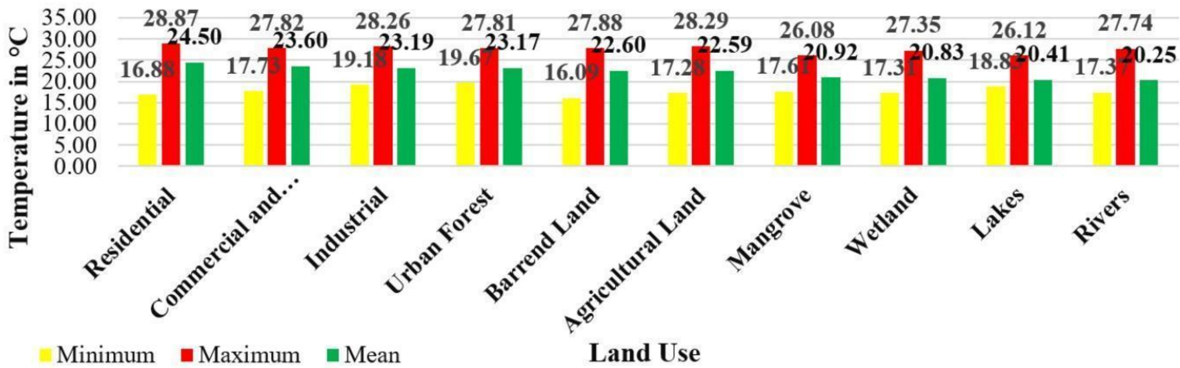

Figure 3. The Land use temperature in °C of Makassar City.

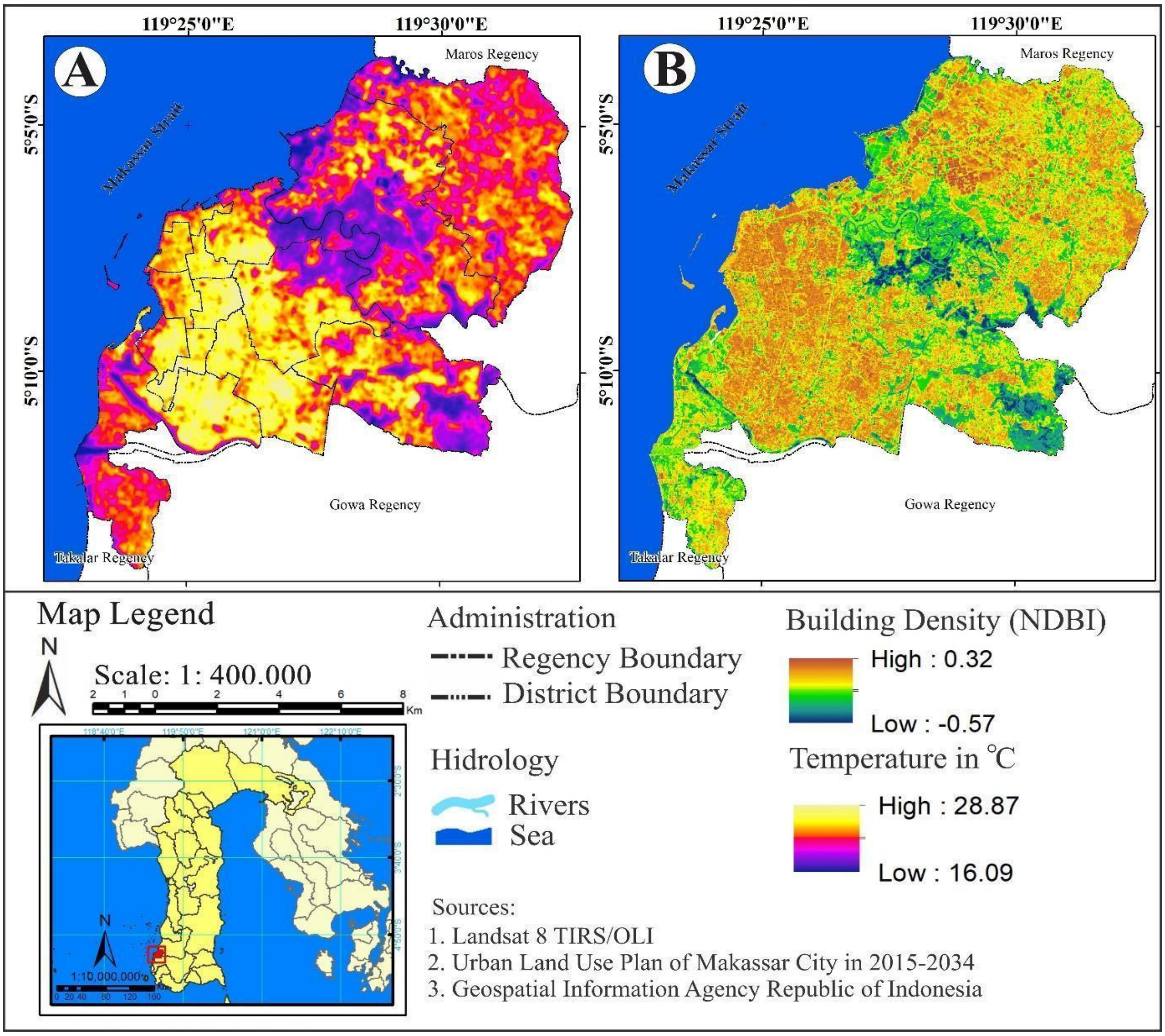

Figure 4. (A) Surface temperature of Makassar City, (B) building density of Makassar City.

The sub-district with the highest average temperature value was Makassar District with a mean surface temperature of 25.85 °C; The lowest average temperature was Sangkarrang District with an average temperature of 19.76 °C, and the highest surface temperature location was Mamajang District with the highest temperature was 28.87 °C. Furthermore, to show the urban heat island in Makassar City and analyze the distribution of temperature in each sub-district, the analysis results also show the distribution of surface tempera*ture to land use in* Makassar *City*. The results showing in Table 2, where land uses with the highest average temperature value are settlements with an average temperature of 24.50 °C. The lowest average temperature is rivers, with a temperature of 20.25 °C.

3.2. Building density

The spectral transformation of the Landsat 8 OLI/TIRS using NDBI transformation showed that the highest building density had a value of 0.32 while the lowest had a value of -0.57. At the spectral transformation's pixel value, the building density intensity can be classification into three classes; low building density with pixel value <0.000247, medium building density 0.000248-0.079, and high building density with a value >0.08. Table 1 shows that the sub-districts with the highest average value in building density according to NDBI analysis are Bontoala, Makassar, and Wajo districts with a value of 0.04 or still in the medium density category. NDBI results also show that areas with very high

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building densities are the Tamalanrea sub-district (0.33) and the Ujung Tanah sub-district (0.32), which have areas with high NDBI values (table 1).

Table 1. The building density of district in Makassar City.

	NDBI		
District	Minimum	Maximum	Mean
Biringkanaya District	-0.48	0.26	-0.05
Bontoala District	-0.30	0.28	0.04
Makassar District	-0.43	0.21	0.04
Mamajang District	-0.40	0.26	0.02
Manggala District	-0.53	0.21	-0.14
Mariso District	-0.45	0.26	-0.02
Panakkukang District	-0.52	0.25	-0.10
Rappocini District	-0.45	0.25	-0.02
Tallo District	-0.53	0.26	-0.08
Tamalanrea District	-0.57	0.33	-0.10
Tamalate District	-0.54	0.31	-0.08
Ujung Pandang District	-0.42	0.23	-0.01
Ujung Tanah District	-0.31	0.32	0.01
Wajo District	-0.30	0.29	0.04
Sangkarrang District	0.57	0.19	-0.15

High building intensity has been found in residential areas. Urban dynamics related to the population's high needs generally affect the construction of facilities and infrastructure around settlements to facilitate the population needs. NDBI results associated with land use in Makassar City show that land uses with the highest average NDBI value are in residential and industrial areas with a value of -0.01. However, if viewed from the land use with a maximum value from the NDBI spectral transformation results, it can be commercial land use (table 2).

Table 2. The land use building density of Makassar City.

	NDBI		
Land Use	Minimum	Maximum	Mean
Rivers	-0.54	0.24	-0.21
Agricultural Land	-0.53	0.31	-0.10
Barren Land	-0.51	0.30	-0.09
Residential	-0.48	0.28	-0.01
Commercial and Services	-0.41	0.32	-0.03
Lakes	-0.42	0.12	-0.22
Industrial	-0.42	0.26	-0.01
Mangrove	-0.57	0.17	-0.28
Wetland	-0.54	0.33	-0.14
Urban Forest	-0.42	0.23	-0.11

3.3. Building density and urban heat island relationship

The relationship test results between building density and UHI were obtained from the regression test between the NDBI spectral transformed image to represent the building density variable and the thermal image as UHI variable. Image pixel sampling is carried out by representing several lands uses related to the field sampling technique. Related to this, Ling (2004) suggests several methods; random spatial sampling, stratified spatial sampling, and systematic spatial sampling. In testing the relationship between building density and UHI, researchers used 30 samples with a stratified spatial sampling technique [16].

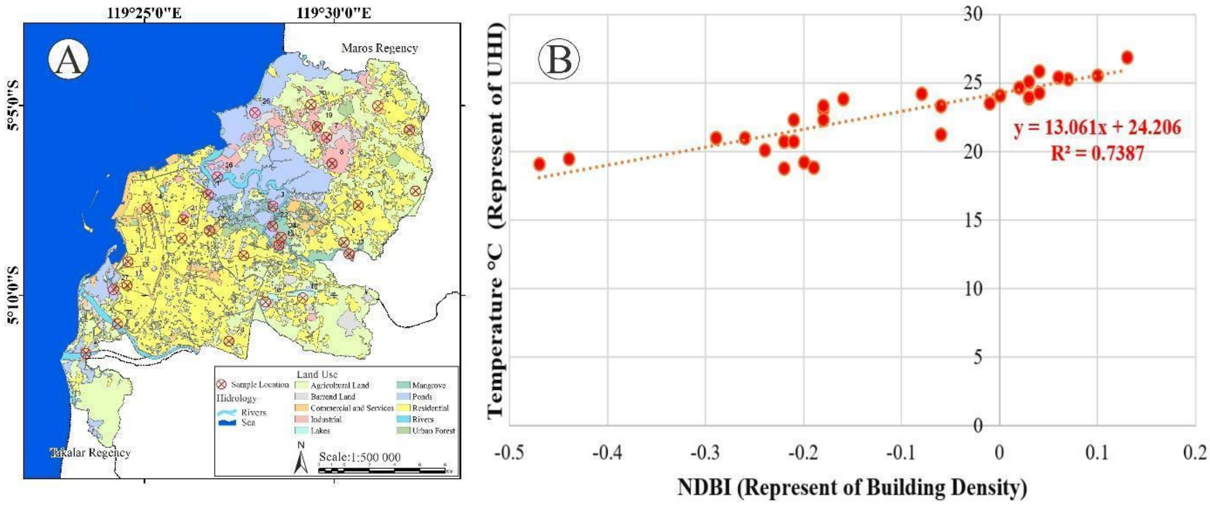

Figure 5. (A) Location of the accuracy test sample, (B) The results of the regression test for the relationship between building density and UHI.

The regression value shows a very high relationship between UHI and building density in Makassar city; this is indicated by the determination test (r^2) value as high as 0.73 (figure.5). The higher the building density indicated by the NDBI value, the higher the surface temperature. Most of the high temperatures found in residential and commercial areas.

4. Conclusion

This study indicates that the urban heat island (UHI) can be identified with Landsat 8 OLI/TIRS imagery data by utilizing the provided thermal channels. The results of the UHI modeling used can show land use that has the highest average temperature value, namely settlements with temperature. The average is 24.50 ° C, while the land use with the lowest average temperature is rivers with a temperature of 20.25 ° C. The Landsat 8 OLI/TIRS imagery data can also apply for building density analysis for urban areas, in the city of Makassar, with the transformation Spectral Normalized Difference Built-up Index (NDBI) shows the high intensity of buildings in residential areas and industrial areas. The data from the UHI and NDBI modeling results used for the determination test, the UHI and Building density relationship test results show a high coefficient of determination, so this shows that the relationship between UHI and building density has a very high relationship.

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