Proceeding International Conference on Religion, Science and Education (2023) **2**, 625-633

Spatial-Temporal Variation of Land Surface Temperature in South Tambun District, Bekasi Regency in 2011 – 2022

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Abstract: South Tambun District is the sub-district with the largest population and the highest density in Bekasi Regency (BPS 2021). One of the factors causing population growth is the high rate of urbanization (Prayojana et al., 2020). The intensity of this urbanization rate can be seen from how much built-up land cover stands in the area (Chen et al., 2021). Then, in the Bekasi Regency Regional Regulation Number 12 of 2011 concerning the Bekasi Regency Spatial Plan for 2011–2031 in South Tambun District it is planned as Development Area I (WP I) which is directed to the main functions of developing industry, trade, services, housing, settlements , tourism and supporting industrial activities. One of the problems that will occur is that it can increase the surface temperature of the soil in areas of land cover change, due to a shift in land cover from undeveloped to built up. Urban ground surface temperature can be detected using remote sensing. Detection analysis was performed on Landsat-8 imagery which depicts the shape of the earth's surface. This change has a relationship with changes in land cover, namely the greenness of the vegetation and the density of buildings in South Tambun District, with a linear correlation test to get the result that the Greenness of the Vegetation is inversely proportional to the value of the land surface. temperature and building density are directly proportional to ground surface temperature.

Keywords: Development Area, Land Surface Temperature, Land Cover, Landsat 8.

Introduction

Development in an area will have a negative effect on evaporation and a positive effect on transpiration of the earth's surface, especially in areas covered with metal, asphalt and concrete (Pratiwi and Safitri, 2019). One of the problems that will occur is that it can increase land surface temperatures in areas of land cover change, due to the shift in land use from undeveloped to built up (Pal and Ziaul, 2017). This is in line with urban areas, where the surface of buildings or buildings absorbs more heat energy than reflects it, resulting in an increase in temperature in the area around the building (Senanayake et al., 2013). Previous research has examined a number of spectral indices to analyze the effect of land cover, vegetation density, soil water content and impermeable surface cover which are known to be determinants of land surface temperature (Ezimand et al., 2018; Guha et al., 2018;).

South Tambun District is the sub-district with the largest population and the highest density in Bekasi Regency (BPS 2021). South Tambun District is one of the most densely populated sub-districts in Indonesia, with an area of 43.10 km2 and a community of 417,008 people (P2KP STIKI 20). One of the factors causing the increase in numbers
Population is the high rate of urbanization (Prayojana et al., 2020). According to Concern (2015), urbanization plays a very important role in accelerating the development process. Where the intensity of this urbanization rate can be seen from how much coverage of built-up land has stood in the area (Chen et al., 2021). Then, in the Bekasi Regency Regional Regulation Number 12 of 2011 concerning the Bekasi Regency Spatial Plan for 2011–2031 in South Tambun District it will be planned as Development Area I (WP I) which will

ISSN 2829-3355 | EISSN 2828-8467

be directed to the main function of developing industry, trade, services, housing , settlements, tourism and supporting industrial activities. One of the problems that will occur is that it can increase land surface temperatures in areas of land cover change, due to the shift in land use from undeveloped to built up.

Urban land surface temperatures can be detected using remote sensing (Nurhuda, 2015). Due to problems such as the RTRW for South Tambun District and Tambun District, which is one of the most densely populated sub-districts in Indonesia, it is necessary to conduct research on how to increase land surface temperatures, related to the condition of land cover in South Tambun District, Bekasi Regency.

Materials and Methods

Study Area

South Tambun District is located at coordinates 05^{0}54' 50" - 060 29' 15" South Latitude and 106^0 58' 5" - 1070 17' 45" East Longitude. South Tambun District is one of 23 sub-districts in the Bekasi Regency, West Java, Indonesia **Figure 1.** South Tambun District has 10 sub-districts in it. It is bordered by North Tambun sub-district in the north, Bekasi City in the west, Cibitung sub-district in the east, and Setu sub-district in the south. South Tambun District is the sub-district with the largest population and the highest population density in Bekasi Regency. South Tambun District is one of the most densely populated sub-districts in Indonesia, because with an area of 43.10 km2 it has a community of 431,038 people (BPS 2021).

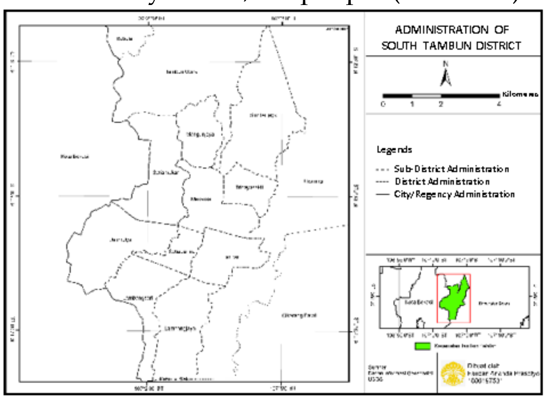


Figure 1. Administration of South Tambun District

Materials

Land cover is a physical manifestation of the material on the earth's surface where this physical manifestation can be the result of human activity or directly from nature, such as built-up land, bodies of water, vegetation, and so on (Bashit et al., 2019). Florensia et al (2021) also explained that land cover is a basic variable for measuring phenomena that exist on the earth's surface, such as climate change, environmental degradation, and evaluating the implementation of spatial planning in an area. Land surface temperature can be defined as an average surface of a surface, which is described in the range of a pixel with a variety of different surface types (USGS, 2015 in Delariska, 2016). In remote sensing, ground surface temperature is a temperature that is controlled by the longwave energy flux returning to the atmosphere, highly dependent on the state of other surface parameters, conditions and vegetation levels (Putri, 2017). The surface temperature of an area can be identified from Landsat satellite imagery extracted from the thermal band. Remote sensing is the recording of information, usually in the form of images, about the surface of the earth, both land and sea, and the atmosphere above it, using aircraft vehicles, both unmanned and with crew, within the scope of airborne and spaceborne (Dimyati, 2022). This process is carried out by feeling or recording the energy that is reflected or emitted, processing, analyzing and applying this information (Anggoro et al, 2017). Remote sensing in this study uses a vehicle, namely satellite imagery, the satellite imagery is Landsat 8 (Nurhuda et al, 2019). Landsat is a result of the earth resource program developed by NASA (The National Aeronautical and Space Administration) of the United States in the early 1970s (Sukristiyanti, et al. 2009). Following are the channel (band) specifications owned by Landsat 8 (BIG, 2016).

Table 1. Wave lengths and bands in the Landsat 8 OLI – TIRS satellite

Bands	**Wavelength (µm)**	**Resolution (meters)**
Band 1 - Coastal aerosol	0.43 – 0.45	30

Band 2 – Blue	0.45 – 0.51	30
Band 3 – Green	0.53 – 0.59	30
Band 4 – Red	0.64 – 0.67	30
Band 5 – Near Infrared (NIR)	0.85 – 0.88	30
Band 6 – SWIR 1	1.57 – 1.65	30
Band 7 – SWIR 2	2.11 – 2.29	30
Band 8 – Panchromatic	0.50 - 0.68	15
Band 9 – Cirrus	1.36 – 1.38	30
Band 10 – Thermal infrared (TIRS) 1	10.60 – 11.19	100
Band 11 – Thermal infrared (TIRS) 2	11.50 – 12.52	100

This study uses primary data and secondary data. Primary data was obtained by field surveys which were distributed at several points in South Tambun District to validate the secondary data. This is done by setting sample points using the random sampling method and setting a sample point of 253 points. Field survey data were obtained by measuring the temperature at each sample point using a temperature gauge at 10-15 o'clock with each sample point 3 times and each measurement was carried out for 5 minutes. Then, in each measurement the results will be recorded and the average calculated for the three measurements will be carried out. Meanwhile, secondary data in this study were obtained from the USGS platform and the Geospatial Information Agency (BIG). The data is Satellite Imagery data for South Tambun District for 2011 – 2022 and a map of the administrative area for South Tambun District. Landsat 8 OLI imagery (path/row: 122/64) for the research area downloaded from the United States Geological Survey (USGS) platform (http://earthexplorer.usgs.gov/).

Procedures

Data Processing

The data processing in this study is entirely derived from Landsat 8 OLI/TIRS imagery. However, before further processing, a radiometric correction process is carried out on Landsat 8 OLI/TIRS images to minimize errors in the image that might interfere with further image processing. Then data processing was carried out in the research, namely land cover, land surface temperature, vegetation greenness index or Normalized Difference Vegetation Index (NDVI), building density index or Normalized Difference Built-up Index (NDBI), and land surface temperature. Where the land surface temperature will later be regressed with the surface air temperature obtained from the field survey results. Land Surface Temperature data processing is carried out using ArcMap 10.1 software with raster calculator tools. According to Al Mukmin et al (2016), image data on satellites are generally in the form of a Digital Number (DN) so several stages of processing are required to obtain surface temperature values that can be extracted from the thermal bands of satellite imagery. Digital Number (DN) is converted to a radiation value or emission value (ToA). The following are the equations in data processing in this study:

$$L\lambda = ML*Qcal+AL$$

Where:
L λ = TOA radiance or radiance value
ML = Band-specific multiplicativae rescaling factor
Qcal = The digital number that exists in each pixel of the Landsat image band
AL = Band-specific additive rescaling factor

The ML and AL values can be seen in the Landsat 8 OLI/TIRS image metadata used. Landsat 8 OLI/TIRS image metadata is generally contained in text files that are also downloaded when downloading image files. Then the next step is to change the radiance value or the emission value to a brightness temperature value which still uses the Kelvin (K) unit.

$$T= K2In\ (K1L\lambda+1)$$

Where:
T = Brightness temperature in Kelvin (K)
L λ = TOA radiance or radiant value
K1 and K2 = Thermal constant band 10 or 11

K1 and K2 values can also be seen in the Landsat 8 OLI/TIRS image metadata used. Then the next step is to change the brightness temperature value which is still in Kelvin (K) units to Celsius (C) units by reducing the brightness temperature value by 273.

Data Analysis

The analysis used in this research is spatial, temporal, statistical and descriptive analysis. Temporal spatial analysis to determine variations and patterns of land surface temperature each year. Variations and patterns of land surface temperature are then analyzed using descriptive comparative to compare land surface temperature based on a predetermined year along with changes in land cover. The statistical analysis used is by using a correlation test to find out how much the relationship between changes in land cover and land surface temperature is. The relationship or relationship between land surface temperature changes and land cover changes was analyzed using a simple correlation analysis method, to obtain correlation values to see the relationship between land surface temperature and land cover changes (NDVI and NDBI).

Results and Discussion

Land Cover Changes in South Tambun District

In **Figure 2** shows the land cover map resulting from supervised classification in South Tambun District. Land cover classes on the map are symbolized by an orange color for built-up land class, green for vegetation land class, and blue for water body land class. The following is a map of the land cover of South Tambun District for each research year.

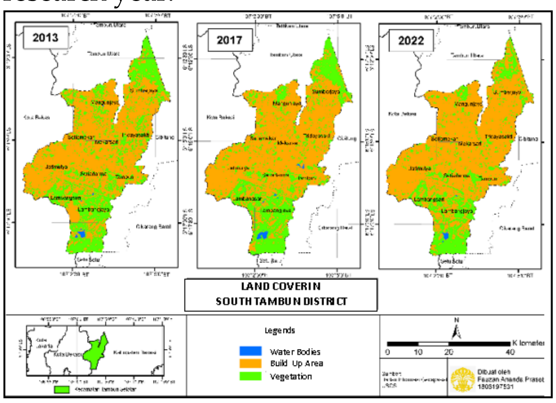


Figure 2. Land Cover in South Tambun District

Table 2. Land Cover Areas in South Tambun District

Land Cover	Area (hectare)			Persentage		
	2013	2017	2022	2013	2017	2022
Water Bodies	15,39	25,83	10,89	0,4%	0,6%	0,2%
Build Up area	2889,81	3019,14	3320,01	65,9%	68,9%	75,7%
Vegetation	1478,79	1339,02	1053,09	33,7%	30,5%	24,0%
Total	4383,99	4383,99	4383,99	100%	100%	100%

On above. can be seen the area of the water bodies class which is the land cover class with the lowest total area and number of grids in South Tambun District. Then, the total area for each class of land cover varies each year, but for the total area and grid there is no difference, which means that the total area of South Tambun sub-district from 2011 to 2022 tends to be the same, neither increasing nor decreasing in area.

The spatial pattern of the land cover in South Tambun District in 2013 can be seen that visually, the vegetation land classes are spread dominantly in the south and north and slightly in the east, center and west of the map. Then, the built-up land class is seen to have dominated almost the entire face of the map. Meanwhile, the class of water bodies is visible slightly to the east and south of the map. Furthermore, in 2017, it can also be seen visually that the vegetation land class has experienced a slight reduction in the southern and northern parts of the map, while the built-up land class seems to be increasingly spreading from the central area to the periphery areas, especially to the north and south areas. As for the water body class, it is still visible in the southern part of the map, although visually it looks like it is slightly reduced. Furthermore, in 2022, it can also be seen visually that the vegetation land has changed in the north and south of the map because these areas have turned into built-up land. while for built-up land cover it seems to dominate almost the entire face of the map, especially in the north and south due to the increasing number of conversions from vegetated land to built-up land. Then for the class of water bodies it still looks the same in the eastern and southern parts of the map which tend not to change during the three years of the study.

Table 3. Land Cover Changes in South Tambun District

Land Cover Changes	Area (Ha)
Water Bodies – Built Up Area	1,35
Water Bodies - Vegetation	0,04
Built Up Area - Water Bodies	0,27
Built-Up Land - Vegetation	57,55
Vegetation - Built-Up	164.025
TOTAL	**223,225**

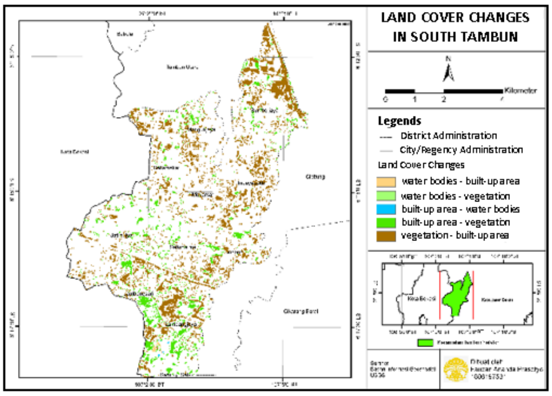


Figure 3. Land Cover Changes in South Tambun District

Changes in land cover as a whole for the research year, namely from 2013 – 2022, obtained the final results of five classes, consisting of classes of water bodies which became built-up lands symbolized in orange, bodies of water which became vegetation were symbolized in light green, built-up land became water bodies symbolized in blue, built-up land becomes vegetation symbolized by dark green and lastly vegetation becomes built-up land symbolized by light brown.

In Table 5.3. Of the 5 classes of land cover changes in South Tambun District from 2013 to 2022, the area varies greatly. The largest change in area occurred in the class of vegetation land cover into built-up land of 164.25 Ha. In second place, the most land change was found in the land cover class built into vegetation of 57.55 Ha. Following in third place is the class of water bodies into built-up land of 1.35 Ha. Furthermore, in fourth place, the change of built-up land into a body of water is 0.27 Ha, and in the last order there is a class of 0.04 Ha of water body into vegetation. From this, information is obtained that the most frequent change is the change from vegetation class to built-up land (symbolized in light brown on the map) with a change of 164.025 Ha during 2013 to 2022, then the least is the class of water bodies into vegetation of 0.04.

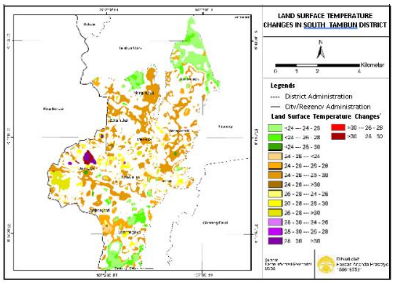


Figure 4. Land Surface Temperature in South Tambun District

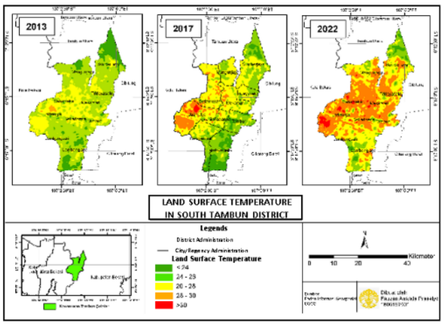


Figure 5. Land Surface Temperature Changes in South Tambun District

Land Surface Temperature Changes in South Tabun District

In Figure 5, it can be seen that there is a map of Land Surface Temperature in South Tambun District in 2013, 2017 and 2022 which has been classified into five classes, <24 ^{o}C which is symbolized by dark green, 24 ^{o}C to 26 ^{o}C which is symbolized by light green, 26 ^{o}C to 28 ^{o}C symbolized by yellow, 28 ^{o}C to 30 ^{o}C symbolized by orange, >30 ^{o}C symbolized by red.

In **Figure 5.** The above is a map of changes in land surface temperature in South Tambun District in each study year. Changes in land surface temperature that occur in South Tambun District can indicate an increase, decrease, and from time to time, in this case from 2013 to 2022. Figure 5.6. made to see changes in land surface temperature spatially by compiling a map of changes in land surface temperature in South Tambun District from 2013 to 2022 so that it can be known which land cover classes have changed and this data can be used as a reference for calculating changes in each each land surface temperature class.

In **Table 4.** below it can be seen that of the 15 classes of changes in land surface temperature in

South Tambun District from 2013 to 2022 have very varied areas. The largest changes in area occurred in the temperature class 24 - 26 °C to 26 - 28 °C of 768.33 Ha. Then the change in land surface temperature is the least, namely the temperature class of 29 – 30 °C to 24 – 26 °C of 0.27 Ha.

Table 4. Land Surface Temperature Changes in South Tambun District

Land Surface Temperature Changes °C	Area (Ha)
>24 -- 24 - 26	338,04
>24 -- 26 - 28	128,25
>24 -- 28 - 30	5,67
24 - 26 -- >24	18,18
24 - 26 -- 26 - 28	184,32
24 - 26 -- 28 - 30	768,33
24 - 26 -- 30<	7,29
26 - 28 -- 24 - 26	6,75
26 - 28 -- 28 - 30	96,66
26 - 28 -- 30<	82,44
28 - 30 -- 24 - 26	0,27
28 - 30 -- 26 - 28	11,25
28 - 30 -- 30<	18,27
>30--- 26 - 28	0,18
>30 -- 28 - 30	14,31
Total	**1.680,21**

Relationship of Land Surface Temperature with NDVI

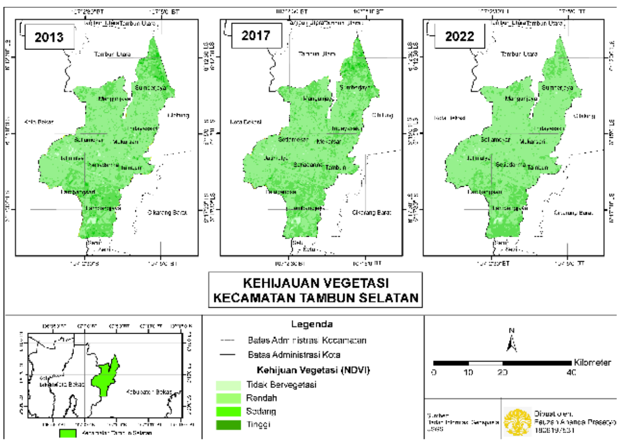


Figure 6. NDVI of South Tambun District

In **Figure 6.** there is a map of the greenness of the vegetation in South Tambun District which has 4 classes in it. For the non-vegetation class with an index value of -1 to 0.1, for the low density class with an index value of 0.1 to 0.2, for the medium density class with an index value of -0.2 to 0.3, and for high density class with an index value of >0.3.

In **Figure 6.** It can be seen visually that the high green class from 2013 experienced a significant reduction in 2017, even up to 2022.

Table 5. NDVI of South Tambun District

No	NDVI	Area (Ha)		
		2013	2017	2022
1	Non-Vegetation	586	348	258
2	Low	34404	34024	39262
3	Medium	12957	13762	9177
4	High	763	556	13

In **Table 5.** the high vegetation density class has decreased from 2013 to 2022 of 207 Ha, and this class has decreased again in 2017 to 2022 of 543 Ha. From Table 5.11. also obtained information that the low-density class always dominates in every three years of research, such as in 2013 amounting to 34404 Ha, 34024 Ha in 2017, and 39262 Ha in 2022. From the information the high vegetation density class experienced a total reduction of 750 Ha from 2013 to 2022 shows that there has been degradation of vegetation land which can certainly affect the value of land surface temperature in South Tambun District. This can be strengthened by the results of the linear regression test between land surface temperature values and NDVI in **Figure 7.**

Figure 7. Correlation of Land Surface Temperature with NDVI

The results of the simple linear regression test in this study produce a line equation Y = 0.3659 - 0.0052X in 2013, Y = 0.4727 - 0.0095X in 2017 and Y = 0.4181 - 0.009X in 2022 with the correlation coefficient is negative, namely 0.02 in 2013, 0.05 in 2017, and 0.08 in 2022, which means be concluded that the lower the greenness of the vegetation (NDVI value), the higher the land surface temperature value.

Relationship of Land Surface Temperature with NDBI

In **Figure 8.** there is a map of building density in South Tambun District which has 4 classes in it. For undeveloped classes with index values of -1 to 0, for low density classes with index values of 0 to 0.1, for medium density classes with index values of 0.1 to 0.2, and red is for high density classes with an index value of >0.2. In Figure 5.10. It can be seen visually that the high-density class has increased from year to year by spreading more and more in the center of the map to the entire face of the map. The same is true for the medium density class, which from year to year has also experienced an increase in area. Further to see the area of each building density class from year to year can be seen in **Figure 8.**

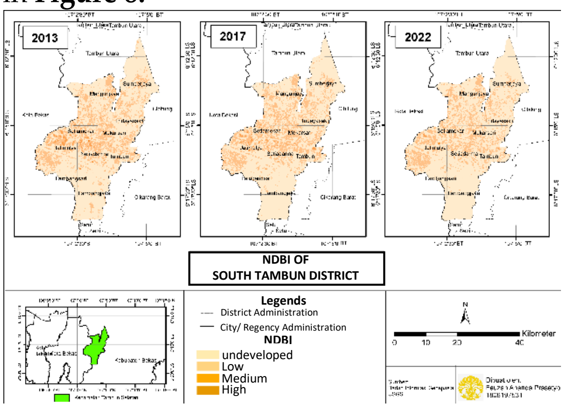


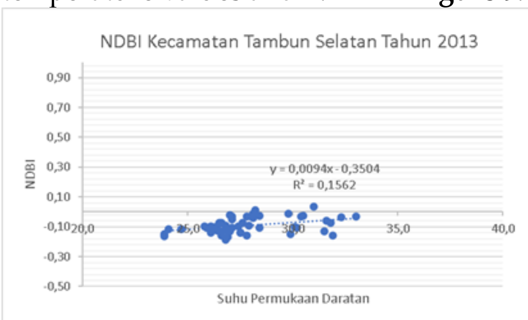
Figure 8. NDBI of South Tambun District

In **Table 6.** It can be seen that the high density class since the beginning of 2013 has indeed been very high and this class is getting higher from year to year because it continues to experience an increase in area, such as in 2013 to 2017 it experienced an increase in area of 320 Ha and from 2017 to 2022 increased by 2075 Ha. This again reinforces the fact that construction of built-up land in South Tambun District is increasing from year to year. From the information on the high density class of built-up land which has increased from 2013 to 2022, it indicates that there has been an expansion of built-up land, which of course can affect the value of land surface temperature in South Tambun District. This can be strengthened by the results of the linear regression test between land surface temperature values and NDBI in **Figure 9.**

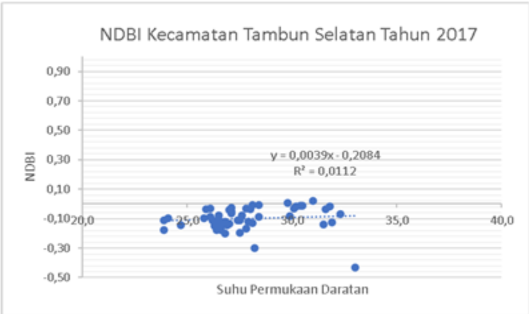
Table 6. NDBI in South Tambun District

No	NDBI	Area (Ha)		
		2013	2017	2022
1	Undeveloped	11	7	4
2	Low	589	431	97
3	Medium	11883	11725	9987
4	High	36227	36547	38622

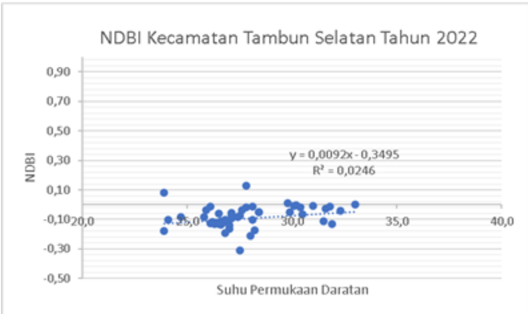
In **Table 6.** It can be seen that the high density class since the beginning of 2013 has indeed been very high and this class is getting higher from year to year because it continues to experience an increase in area, such as in 2013 to 2017 it experienced an increase in area of 320 Ha and from 2017 to 2022 increased by 2075 Ha. This again reinforces the fact that construction of built-up land in South Tambun District is increasing from year to year. From the information on the high density class of built-up land which has increased from 2013 to 2022, it indicates that there has been an expansion of built-up land, which of course can affect the value of land surface temperature in South Tambun District. This can be strengthened by the results of the linear regression test between land surface temperature values and NDBI in **Figure 9.**



Land Surface Temperature



Land Surface Temperature



Land Surface Temperature

Figure 9. Correlation of Land Surface Temperature with NDBI

The results of the simple linear regression test in this study produce a line equation Y = 0.0094x - 0.3504 in 2013, Y = 0.0039x - 0.2084 in 2017 and Y = 0.0092x - 0.3495 in 2022 with a positive correlation coefficient of 0.15 in 2013, 0.01 in 2017, and 0.02 in 2022, which means that the NDBI variable and land surface temperature produce a positive relationship. It can be concluded that the higher the building density (NDBI value), the higher the land surface temperature value.

Conclusions

South Tambun District has changed from year to year in terms of its land cover area and is dominated by changes from vegetation areas to built-up land areas. During the last 12 years, 425.7 Ha or 4730 grids of land has experienced land degradation. Then, the class of water bodies has also experienced land degradation of 4.5 Ha or 50 grids and the class of built-up land has experienced land expansion of 430.2 Ha or 4780 grids. Where if seen visually, the addition of built-up land spreads from the sub-district center to the outskirt areas and is dominant to the south and east and west of South Tambun sub-district.

The increase in built-up land has also resulted in an increase in land surface temperatures in South Tambun District with the lowest temperature in 2013 being 21.6 oC and the highest temperature of 29.2 oC changing to the lowest temperature of 24.1 oC and the highest temperature of 34. 5 oC in 2022. This change is related to changes in land cover in South Tambun District.

The relationship between land cover change and land surface temperature can be seen through the results of a correlation analysis between land surface temperature and green vegetation and building density. These results are, for the greenery of vegetation with land surface temperature produces a relationship that has a negative value. It can be concluded that the lower the greenness of the vegetation (NDVI value), the higher the land surface temperature value. And for, building density with land surface temperature produces a positive relationship. It can be concluded that the higher the building density (NDBI value), the higher the land surface temperature value.

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