The Study of Taichung Area Land Use Change on Heat Island Effect

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ABSTRACT: In the past 40 years, Taiwan has high degree of industrialization and rapid economic development, resulting in the increase of energy use by nearly 20 times and higher plant density and energy consumption rate per unit area. Therefore, the heat island effect in Taiwan has become an urgent and significant issue about living environment. Urban heat island is mainly due to the artificial impermeable pavement used to replace the original ground surface. The replacement has caused unbalanced temperature and made higher temperature at urban areas than the rural ones. With the development of spatial information technology, the remote sensing has advantages of high spectral rate, multi-scale images, multi-temporal and fast data acquisition. The application of remote sensing has been focused on urban heat island study nowadays. In this research, the remote sensing was used to analyze the land-use change, and their impacts on the effect of urban heat island in Taichung.

In this study, the thermal infrared band images generated by the Landsat satellite were used to estimate the surface temperature change. National land use data was applied to analyze land use change of Taichung. The study also discussed the correlation of land use and urban heat island.

The results indicated that land surface radiation temperature increased 2 Kelvin degrees in average within 14 years. In addition, the temperature at central area is obviously higher than rural area. The area which premier affected by heat island is increased 13%, which can be recognized as artificial land and some other uses where located at prior Taichung City and western part. On the other hand, the area which has less influence from heat island is decrease 9%, which can be recognized as vegetation land and water where located at eastern part.

1. Introduction

In the past 40 years, Taiwan has high degree of industrialization and rapid economic development, resulting in the increase of energy use by nearly 20 times and higher plant density and energy consumption rate per unit area. Therefore, the heat island effect in Taiwan has become an urgent and significant issue about living environment. Urban heat island is mainly due to the artificial impermeable pavement used to replace the original ground surface. The replacement has caused unbalanced temperature and made higher temperature at urban areas than the rural ones. With the development of spatial information technology, the remote sensing has advantages of high spectral rate, multi-scale images, multi-temporal and fast data acquisition. The application of remote sensing has been focused on urban heat island study nowadays. In this research, the remote sensing was used to analyze the land-use change, and their impacts on the effect of urban heat island in Taichung.

2. Study Area and Data Set

2.1 Brief description of study area

Taichung city is located in central Taiwan, the area is 2214.9 square hectares, with 29 districts. The annual average temperature is 23 degrees. and it has higher temperature within urban area, or place with higher population. The development of Taichung was mainly at the western region as Heping Dist. Taichung City has been selected for the case area in this study, without including Heping Dist, as figure1.

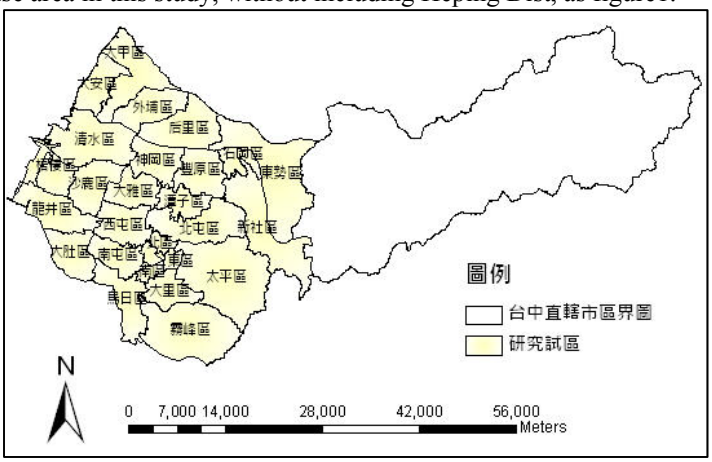


Figure 1. Taichung's administrative distribution

2.2 Data set

The Landsat program is the United States' longest operating Earth imaging program, and has significantly contributed to the understanding of the Earth's environment through the unprecedented global archive of multispectral and high spatial resolution data since 1972 (Williams et al., 2006).The program's current operational platforms are Landsat-5 and Landsat-7. Landsat-5 was launched in March 1984 carrying the Multispectral Scanner (MSS) and the Thematic Mapper (TM) instruments.

Landsat satellite images captured in 09:25:06, July 20, 1995, 10:25:34, July 17, 2009 was used in this study. The thermal infrared band (TM6) was used to calculate thermal radiation and the land surface temperature, the spatial resolution is 120m, wavelength range is between 10.45-12.5μm.

In addition, National Land Use Data published in 1995 and 2008 by Inner fair department was also used in this study for getting land use change information in Taichung.

3. Methods

3.1 Calculation of LST and heat island strength

The thermal data of Landsat TM image is based on gray-level value (Digital Number value). DN values are recorded between 0 to 255, and higher number with higher thermal reflection from land surface, also with higher temperature. Dr. Tan proposed the Single-window algorithm in 2001. It use the thermal band to calculate brightness temperature, including DN value to transform the thermal radiation intensity values.

Equation 1 indicated the association with radiation intensity values and the DN values:

$$L(\lambda)= Lmin(\lambda)+[Lmax(\lambda)-Lmin(\lambda)] Qdn/Qmax \quad (1)$$

L(λ) refer to the radiation strength receive from TM sensor(mWcm^(-2) sr^(-1) μm^(-1)), Qmax refer to the maximum of DN value (Qmax=255), Qdn is digital value of each pixel, Lmax (λ) and Lmin (λ) are the maximum and minimum radiation strength received from the sensor . The centeral wavelength of thermal band of TM sensor (TM6) is 11.475μm, the constant parameter has been defaulted before launch, which assume when Lmin (λ) =0.1238, then Qdn=0; when Lmax (λ) =1.56, then Qdn=255.

Due to the above assumption, the equation 1 can be simply transfer to equation 2

$$L(\lambda)=0.1238+ 0.005632156 Qdn \quad (2)$$

In the TM6 data, we already have gray-level values Qdn, equation 2 can be work out the appropriate thermal radiation intensity l (lambda). Once l (lambda) evaluated, with the following approximate calculation

$$T6= K2/\ln(1+ K1/ L(\lambda)) \quad (3)$$

T6 refer to the satelliate brightness temperature (° k) fromTM6, K1 and K2 are default constants which set before satellite launching. In the TM data, K1=60.776 mWcm^(-2) sr^(-1) μm^(-1), K2=1260.56K。

The meaning of urban heat island refers to the higher temperature inside the city and lower temperature surrounding suburbs. Urban heat island will be more significant and serious with more heat energy usage difference between urban and suburban area. The atrength of heat island effect can be calculated as follows:

$$\omega = T_u - T_s \quad (4)$$

ω is the strength of urban heat island, Tu is the temperature in urban area(highest temperature), Ts the temperature in suburban and rural area(lowest temperature).

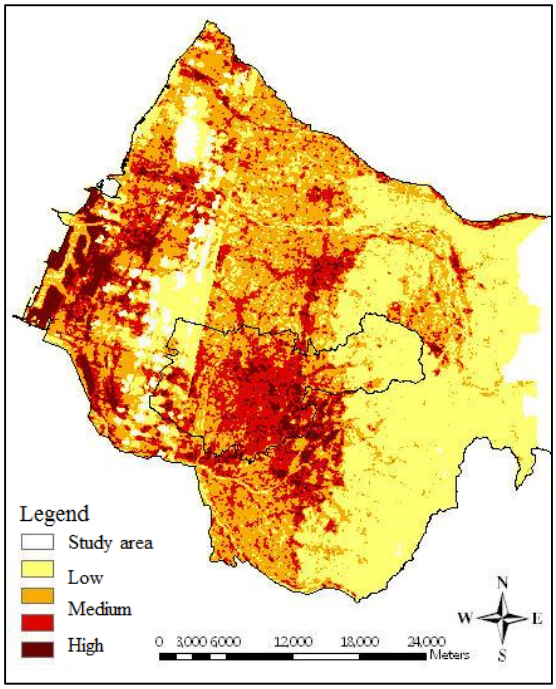
$$\overline{\omega} = \frac{\sum \omega}{n} \quad (5)$$

$\overline{\omega}$ is average strength of urban heat island, $\sum \omega$ is the sum of heat island strength.

4. Results

4.1 Impact of increased urban heat island strength

The strength value of urban heat island was deployed into spatial analysis method with Nature Break classification method into four class, shown as figure 2 and figure 3, the parcel with deeper color represent higher strength value of heat island: for the value 0 to 0.52 was defined for low effect distribution area; the value between 0.52 to 0.58 was defined as medium effect area; the value between 0.58 to 0.64 was defined as high effect of urban heat island (Figure2 and 3).



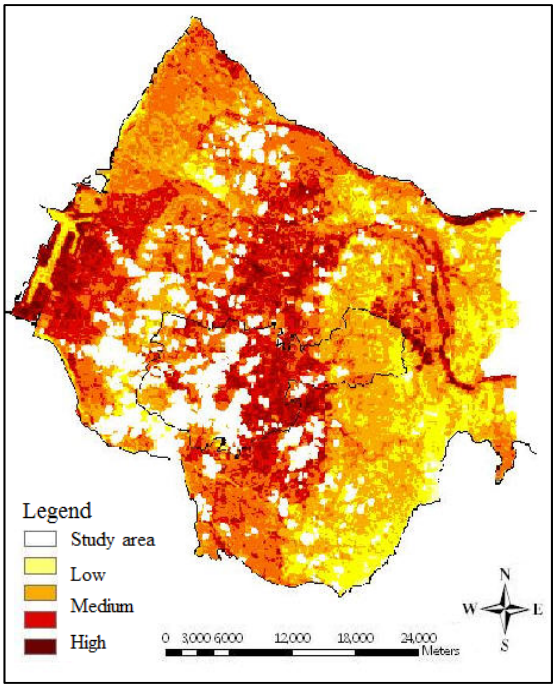


Figure 2. Heat island grading distribution in 1995 Figure 3. Heat island grading distribution in 2009

The figures shown urban heat island intensity with high temperature place is concentrated in the old Taichung City area, which include East Dist., West Dist., South Dist., North Dist. and Central Dist. (Simplified the Taichung city area), and Wuqi Dist.. Percentage from the area, from the increase in per cent in 1995 to the cent in 2009. Taichung City previous development from Taichung station as the Center to scale out, its development is mainly Taichung area; and in 1973 began the construction of Harbor, led the city to the West of Northern Development, and shoreline towns such as clean water, Wuqi Dist. and other places.

temperature zone area in percentage from 35.32% reduced to six; low temperature zone in the East such as Dongshi Dist., Xinshe Dist., Taiping Dist., and Wufeng Dist., retaining a lot of green areas, in contrast to the development-intensive areas, its temperature is relatively low. From the two images can be found, later images the overall temperature of a rising phenomenon, reduce the percentage of low-temperature distribution area from 39.98% to 31.16%.

5.2 Land use change

Water area is the mainly reduced land use type in Taichung City during last 13 years., reduced 7.83%, and the agricultural land also reduced 7.04%; instead, the architectural land has increased for 3.58%, and the industrial land also increased for 2.78%（Figure 4）.

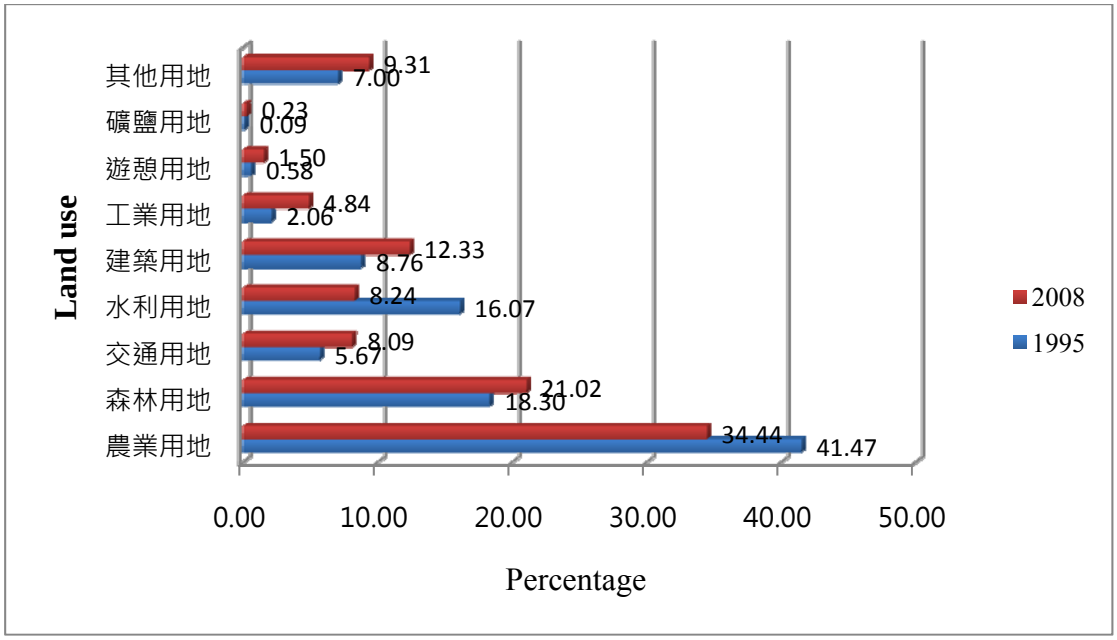


Figure 4. The ratio of land cover changes in Taichung

The artificial land in 1995 is gathered on different area of Taichung city, Dali Dist., Fengyuan Dist. Others such as Xitun Dist., Shalu Dist. In 2008, the artificial land increased to 3.58%. It is concentrated on human activity areas with urban development. The water land area ratio decreased to 7.83%. And because of the intensive development of agricultural area, the ratio of 2008 decreased to 7.04%. Under the influence of urbanization, the buildings and roads continue to increase, green cover is declining, as one of the main causes of urban heat island effect.

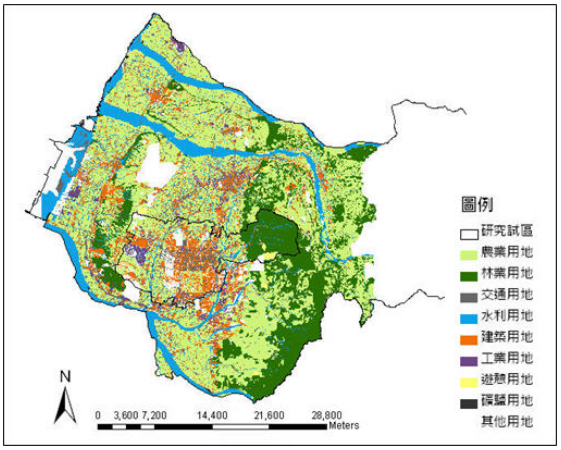


Figure 5. Distribution of land use classification in 1995

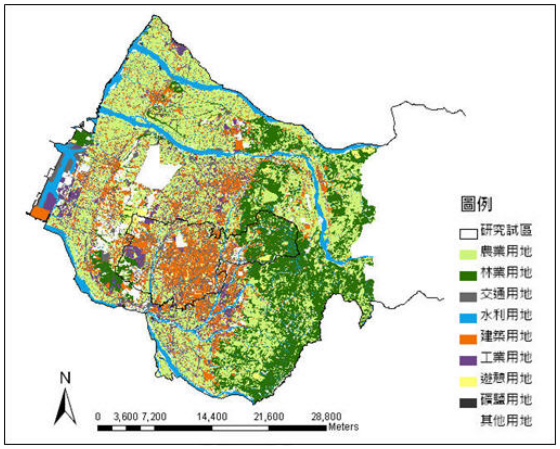


Figure 6. Distribution of land use classification in 2008

5.3 Relationship between land use and heat island effect

The high temperature areas built mainly in the Taichung area, and Wuqi Dist. and the northwest coastal zone, this place is a coastal sandy geology, may be subject to the impact of air or power plants; in the land use classification is artificial in the highest proportion of pavement area, followed by other land uses; the heat island effect can be pointed out that the greater Taichung area is located in the category of land use artificial pavement

and other land uses, and literature review of the contribution of the heat island effect is positively related to factor in line.

Second, temperature and low temperature distribution in the coastal areas, and Taichung city in Central and Eastern region; the percentage area from land-use classification, is planting and water body, contribute a negative degree related to the heat island effect of factor, degree of contribution to the heat island effect compared to these factors reduce the many.

6. Discussion

In this study, the thermal infrared band images generated by the Landsat satellite were used to estimate the surface temperature change. National land use data was applied to analyze land use change of Taichung. The study also discussed the correlation of land use and urban heat island.

The results indicated that land surface radiation temperature increased 2 Kelvin degrees in average within 14 years. In addition, the temperature at central area is obviously higher than rural area. The area which premier affected by heat island is increased 13%, which can be recognized as artificial land and some other uses where located at prior Taichung City and western part. On the other hand, the area which has less influence from heat island is decrease 9%, which can be recognized as vegetation land and water where located at eastern part.

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