Cover sheet

Assignment title:

Analyse the relationship between land surface temperature and land use of GBA area based on time series NDVI data: A case study of Guangzhou city

Programme:

CASA0005 – Geographic Information Systems and Science

Department:

The Bartlett Centre for Advanced Spatial Analysis

Appendix:

Download the code for this study:

Landsat 2013 code: https://rpubs.com/jinbai12/rmd2013

Landsat 2017 code: https://rpubs.com/jinbai12/gis_assignment

Landsat 2021 code: https://rpubs.com/jinbai12/rmd2021

File path:

https://drive.google.com/drive/folders/1pTAee3xhnkdsXQHqV3k9vjpAZDAvA7o2?usp=sharing

https://github.com/jj6666666/GIs-Assignment

Analyse the relationship between land surface temperature and land use of GBA area based on time series NDVI data: A case study of Guangzhou city

Introduction

The Guangdong-Hong Kong-Macao Greater Bay Area (abbreviated as GBA) is composed of two special administrative regions of Hong Kong and Macau and nine Pearl River Delta cities in
Guangdong Province (Lixun L, 2017), including Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing, with a total area of 56,000 square metersKilometers, with a total population of 70 million at the end of 2018, it is one of the most open andeconomically dynamic regions in China, and has an important strategic position in the overalldevelopment of China. This study will focus on Guangzhou city as a case study.

The normalized vegetation index is one of the important parameters reflecting is an indicator of vegetation productivity which can detect vegetation growth status, vegetation coverage and vegetationvitality, NDVI is calculated as the ratio of the difference between the reflection value of the near-infrared and the reflection value of the red visible light band isomer to the sum of the two(Tucker et al. 2005).The value range is between -1 and 1, the lower the value, the weaker thevegetation information, generally snow, water, and buildings; the higher the value, the stronger the vegetation information, generally forest, farmland and grassland.

This study is based on the importance of the development of the Guangdong-Hong Kong-Macao Greater Bay Area in China and the characteristics of normalized vegetation index that can express vegetation information. The case study is based on Guangzhou city, and it evaluates the changes in vegetation and non-vegetation areas' value in 2013, 2017, and 2021 these time nodes. It also investigating the relationship between NDVI, NDBI and land Surface Temperature （LST） in the Great Bay Area aiming to provide support for further Urban Heat Island studies within Guangdong and Greater Bay Area(Yang et al. 2019). As the "Belt and Road" region's need of decision support in construction and ecological environmental protection (Huang et al. 2020).

1. Research question

a. Is there a relationship between NDVI and LST in Guangzhou?
b. Is there a relationship between NDBI and LST in Guangzhou?

2 Literature review

Due to its important political, economic and geographic location, the Guangdong-Hong Kong-Macao Greater Bay Area has gradually developed into a key area of research. At present, the main
research includes spatial pattern research (Lixun L et al, 2021) and remote sensing feature change analysis (Chen Y et al, 2020). These studies mainly focus on the spatial analysis aspects that have been determined so far, and use moredata sources, and the method operation is cumbersome. Also, studies focus on specific cities within the large GBA are is rather less, main researches on Guangdong city focus on its thermal environment and urbanization.(Xiong Y et al, 2012) (Sun Q, et al 2012).

(Yang et al,2020) states that the regional difference of vegetation's growth condition, change process and its factors of influences is significant, therefore, relevant research on vegetation is needed to contribute to the improvement the ecological environment. However, the author states that the current understanding of Normalized Difference Vegetation Index (NDVI) of the Belt and Road region is unclear, the authors' results suggest the influencing factors of NDVI in different Belt and Road regions, however, these regions are considered on a country level geographic scale. Which suggest there is a significance in studying NDVI on a smaller scale, where Guangzhou, in Great Bay Area occurs to be one of the major regions that Belt and Road project considers.
According to (Yang et al. 2019). The proportion of vegetation and water area is negatively correlated with the surface temperature in the GBA's urban heat island region. Urban heat island affects aspects such as the air quality, local climate and energy consumption in the GBA, also, residences'' heath is affected as well. Therefore, there is a need to investigate the statues of urban temperatures in the GBA area, by studying the correlation between NDVI and LST data could be useful in this field of study. Research suggests that LST and NDVI values are generally correlated. (Kafatos M.2007) found that the correlation between LST and NDVI is positive for winter and negative during warm seasons.

(Sun Q, et al 2012) suggest that Guangzhou city, a major urbanisation development area within the GBA, its ecological environmental process is affected by urban heat islands. the study investigated Guangzhou's land surface temperature and its land use in 2005, which suggest that land use will affect the land surface temperature, also, NDVI with NDBI are effective indexes to study the relationship between vegetation and urbanisation in city build up area. Following this research, fowling the results arise from literatures, in this study, Guangzhou's NDVI will be calculated from 2013, 2017, and 2021, to update the relationship of Guangzhou's' land vegetation and land surface temperature. To investigate changes in Guangzhou's land use for supporting further research on mitigating Guangzhou's urban heat island and other environmental studies. The study also aims to support government's land use planning policy according to (Sun Q, et al 2012).

With the addition of the spatial location attribute, the Moran index is an important analysis index for analysing spatial autocorrelation (Epperson B K and Li T, 1996). Based on the analysis of the Moran index, the degree of aggregation of the space can be analysed and determined.Based on this analysis, this study explores the characteristics and rationality of Guangzhou's land use for supporting investigation on land surface temperature and vegetation.

3 Methodology

The analysis of the results achieved in this study is mainly through the following processes.

3.1 Study area and data collection

The study area Guangzhou (112° 57′ to 114° 03′ E longitude and 22° 26′ to 23° 56′ N latitude) is located in southern China, and it is the largest city within the Great Bay Area, with total area of 7,434,40 km^2, with build-up area straight connect to other cities. This city is also an important economical centre not only in Great Bay Area, but also in China, with GDP approximately 2.5 trillion yuan in 2020(*GDP: Guangdong: Guangzhou CEIC*, 2021. The city has 12.78 million population with population density of 1,800 people per km$^{2.}$ which makes it necessary to investigates its LST and vegetation area's relationship aiming to support government planning and studies on Urban Heat Island effect in this area.

Currently free remote sensing data includes Landsat series, modis series and sentinel series, butconsidering the resolution of the data and the use time of the data, landsat8 OLI level 1 is selected as the data acquisition source. In the process of using remote sensing data, there are problems of data splicing and colour difference and the existence of clouds, causing about 50% of the data to be invalid data. Based on this problem, data selected for this study are the winter's data from 2013, 2017, and 2021, as china's southern winter generally shows the best data quality (the NDVI value of clouds is low, and the NDVI value of vegetation is high).The data was downloaded form the usgs's earth explorer website. :https://earthexplorer.usgs.gov/.

The downloaded data can be found on google drive:
https://drive.google.com/drive/folders/1pTAee3xhnkdsXQHqV3k9vjpAZDAvA7o2?usp=sharing

3.2 Calculate LST

$$\lambda = \text{Grescale} \times \text{QCAL} + \text{Brescale} \quad (1)$$

$$T_b = K_2 \times \ln\left[\left({}^{K_1}/_{\lambda}\right) + 1\right] \quad (2)$$

$$F_V = (NDVI_{min} - NDVI_{min} \times NDVI_{max} - NDVI_{min})^2 \quad (3)$$

$$\varepsilon = 0.004 \times F_v + 0.986 \quad (4)$$

$$\text{LST} = T_{b1} + \frac{\lambda_\rho \times T_b}{p} \times \ln \varepsilon \quad (5)$$

$$p = \frac{h \times c}{\varrho} \quad (6)$$

- h which is Plank's constant $6.626 \times 10{-}34 Js 6.626 \times 10{-}34 Js$
- c which is the velocity of light in a vaccum $2.998 \times 10^8 m/sec 2.998 \times 10^8 m/sec$
- ϱ which is the Boltzmann constant of $1.38 \times 10{-}23 J/K$
- λ which is the effective wavelength of our data (10.9 for Landsat 8 band 10)
- ε emissivity
- T_b Brightness Temperature

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)} \quad (7)$$

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (8)$$

3.3 Data processing and mapping

Using Landsat8 OLI images in 2013, 2017, and 2021 as source data, NDVI, NBVI and LST maps of the corresponding years in Guangzhou were drawn. These maps were used to perform trend change analysis and correlation analysis. The drawing process is as follows:
1. Perform batch cropping on all images using the right number of boundaries in the Guangzhou area, and get Landsat8 OLI images that only include the Guangzhou area.
2. Use the raster calculator of QGIS software to complete the calculation of NDVI, NBVI, LST, and get the pixel-by-pixel NDVI, NBVI, LST map of Guangzhou. It is worth noting that the colour bars of NDVI and NDBI are linear sampling from -1 to 1, so the value can be judged according to the colour. However, the LST colour system is independent, and the trend needs to be visually determined based on the respective colour bar information and map colours.
3. Use QGIS's image editing tools to complete the post-processing of the pictures to meet the basic information requirements.

3.4 Correlation analysis

Our research used the R language function package and calculated the NDVI and NBVI (see formulas (7– 8) for details) maps of Guangzhou urban area for many years based on Landsat8 OLI multispectral data. In addition, we used Landsat8 OLI multispectral data to achieve the inversion of the land surface temperature (LST, which was calculated by formulas (1–6)) in Guangzhou. LST data is used to perform correlation statistics with NDVI and NBVI. Therefore, for different years, the pixel-by-pixel LST and NDVI and NBVI from Guangzhou City of Landsat8 OLI images were extracted, and then we drew a scatter plot between the LST and NDVI and NBVI corresponding to each pixel. The Pearson correlation coefficient (R) is used to quantify the level of correlation between LST and NDVI and NBVI.

4 Results

4.1 Trend analysis of NDVI

Figure 1 shows the changing trend of NDVI in Guangzhou from 2013 to 2021. It can be seen from Figure 1 that the NDVI of Guangzhou City showed a trend of increasing first and then decreasing during the three-year period. From 2013 to 2017, NDVI has increased significantly, with the highest value rising to 0.5963 and the lowest value rising to -0.1867, which indicates that Guangzhou has shown a clear green trend in the first five years. However, Guangzhou's NDVI between 2017 and 2021 has shown a significant downward trend. It can be seen intuitively that the green part of the figure (2021) has been significantly reduced. In addition, the highest value of NDVI has dropped significantly compared with 2017, which is close to 0.1 (about 20%). This shows that the greening of Guangzhou has received serious disturbances until it declines, and this change is likely to be related to the acceleration of the urbanization process of Guangzhou.

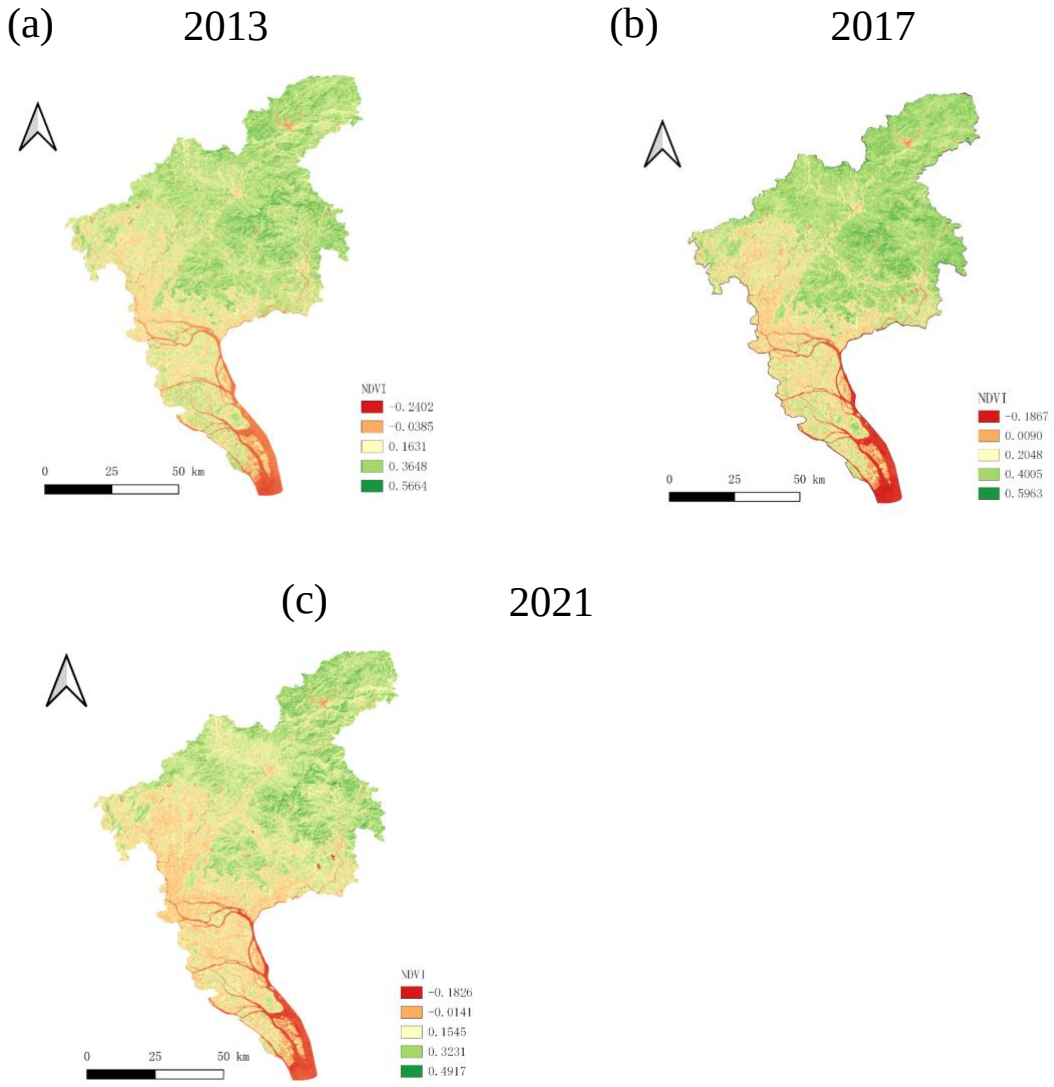


Figure 1. The NDVI map of Guangzhou for 3 years (2013, 2017, 2021). NDVI is divided into 5 grades and marked with different colours.

4.2 Trend analysis of NDBI

Figure 2 shows the changing trend of the NDBI chart of Guangzhou in three years (2013, 2017, 2021). It can be seen from Figure 2 that the NDBI in Guangzhou City has shown an upward trend (the colour turns green) during the three years. The high-value areas of NDBI can reflect the densely built-up areas in Guangzhou, while the low-value areas are the opposite. From 2013 to 2017, the NDBI in the upper half of Guangzhou did not change much, and the NDBI in the lower half showed a slight increase, which to a certain extent reflects the slow urbanization process of Guangzhou. The suburbs are basically undeveloped, while the urbanization is undergoing a slow process of urbanization. From 2017 to 2021, Guangzhou's NDBI showed a sharp increase, and the trend of turning green in Figure 2 is very obvious.

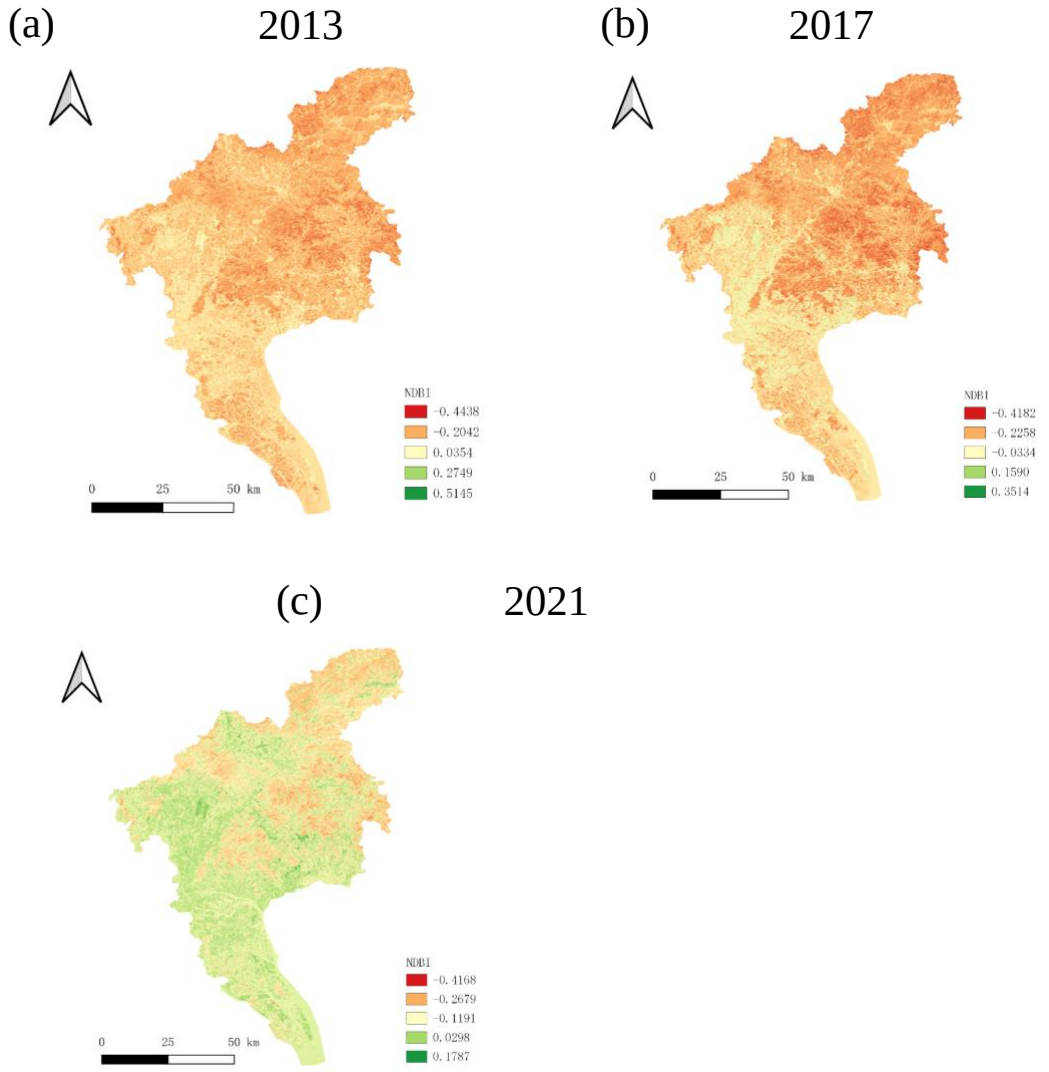
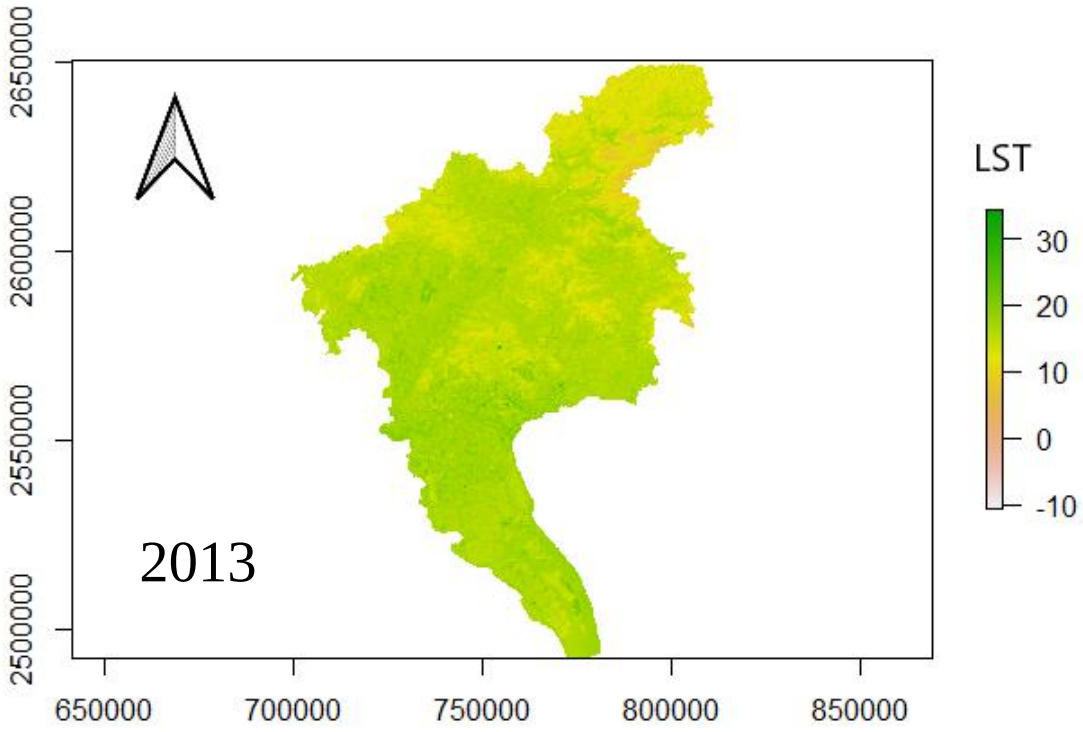


Figure 2. The NDBI map of Guangzhou for 3 years (2013, 2017, 2021). NDBI is divided into 5 grades and marked with different colours.

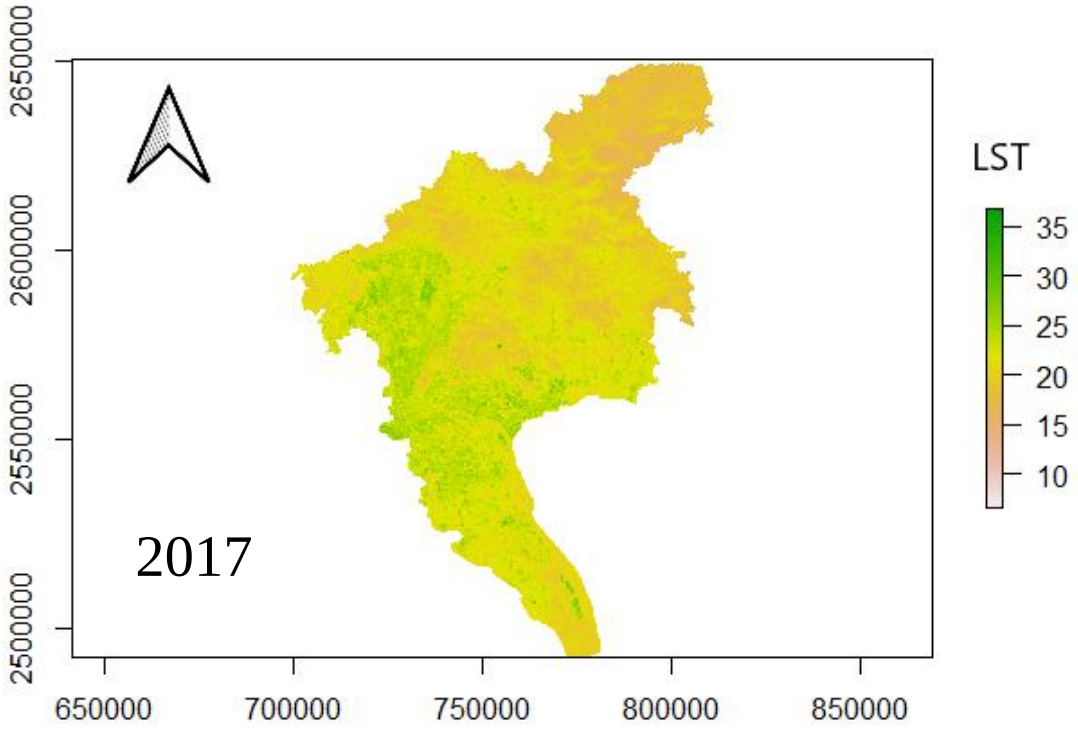
4.3 Trend changes in LST

Figure 3 shows the changing trend of LST in Guangzhou in 3 years. Observing the annual LST colours and their corresponding values in Guangzhou City, we can see that the temperature in Guangzhou City has shown an upward trend in the three years. Although there are more green parts in 2013 (Figure 3(a)), its colour bar represents a lower value, so it has a lower temperature. From 2013 to 2017, the temperature in Guangzhou has changed significantly, with the highest value rising by nearly 5 degrees Celsius. From 2017 to 2021, the temperature in Guangzhou City has not changed much, and the overall trend is higher.

(a)



(b)


2650000
2600000
2550000
2500000
650000
700000
750000
800000
850000
2017
LST
35
30
25
20
15
10

(c)

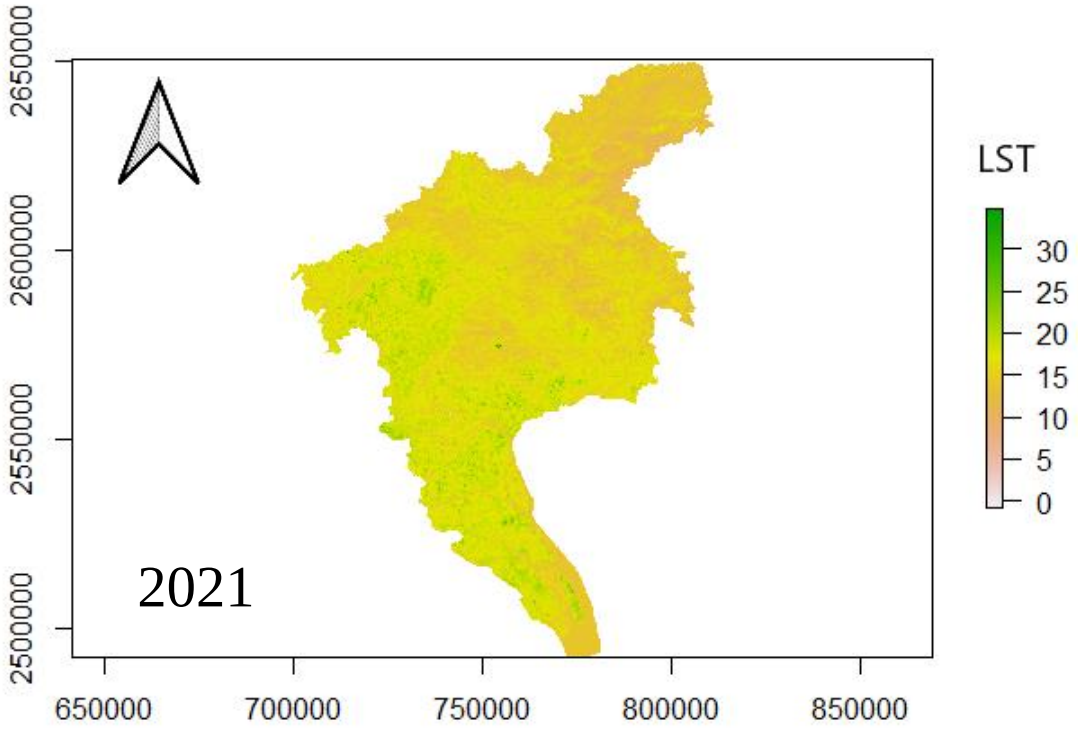
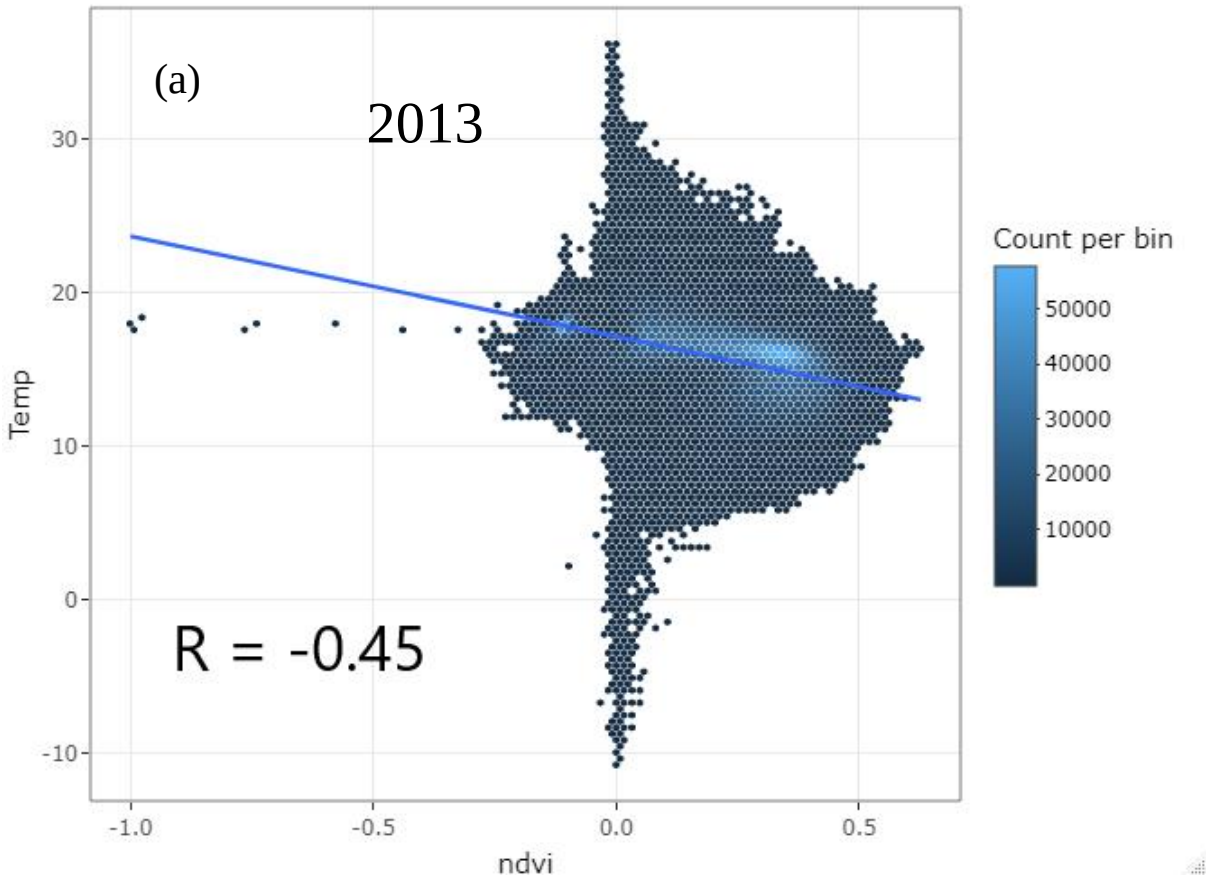
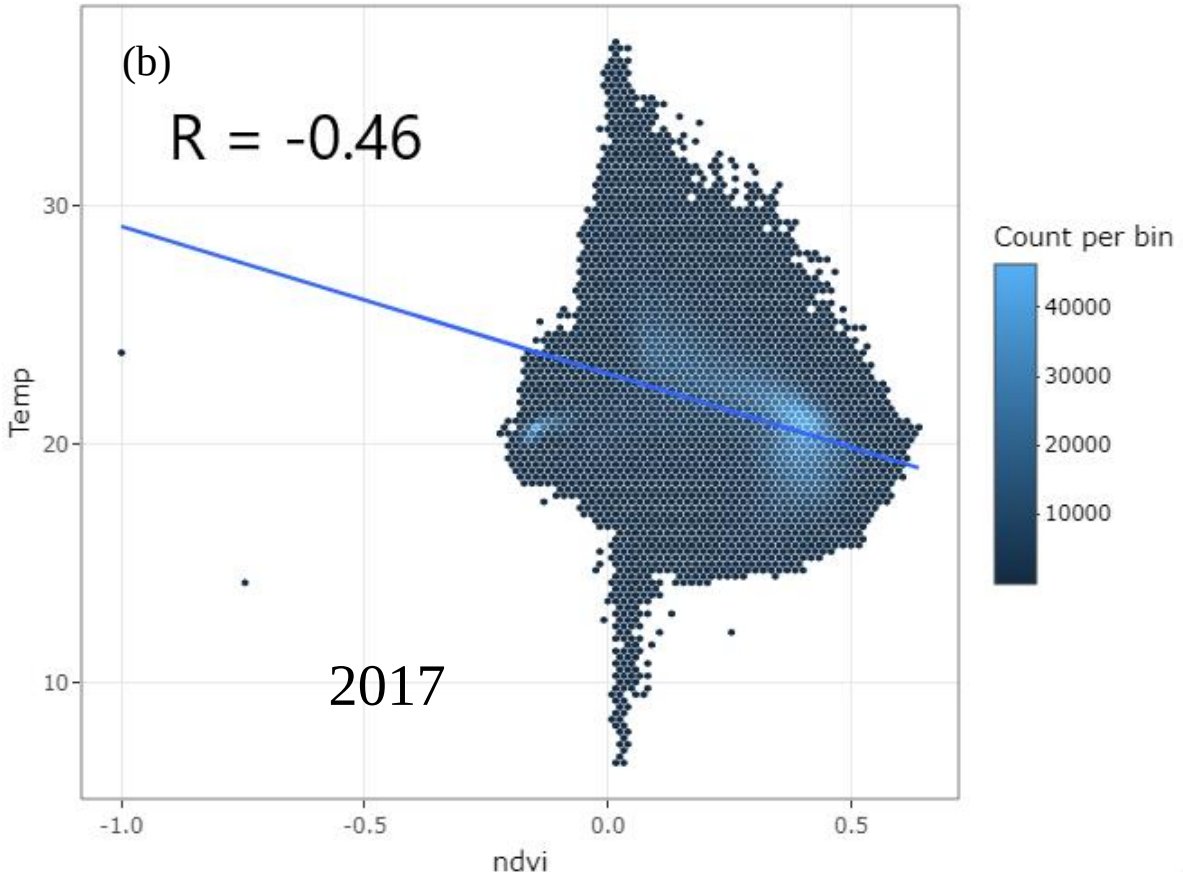

2650000
2600000
2550000
2500000
650000
700000
750000
800000
850000
2021
LST
30
25
20
15
10
5
0

Figure 3. The LST map of Guangzhou for 3 years (2013, 2017, 2021), different LST levels are marked with different colours.

4.4Correlation analysis between NDVI and LST

Figure 4 shows the results of the correlation analysis between NDVI and LST for 3 years in Guangzhou. It can be seen from the figure that between 2013 and 2017, the correlation between NDVI and LST in Guangzhou City weakened, and the absolute value of R decreased from 0.45 to 0.31. In addition, there is an obvious negative correlation between NDVI and LST, that is, a decrease in NDVI will cause a corresponding decrease in LST.




(b)
R = -0.46
2017
Temp
ndvi
Count per bin
40000
30000
20000
10000
30
20
10
-1.0
-0.5
0.0
0.5

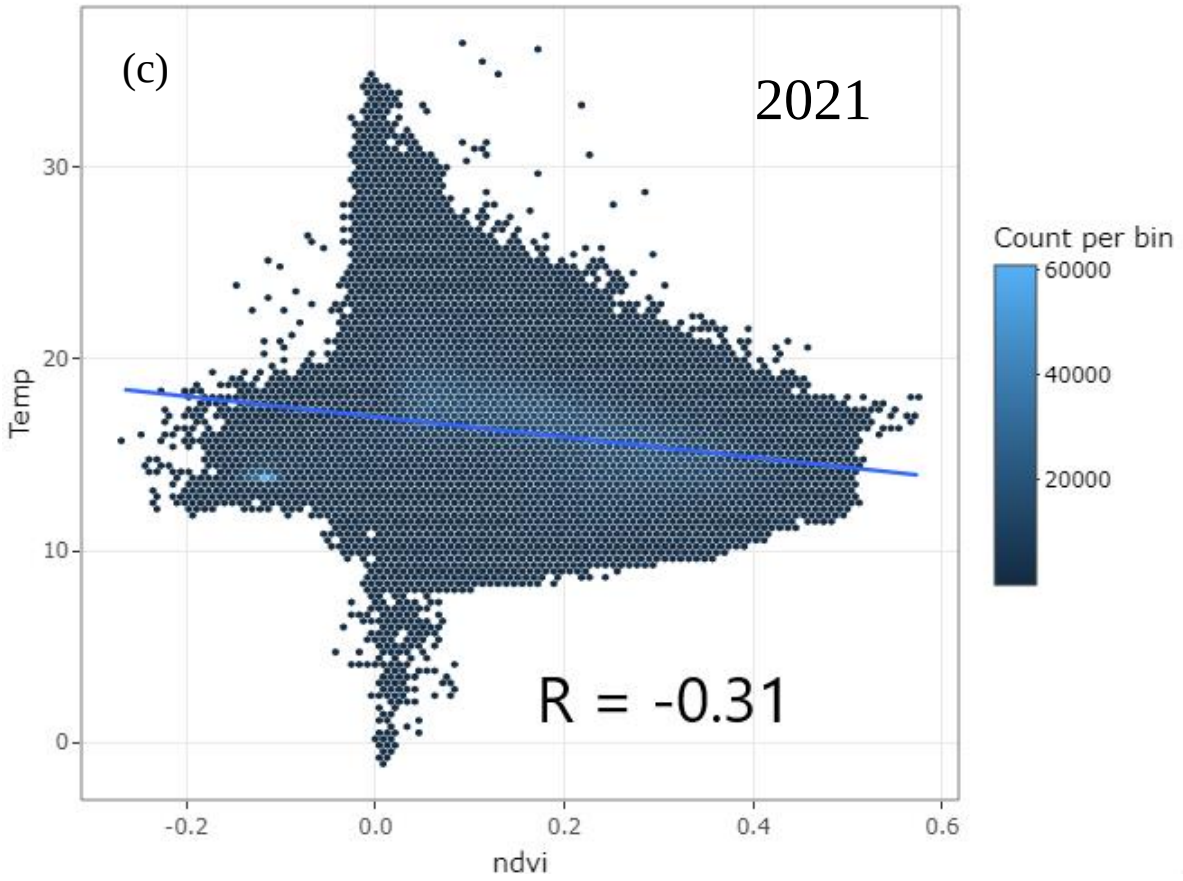
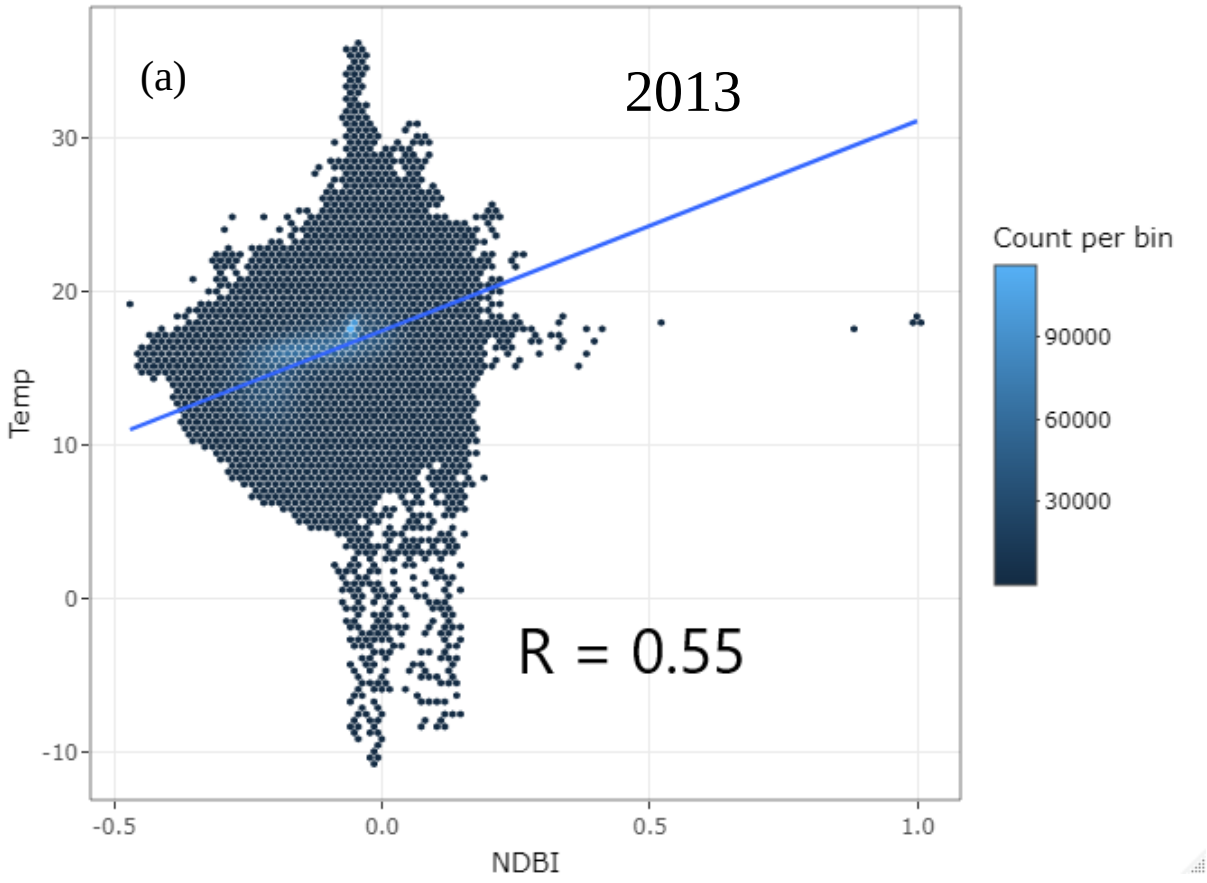
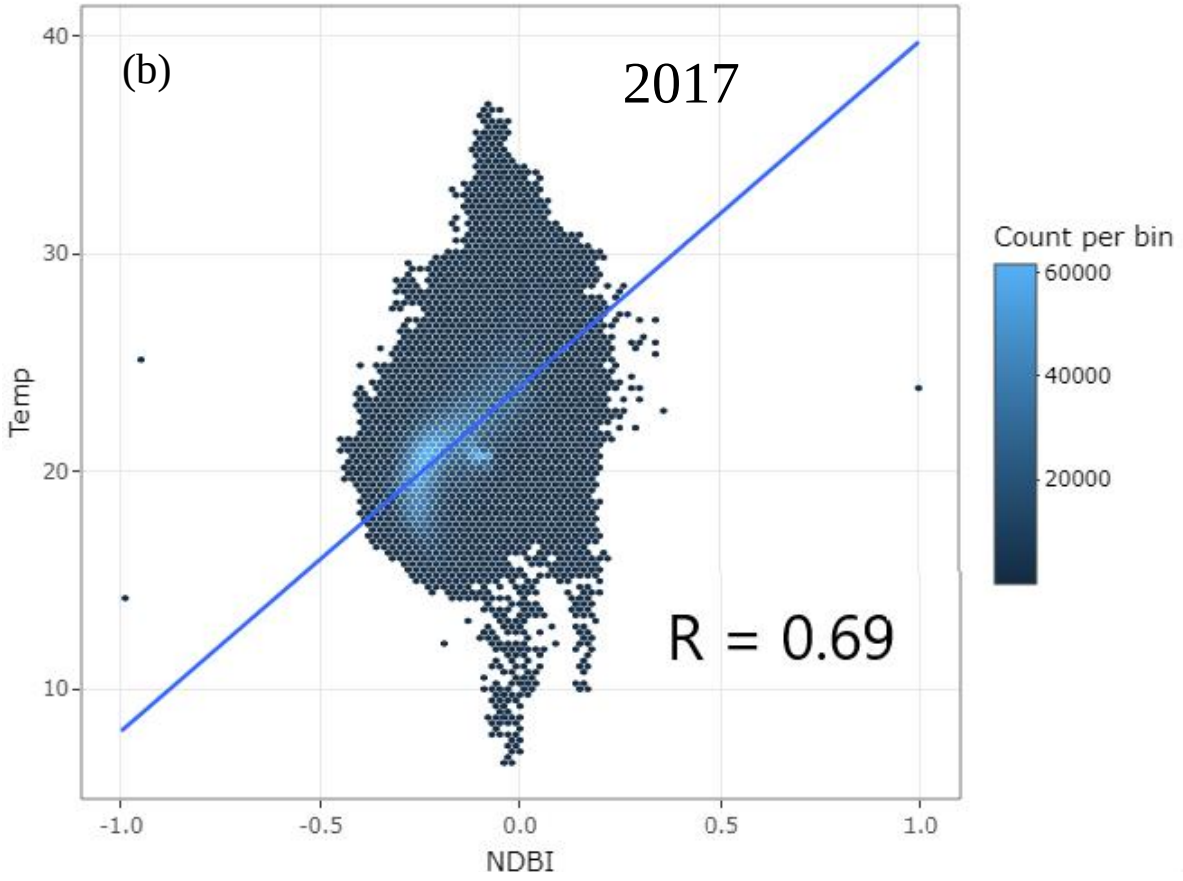

(c)
2021
R = -0.31
Temp
ndvi
Count per bin
60000
40000
20000
30
20
10
0
-0.2
0.0
0.2
0.4
0.6

Figure 4. Scatter plots of NDVI and LST in Guangzhou for 3 years (2013, 2017, 2021). Different dot densities are marked with different colours.

4.5Correlation analysis between NDBI and LST

Figure 5 shows the results of the correlation analysis between NDBI and LST in Guangzhou over 3 years. It can be seen from Figure 5 that the correlation between NDBI and LST in Guangzhou City showed an overall increasing trend during the three years, with R increasing from 0.55 to 0.6. There is a clear positive correlation between NDBI and LST, which shows that the increase in NDBI will be accompanied by a corresponding increase in LST. In other words, the huge increase in the construction area of Guangzhou will largely be accompanied by an increase in LST.




(b)
2017
R = 0.69
Temp
NDBI
Count per bin
60000
40000
20000
40
30
20
10
-1.0
-0.5
0.0
0.5
1.0

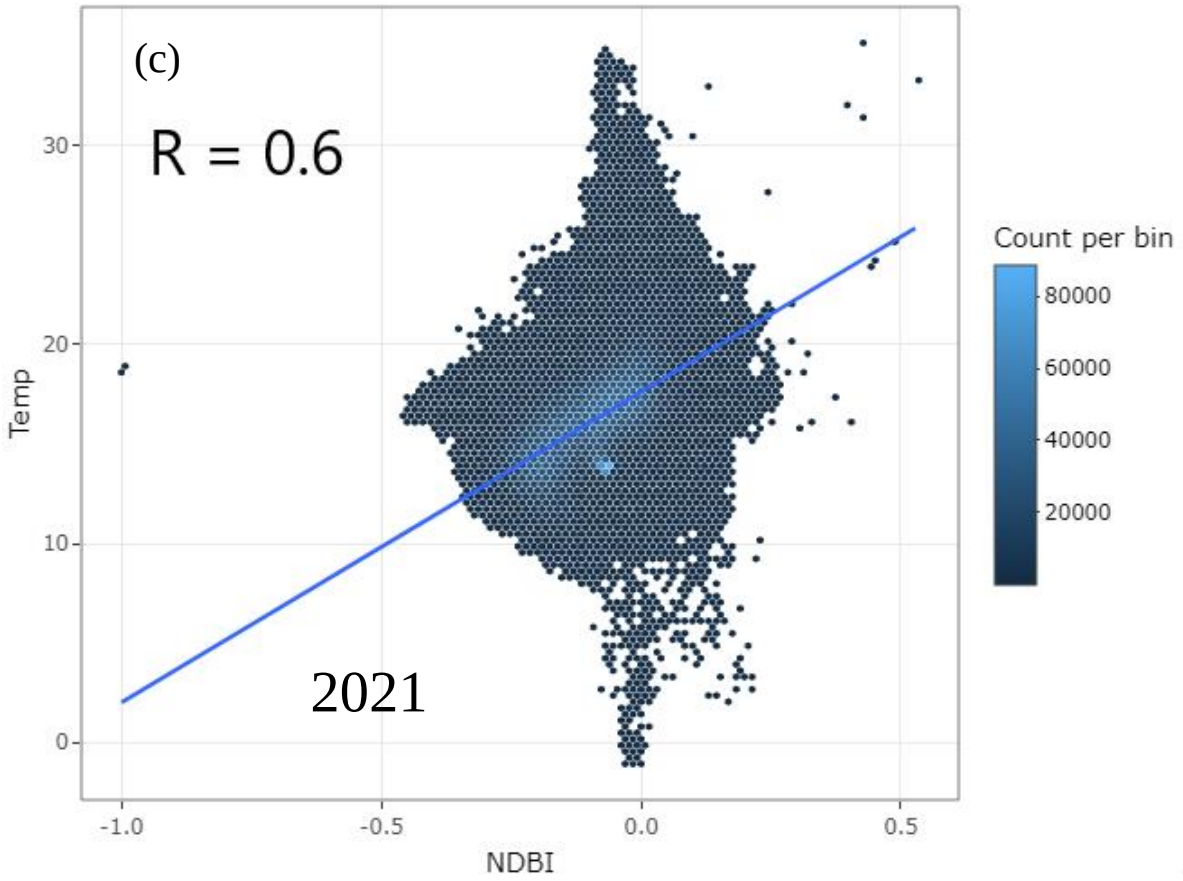

(c)
R = 0.6
2021
Temp
NDBI
Count per bin
80000
60000
40000
20000
30
20
10
0
-1.0
-0.5
0.0
0.5

Figure 5. Scatter plots of NDBI and LST in Guangzhou for 3 years (2013, 2017, 2021). Different dot densities are marked with different colours.

5 Discussions

5.1 The relationship between NDVI and NDBI

As can be seen from Figures 1 and 2, there is a certain connection between NDVI and NDBI in Guangzhou. NDVI represents the vegetation coverage and environmental carrying capacity to a certain extent, while NDBI represents typical human activities to a certain extent. Many studies have shown that the impact of human activities on the natural ecology cannot be ignored. Figures 1 and 2 clearly show that an increase in NDBI will correspondingly decrease NDVI. Especially in the main urban area with rich human activities (that is, the lower half of the figure), NDBI has increased significantly, and NDVI has also shown a significant decline. This shows that the huge increase in construction area will bring a great burden to the ecological environment, and the most direct impact of this is the obvious decline in vegetation coverage. And this impact will not be endless, urbanization can develop together with vegetation coverage to a certain extent. Appropriately increasing the green area can alleviate the destruction of vegetation caused by urbanization to a certain extent.

5.2 Synergy of NDVI and NDBI on LST

It can be concluded from Figures 4 and 5 that both NDVI and NDBI will have a certain impact on the changes in LST. Obviously, NDVI has a small impact on LST ($R<0.5$), while NDBI has a large impact on LST ($R>0.5$). In other words, the increase in vegetation coverage can avoid excessive temperature to a certain extent, but urbanization has a clear destructive effect on this model. Take Guangzhou as an example. The increase in building density (increased NDBI) increases the correlation between NDBI and LST, while the correlation between NDVI and LST greatly decreases.

6 conclusion

Taking Guangzhou as an example, this study studied the potential connection between NDVI and NDBI, as well as their individual and synergistic effects on LST, which can provide some unique and meaningful insights into the sustainable development of man and nature. Based on the research results, we have reached the following conclusions: (1) There is a significant negative correlation between NDVI and NDBI, and the increase in NDBI is accompanied by a decrease in NDVI to a certain extent; (2) NDVI and LST show a negative correlation. There is a positive correlation between NDBI and LST, but the impact of NDBI on LST is more severe (R between NDVI and LST below 0.5, and R between NDBI and LST above 0.5).

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Declaration of Authorship

I, [Jinjin Bai], confirm that the work presented in this assessment is my own. Where information has been derived from other sources, I confirm that this has been indicated in the work.

[Jinjin Bai]

Date of signature: 05/10/2021

Assessment due date:05/10/2021