

Application of Remote Sensing Technology in Heat Island Effect of Major Cities in Fujian Province

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Abstract. Remote sensing technology has many advantages for the investigation of the urban heat island (UHI) effect. Firstly, remote sensing technology is real-time and dynamic, which can monitor the change of environment in real-time. Secondly, remote sensing technology has low cost and high efficiency, which saves a lot of manpower and material costs. Finally, remote sensing technology has accuracy and reliability, which provides scientific basis for environmental monitoring. Focusing on the UHI in Fujian Province, this paper introduces the data, sources and methods of remote sensing technology, and discusses the features and determinants of the UHI effect in Pingtan Island, Xiamen City and Fuzhou City. In the evaluation of land surface temperature (LST), the remote sensing image data of Landsat5 and Landsat8 are obtained firstly, and LST inversion method is used to obtain. It is found that underlying surface properties are changed by human activities, such as reclamation activities and changes in land use types, increases the mean surface temperature in Fuzhou, Xiamen and Pingtan Island, which intensifies the UHI effect. Based on the research review, relevant suggestions are put forward for city managers. In the process of urbanization, city managers should pay attention to the economy and ecology development, and take relevant measures, such as increasing the urban green space, optimizing the layout of green space, improving the property of urban underlying surface, and improving the surface reflectivity, to alleviate the UHI effect.

Keywords: Remote Sensing Technology; Urban Heat Island Effect; Fuzhou; Land Use Change.

1. Introduction

The urban heat island effect (UHI) refers to the increased temperature in urban areas due to the concentration of buildings and human-induced activities, marking a distinct feature of city climates. Human activities, such as the emission of greenhouse gases like carbon dioxide and man-made heat sources, could change the urban underlying surface. It leads to the temperature in cities considerably greater than that in suburbs [1], which greatly intensifies the UHI effect. The intensification of UHI effect further leads to air pollution, heavy precipitation, ecological environment damage and other serious problems.

The main research methods of UHI include weather station method, remote sensing method and numerical simulation method [1]. Many experts and scholars in our country have used these methods to study UHI. Xie et al. processed and calculated the obtained data by using statistical methods such as linear regression to analyze the temporal and spatial distribution of UHI intensity in Jinjiang, Fujian [1]. Miao Shiguang et al., by using digital simulation method, simulated the atmospheric boundary layer effect of UHI. The distribution of UHI in Jinjiang, Fujian Province was analyzed [1].

Remote sensing (RS) technology is a field of technology that collects information about the earth's surface and atmosphere from aircraft, satellites, or other platforms far away from the earth through different types of sensors to achieve non-contact and long-distance monitoring of the surface and atmosphere [2]. Remote sensing technology has many advantages for the review of UHI impact. Firstly, remote sensing technology is real-time and dynamic, which can monitor the change of environment in real time. Secondly, remote sensing technology has low cost and high efficiency, which saves a lot of manpower and material costs. Finally, remote sensing technology is accurate and reliable, providing scientific basis for environmental monitoring [3].

Located on the southeast coast of China, Fujian Province is a mountainous and river-rich province with abundant natural resources. However, in recent years, Fujian has experienced rapid economic

development, increased industrial activities, and increased energy consumption, resulting in an increase in greenhouse gas emissions. At the same time, because Fujian is mountainous and most cities are distributed along rivers and valleys, it is not conducive to air flow and aggravates the UHI effect in Fujian [2]. The intensification of UHI effect in Fujian Province is not conducive to human production activities [3]. As a result, analyzing the UHI effect in Fujian Province through remote sensing technology is of significant importance.

This study summarizes, collects and analyzes the remote sensing information of major cities in Fujian Province in recent years, analyzes the spatial and patterns of temporal distribution and contributing factors of the UHI effect in Fujian province in accordance with the surface temperature change. This study also proposes countermeasures and suggestions for city managers to mitigate the UHI effect in Fujian Province taking into account the distribution and impact factors of the UHI effect.

2. Background of Fujian Province

Fujian occupies the southeastern seaboard of China. It borders Zhejiang to the north and Jiangxi to the northwest, while to the south and west it is flanked by Guangdong. Additionally, it is situated across the Taiwan Strait from Taiwan. The terrain of the Fujian is high in the northwest and low in the southeast, showing a situation of mountain and sea. About 90% of the province are covered by mountains and hills, with 124,000 square kilometers of land areas and 136,000 square kilometers of sea areas.

Fuzhou City, Xiamen City and Pingtan Island have different performances on UHI effect. As the provincial capital city, Fuzhou has a large amount of population and dense buildings, which leads to obvious UHI effect. Xiamen city also has high degree of urbanization, but it is a coastal city, the regulating effect of sea breeze makes the UHI effect relatively weakened. Resulting from the late development of Pingtan Island, low degree of urbanization, high vegetation coverage, weak UHI effect and natural temperature change.

3. Data Source and Methodologies in UHI research

3.1. Data Source

In Fujian Province, the commonly used remote sensing data mainly includes Landsat8 and Landsat5 images. The data comes from Landsat images covering Fuzhou and its surrounding areas with good imaging quality, which can be used for surface temperature monitoring. Landsat8 OLI images, LandSAT5tm images of Pingtan Island and the vector data of the administrative divisions of Fuzhou, Fujian Province, supplemented by the functional zoning diagram of Pingtan Island. Based on the ENVI platform, Landsat8 satellite images and Landsat5 satellite images were selected to analyze the land surface temperature (LST) change in Xiamen region.

3.2. Data Processing Methods

Multiple remote sensing data images such as Landsat8 OLI image [4] and Landsat5 TM image [5] are commonly selected to invert LST by remote sensing method and reflect the change of LST in Fujian Province.

The main algorithms for surface temperature inversion can be divided into the following three types: single channel, split window and atmospheric correction algorithm (radiative transfer equation) [6]. In this study, the atmospheric correction method is applied for calculating and recovering surface temperature. After the remote sensing image is preprocessed, the surface specific emissivity and radiation brightness value are calculated, and the surface temperature inversion results are obtained by using Planck formula. The main formulas used in the inversion process are as follows:

3.2.1. Calculation of surface specific emissivity

Surface specific emissivity (ϵ) is the ratio of surface radiation and blackbody radiation at the same temperature, which is used to characterize the emission capacity of the surface of an object and is a necessary parameter for retrieving surface temperature [6].

$$\epsilon = 0.004\rho v + 0.986 \quad (1)$$

where ρv refers to the vegetation coverage. Landsat8 contains two thermal infrared bands, and the atmospheric transmittance value of TIRS Band10 is more accurate than that of TIRS Band11. Therefore, the TIRS Band10 band is selected for surface temperature inversion in this paper.

3.2.2. Calculation of radiation brightness

Radiation brightness (B) can be obtained by the following formula [6]:

$$B = \frac{L\lambda - L_u - \tau \times 1 - (1 - \epsilon)L_d}{\tau \times \epsilon} \quad (2)$$

where L_u , L_d and τ are the atmospheric correction parameters, and these three parameters (atmospheric radiation brightness and atmospheric transmittance) are calculated through the website of NASA atmospheric correction parameters (<https://atmcorr.gsfc.nasa.gov>) can be queried, $L\lambda$ refers to the thermal infrared radiation value, ϵ refers to the surface specific emissivity.

3.2.3. Calculation of land surface temperature

LST could be calculated by Planck formula [6]:

$$LST = \frac{K_2}{\ln\left(\frac{K_1}{B} + 1\right)} \quad (3)$$

where K_1 and K_2 are $774.89W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$ and $1321.08K$, respectively, as the remote sensing data used in this study are all Landsat8 OLI_TIRS images.

4. UHI Characteristics and Impact Factors in Fujian Province

4.1. UHI Characteristics and Impact Factors in Ping Tan Island

The LST change of Ping Tan Island could be obtained by selecting Landsat OLI images and Landsat 5tm images of Ping Tan Island and using the LST inversion method [2]. Based on the surface temperature, heat islands are classified into five degrees from weak to strong: green, weak, middle, strong and extremely strong (Fig. 1).

The UHI in Ping Tan Island shows that most of Ping Tan Island is Middle UHI, with Strong UHI and Extremely strong UHI in the inland part, and Green UHI in some coastal areas. As time goes by, the proportion of extremely strong UHI increases greatly, while that of Middle UHI decreases.

It indicates that after reclamation activities on Ping Tan Island, the green islands in the original sea area are sharply reduced, while the areas of strong and extremely strong UHIs are increased. The nature change of the underlying surface can both exacerbate and alleviate the UHI effect. With the process of urbanization, the most significant change in scope and degree is in the artificial reclamation area. Due to the temporary wasteland after reclamation, a large area of forest and grass land is generated in the sea area of Houyu, so that the green island in the reclamation area is mostly transformed into a medium UHI, while the area near the ocean is only transformed into a mild UHI or even a green island. Therefore, it can be seen that vegetation cover contributes significantly to alleviating UHI effect [7].

This analysis of Ping Tan Island's LST and UHI classification reveals the complex interplay between urbanization, reclamation activities, and the resulting UHI effects. The transformation of coastal and marine environments into reclaimed land has led to a noticeable shift in the distribution

of UHIs, with a significant increase in areas classified as strong and extremely strong UHIs. This trend underscores the importance of managing land use changes carefully, particularly in sensitive coastal regions.

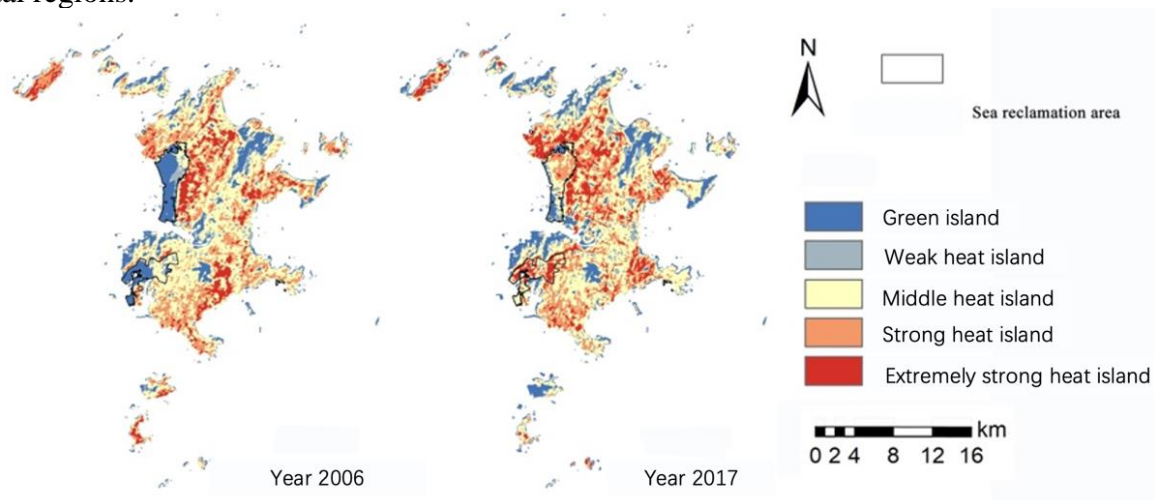


Fig. 1 Heat island classification distribution map of Ping Tan Island from 2006 to 2017 [2]

4.2. UHI Characteristics and Impact Factors in Xiamen and Fuzhou Cities

For Xiamen City and Fuzhou City, Landsat8 and Landsat5 satellites were selected. The land types are divided into four main categories. The first category is urban and rural construction land, which is referred to as construction land in the paper. The second category is urban and rural bare land, hereafter referred to as bare land; The third type of urban and rural green land and farmland, hereafter referred to as green farmland; The fourth category is water.

Through the land classification method and the data statistical function of arcgis platform, the respective change rules can be obtained. The spatial analysis tool of arcgis platform was used to extract land use in remote sensing images of Fuzhou and Xiamen respectively according to the above four types. The land use was extracted by mask. According to different land use attributes, the land use temperature pattern change in corresponding years were extracted, and the relationship between land use types and land use temperature was determined by the obtained data.

As can be seen from the LST values of different types of land, in the change projects of Fuzhou and Xiamen in recent years, different land uses also maintain similar change rules, in which the maximum and average surface temperature of bare land and construction land are both larger (Fig. 2). It can be inferred that the overall order of LST of the four types of land involved in the above figure from high to low is construction land > bare land > green space > water body [5]. Therefore, the rapid urbanization process has played a role in promoting the intensification of UHI effect. The transformation of green and bare land into construction land increases the surface temperature and intensifies the UHI effect [7].

The impact of vegetation coverage on surface temperature shows negative correlation [8]. With coverage, vegetation has an increasingly strong cooling effect on LST [8]. Water area also exerts a significant influence on the UHI effect, and the surface temperature decreases as the proportion of water area increases [9]. From this, we can know that the UHI effect of Fuzhou and Xiamen is more important because of the urban land use type. Due to the urbanization of Fuzhou and Xiamen, the land use type changes, the proportion of green space and water decreases, and the construction land increases, resulting in the intensification of UHI effect of Fuzhou and Xiamen. Therefore, in order to mitigate the UHI effect, the land use type can be changed, the proportion of green space and water body can be increased, and the proportion of construction land can be reduced [10]. Increasing vegetation coverage not only enhances the cooling effect on the land surface but also contributes to improved air quality and ecological balance in urban areas. Additionally, the expansion of water bodies within cities can further moderate temperature fluctuations, providing a cooling buffer against the intense heat generated by dense urban infrastructure.

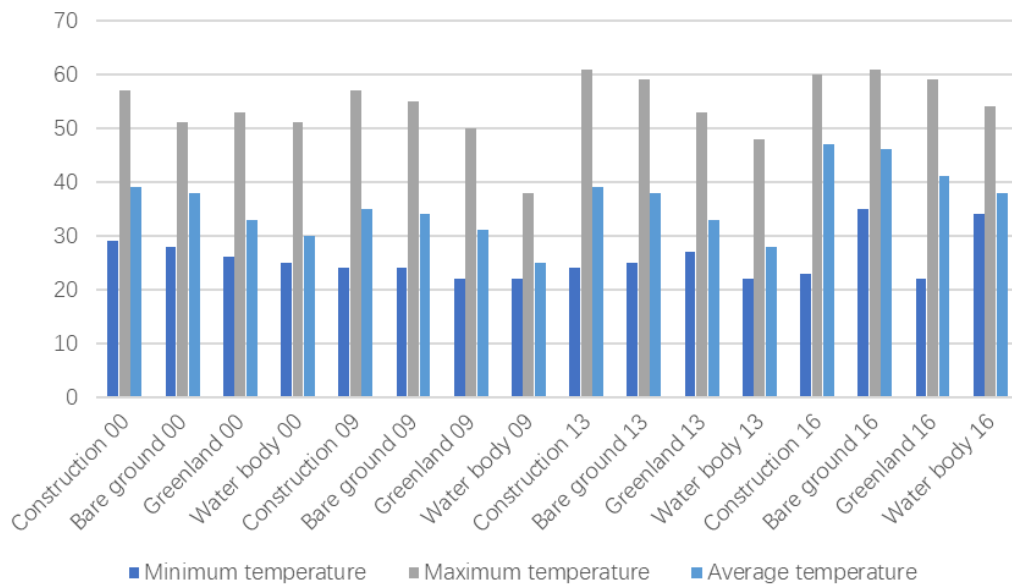


Fig. 2 Annual analysis of LST corresponding to four types of land use in Xiamen [5]

5. Conclusions

The research methods of UHI mainly include weather station method, remote sensing method and numerical simulation method, and the research data mainly include Landsat8 and Landsat5 remote sensing satellite images.

As for the UHI effect of Pingtan Island, the artificial reclamation project has dramatically changed the coastline of Pingtan Island, which not only significantly enhanced the UHI effect of the reclamation area, but also reduced the area occupied by water bodies and increased the area occupied by construction land due to the change of land use type, which has changed the UHI type of the nearby area to varying degrees. Artificial reclamation activities have changed the original underlying surface of Pingtan Island and intensified the generation of UHI. The UHI effect of Pingtan Island is mainly affected by the change of land use type, and the UHI effect of Pingtan Island can be mitigated by increasing the area occupied by water bodies.

For the UHI of Fuzhou and Xiamen, remote sensing analysis shows that with the acceleration of urbanization, green space and bare land are gradually transformed into construction land, which increases urban surface temperature. It reflects the gradual deterioration of surface temperature and thermal environment in Xiamen and Fuzhou. It can be seen that for Xiamen City and Fuzhou city, the change of land use type also leads to the intensification of UHI effect.

It is suggested that city managers should pay attention to the harmonious development of economy and ecology and the impact of urbanization process on UHI effect when carrying out urban construction. Corresponding measures should be taken to alleviate the UHI effect, such as increasing the green space and optimizing its layout.

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