Applying RS and GIS to Study the Impacts of Urban Regeneration on Thermal Environment in Built-up Areas: A Case Study of Kowloon, Hong Kong

Jin Yeu Tsou[1], Ming Chun Chao[2], Xiang Li[3] and Ke Chen [4]

[1]Center for Housing Innovations, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong; PH (852) 29940495; FAX (852) 26036515; email: jinyeutsou@cuhk.edu.hk
[2]Center for Housing Innovations, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong; PH (852) 29940495; FAX (852) 26036515; email: sarachao@cuhk.edu.hk
[3]Center for Housing Innovations, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong; PH (852) 29940495; FAX (852) 26036515; email: chi.lixiang@cuhk.edu.hk
[4]MSc. in Advanced Environmental Planning Technologies, Center for Housing Innovations, The Chinese University of Hong Kong. Shatin, New Territories, Hong Kong; PH (852) 56089428; email: 295818900@qq.com

ABSTRACT

Land use/Land cover (LULC) change is one of the key reasons of Urban Heat Island (UHI) dynamic. Previous studies focused on the relationship of urban sprawl and emergence of UHI, but less attention was paid to how urban regeneration progress influences on the thermal environment in built-up regions.

In this paper, a comparative study of Kowloon, Kuwn Tong and Kwai Tsing, on the LULC and Urban Heat Island Intensity (UHII) in 2000 and 2010 was conducted. The study investigated the effect of urban regeneration progress on thermal behavior of the built-up environment.

Landsat 7 ETM+ data was used to retrieve the UHII of the two periods in the study area. A spatial quantitative analysis was made through the integration of Remote Sensing (RS) and Geographical Information System (GIS) analysis tool. The results presented an evident enhancement of UHI in Kowloon East within the 10 years of urban development. The study results provides reference to optimize the master plan of Kowloon East and contribute to the innovative thinking in applying scientific methods to support the decision-making in urban regeneration schemes to avoid environmental issues that the urban regeneration process may bring about.

INTRODUCTION

The Urban Heat Island (UHI) effect impacts on the urban micro-climate and is a serious problem that hinders the living comfort of urban areas. Urbanization progress is one of the major roles that play in the daytime of Urban Heat Island effect (Radhi, Fikry, and Sharples, 2013). Many previous studies had conducted research to

uncover the contribution of different urban development activities on the spatial and temporal change of UHI. Saleh (2011) assessed how urban growth in Baghdad city impact on the land surface temperature (LST) with integration of GIS and RS. Giannopoulos et al. (2011) found that the high LST can be enhanced by the increasing in urbanization and the reduction of lack of vegetation. In the study of the thermal environment of the cooling effect of green space, there are a large number of studies have shown that urban greenery has good cooling effect. Wen Xingping , Hu Guangdao , Yang Xiaofeng (2008) studied the application of Landsat image temporal changes in vegetation cover for the Guangzhou urban heat island effect; Onishi A, Cao X, Ito T, et al., (2010) has studied the effect of parking lot in reducing the UHI effect with the potential green coverage space. Urban land use condition is another factor that influenced on UHI development. The studies of Jusuf, Wong, Hagen, Anggoro and Hong (2007) proved that land use would have diverse impacts on the urban temperature. Li et al. (2011) investigated how landscape composition and configuration would impact on the UHI in the metropolitan centers. Tian, Chen, and Yu (2013) studied the effect of urbanization progress on the UHI formation in Shenzhen and concluded that the land use is responsible for the UHI transitions.

Urban regeneration is to solve the urban problems through a series of long-term actions to improve the economic, physical, social and environmental conditions (Roberts, 2000; Alpopi and Manole, 2013). Many cities are conducting urban regeneration actions to revitalize their economic, environmental and social functions. With the aging of urban infrastructures and buildings in the cities, the contradiction between quality of life and fading living environment become a key urban issue. Therefore, urban regeneration is required to revitalize the activities of city centers, old industrialized areas and old towns. As one of the inevitable phases in the urbanization progress, urban regeneration becomes the new starts and motivation for further urban development. Many cities are programming urban regeneration projects to meet the demand of further development. The urban regeneration process in Singapore integrated traditional buildings conservation with the new urban plan through written conservation into the law as compulsory part. Some of the urban regeneration aims to mitigate the environmental issues to improve living comforts. The urban regeneration process of Bucharest, Romania, started in 2009 (Alpopi and Manole, 2013). The scheme increased the quality of life of people by improving the management of green spaces, access routes, etc. Among the current cases of urban renew, seldom discussed or assessed the potential influence of regeneration progress or results on the urban thermal environment. However, it is vital that the urban renew project will not make sense if the byproducts of new construction make our environment hotter.

In this paper, we cited the Kowloon and part of Kwai Tsing District (see Figure 1), which are old as the study area to conduct a research on the influence of the urban construction activities from 2000 to 2010 on the change of urban heat island. With the comparison of different periods of data, we retrieve the Land Surface Temperature (LST) and detect the land use change of this region through a series of Remote Sensing (RS) and Geographical Information System (GIS) programming.

STUDY AREA

The Kowloon District locates in the centre of Hong Kong and composed of Sham Shui Po, Yau Tsim Mong, Kowloon City, Wong Tai Sin, Kwun Tong, Tsuen Wan and Kwai Chung . It is the first urbanized area in Hong Kong with high population density and urban density. Tsuen Wan New Town was developed in 1959. It is Hong Kong's earliest new town for the "New Development Area" and now has become one of Hong Kong's major residential districts. Sham Shui Po is also one of the early developed areas in Hong Kong and was redeveloped into residential area after its transformation from a commercial, industrial and transportation hub of the territory. Kwun Tong is one of the first New Towns and still one of the major industrial areas in Hong Kong. Due to the increasing population, the demands for housing, public services and infrastructures also go up accordingly. In light of this situation, a number of redevelopment projects were implemented there.

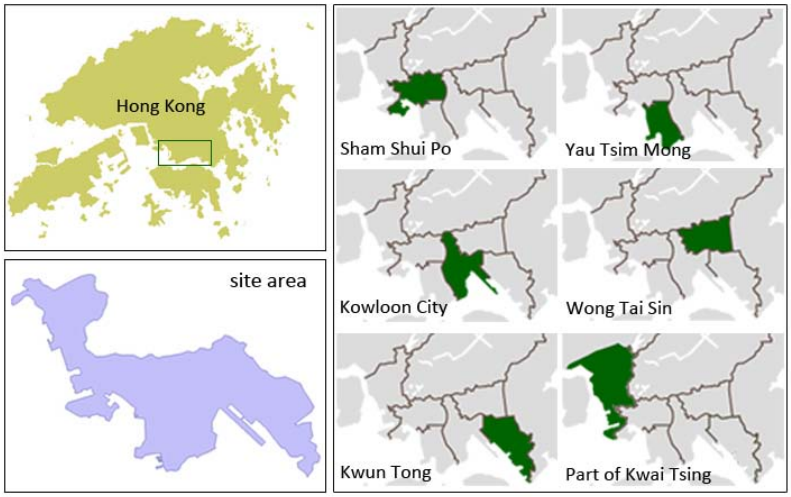


Figure 1. the site area: Kowloon District and Urbanized area of Kwai Tsing District

DATA

The Remote Sensing image has the privilege of monitoring spatial changes of land surface environment. Its accuracy and timeliness to detecting land information is very significant to analyze the Land Use/Land Change (LULC) and land surface temperature (LST). The Landsat -7 Enhanced Thematic Mapper Plus (ETM+) data contains 8 bands in 3 resolution levels. Band 1-5 and 7 are obtained through 30m resolution sense, while band 6 (61 and 62) through 60m resolution sense, band 8 through 15m resolution sense. Regarding to the difference emissivity of the bands, we applied the various combinations of bands to process for different target of analysis.

In this study, the Landsat-7 ETM+ images obtained on 14 September 2000 and 28 October 2010 were utilized to process the analysis of LST and LULC in Kowloon and Kwai Tsing District.

Table 1. Landsat -7 ETM+ data for this study

Obtain Date	Sun Elevation Angle	Scene center Coordinate
14 September 2000	58.9983998	Lat: 23.11663 Lon:113.53951
28 October 2010	48.29343796°	Lat: 23.10801 Lon: 113.58596

METHODOLOGY

Land Surface Temperature Retrieve. Basic data processing is required before put the data for band math calculation. Polygon of the site area was used to mask the data to identify the boundary. This polygon can be a shapefile format data generated through ArcGIS as it should be spatially adjusted to the positions in the same as the coordinate of the site area in the earth.

Band 6 is utilized to retrieve LST in the site area, as it is the thermal infrared band that can identify land objects and retrieve temperature with its thermal information. Wavelength of band 6 can range from 10.40 to 12.50 μ m of the electromagnetic spectrum (NASA, 2012).

After basic data process of atmospheric correlation and landsat calibration, there are three major processes to retrieve the LST: radiation calibration, land surface emissivity and calculating real temperature via the thermal infrared. For NDVI, it is the Normalized Difference Vegetation Index (NDVI), an important factor to evaluate the vegetation coverage on the ground, is necessary in the study of both LST and LULC identification of each cell. The formula for NDVI calculation is as equ.1 :

$$NDVI = \frac{(\rho NIR - \rho RED)}{(\rho NIR + \rho RED)} \qquad \text{(equ.1)}$$

Where ρNIR is radiance in reflectance units of band 4 and ρRED is the radiance in reflectance units of band 3 (Red light).

Land Use / Land Change Detection. Maximum Likelihood Classification method is utilized in this studies to acquire the LULC condition both years. The Maximum Likelihood is a supervised classification method which classifies surface objects according to sample cells we define as different classes of lands. Obtained the land use condition of the two years, we do the Change Detection Statistics to further analyze the spatial and temporal dynamic of land classes of urban, bare land and vegetation.

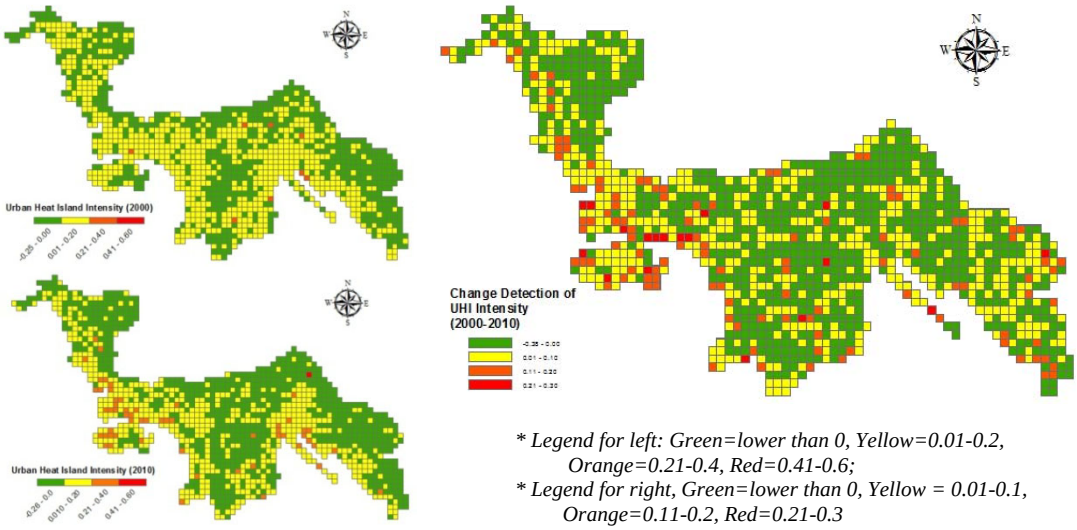
RESULT

Urban Heat Island Intensity (UHII) Detection. To normalize the data for comparison, we use the Urban Heat Island Intensity (UHII) to present the thermal environment of site area. UHII was defined as the variation of spatially-averaged air-

temperature between an urbanized area and its surrounding rural area (Memon, Leung, and Liu, 2009). We evaluate the intensity of Urban Heat Island of 2000 and 2010 as

Figure **2** (left). The UHII of urbanized areas are all more than 0, with mean there is significant urban heat island effect. In 2000, Kowloon City, Yau Tsim Mong, Kwai Tsing and Kwun Tong area have UHII of 0.01-0.2 ℃. In 2010, the UHI accumulated areas are similarly distributed as that of 2000. However the UHII were enhanced in several places. The area for Yao Tsim Mong and Kowloon with UHI effect is reduced. However, the UHII of some places in Kwai Tsing and Kwun Tong increased from 0.21-0.4 ℃. Seeing form

Figure **2**(right), there is the change detection of UHII of 2000 and 2010 of the site area. The class of change was ranked from 0 to 0.3 ℃. We can find that the biggest change occurs at Kwai Tsing and Kwun Tong where are New Towns for residential use.



** Legend for left: Green=lower than 0, Yellow=0.01-0.2, Orange=0.21-0.4, Red=0.41-0.6;*
** Legend for right, Green=lower than 0, Yellow = 0.01-0.1, Orange=0.11-0.2, Red=0.21-0.3*

Figure 2. Urban Heat Island Intensity distribution for 2000 (up left) and 2010 (low left) as well as the variation quantification (right)

Land Use Land Change Detection. Comparing the land use result (see Figure 3) acquired from Landsat image of the two year, land transformation between urban, bare land and vegetation is obvious. The original land for green space was deduced and changed into bare land for further development. Some of the urban areas are also changed into bare land for regeneration.

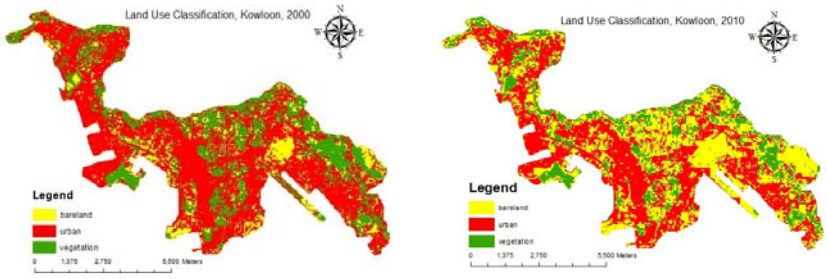
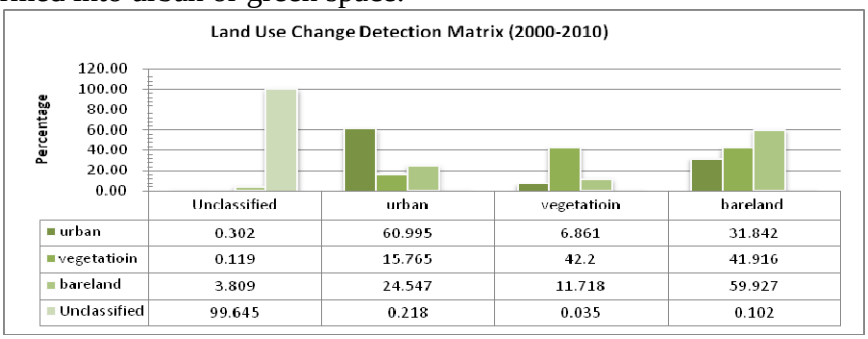


Figure 3 LULC detection through Maximum Likelihood Method for 2000 (left) and 2010 (right)

According to the Land Use Change Detection Matrix (see Figure 4), we can easily find the specific number of land transformation. 6.86% and 31.8% of urban land was transformed into green space and bare land. 15.76% and 41.9% of green space was transformed into urban land and bare land. 24.54% and 11.7% of bare land was transformed into urban or green space.



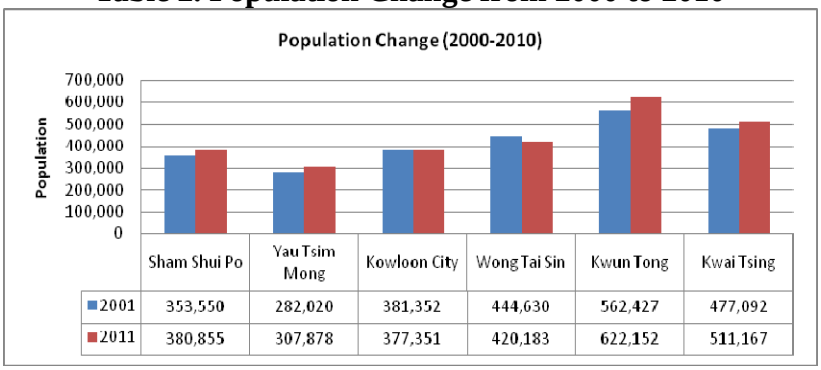
	Unclassified	urban	vegetatioin	bareland
urban	0.302	60.995	6.861	31.842
vegetatioin	0.119	15.765	42.2	41.916
bareland	3.809	24.547	11.718	59.927
Unclassified	99.645	0.218	0.035	0.102

Figure 4 Land Use Change Matrix (2000-2010), up classes for 2010 and left classes for 2000

DISCUSSION

Urbanization progress and dynamic of living environment are always associated with population change. According to the population census in 2001 and 2011, the population in Kwun Tong increased from 562,427 to 622,152; population in Kwai Tsing increased from 477,092 to 511,167; population in Yau Tsim Mong increased from 282, 020 to 307,878; population of Sham Shui Po increased from 353,550 to 380,855 (see Table 2). As we analyzed, the UHII of these places also increased in accordance with the districts where the population grow up. Human activities have great impacts on the formation and dynamic of urban thermal environment.

Table 2. Population Change from 2000 to 2010



	Sham Shui Po	Yau Tsim Mong	Kowloon City	Wong Tai Sin	Kwun Tong	Kwai Tsing
2001	353,550	282,020	381,352	444,630	562,427	477,092
2011	380,855	307,878	377,351	420,183	622,152	511,167

CONCLUSION

For most of the cities, especially the big cities, urban regeneration is important to ensure the long-term energy and social-economic attractions of people. In the progress of urban regeneration, new environmental issues may occur. Thus it requires more consideration on the further impact on urban environment, especially the thermal behavior, from new buildings or revitalized old buildings. We see from the above studies that degeneration of urban green land in Kowloon resulted into the enhancement of urban heat island intensity. Previous studies also proved that vegetation is useful to cool down the temperature of environment. Thus, more parks, open space with green land are necessary for urban renew or regeneration. Moreover, population increase is another issue that makes the UHI severe. In many new towns or residential areas, the UHI effect is more significant than other places, because human activities and the accompany transportation emission and the long-wave radiation emitted from building facades are major heat resources to increase the regional temperature. To avoid the side effect from population aggregation, air ventilation optimization of blocks and the development for more open spaces should be considered to increase the urban heat dissipation.

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