Urban Green Space Growth Impact
on Surface Temperature Distribution

Siti Nor Afzan Buyadi, Wan Mohd Naim Wan Mohd, Alamah Misni

Faculty of Architecture, Planning and Surveying,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor

n_afdzsan@yahoo.com

Abstract

Trees and vegetation play a vital role to mitigate urban heat island (UHI) effects. Land use, vegetation growth detection and land surface temperature (LST) maps of two different dates are generated from Landsat 5 TM (1991 and 2009) in the city of Shah Alam. The conversion of natural green areas into residential and commercial development significantly increases the LST. The result reveals that mature trees in urban green space help to mitigate the effects of UHI as well as to sustain the urban development.

Keywords: trees; land surface temperature (LST); urban; development

1.0 Introduction
The urban heat island (UHI) phenomenon has been found in cities throughout the world. It is defined when the air and surface temperatures are hotter than their rural surroundings (Shahmohamadi, Maulud, Tawil, & Abdullah, 2011). Due to urbanization demand, the rapid growth of urbanization caused reduction of vegetated areas and increased the built-up surfaces. One of the possible causes of UHI is a drastic reduction of the greener areas to built-up surfaces. The natural land cover was converted by built surfaces that trap incoming solar radiation during the day and then re-radiate it at night (Solecki, Rosenzweig, Pope, Chopping, & Goldberg, 2004). Several studies have been carried out in investigating the UHI impacts (Choi, Lee, & Byun, 2012; Mallick & Rahman, 2012; Yan, Wang, Hao, & Dong, 2012). Thus, the seriousness of UHI phenomena cannot be denied and the mitigation strategy should be applied to combat the UHI effects at the macro and micro level.

2.0 Literature Review
The impact of the heat island suffered so many people in many ways. The investigation of UHI impacts such as in energy consumption, management of storm water run-off, environmental disturbance, community health, and altering climatic conditions. The UHI project is to produce historic air temperature maps based upon satellite and derived land surface temperature data for multiple years as well as the land use change monitoring. Based on the previous research, the UHI mitigations are discovered and have been applied in sub-tropic countries (example China and Hong Kong). The mitigation strategies are green/cool roof, use of lighter-colour and reflective surfaces for building. A more practical method of mitigating the UHI is strategic planting of vegetation in urban areas and designing green technology approach (Ng, Chen, Wang, & Yuan, 2012; Saffuan, Ariffin, & Amin, 2013).

The Landsat 5 TM and 7 ETM+ are widely used to derive the land use changes monitoring and land surface temperature retrieval. Additionally, the thermal infrared band of the Landsat imagery is capable of deriving the surface temperature. Previous studies have been developed LST using Landsat 5TM or 7ETM+ to estimate radiation budgets in heat balance studies and as a control for climate models (Buyadi, Mohd, & Misni, 2013). The remotely sensed image such as Landsat image and GIS technique are used to generate land use map, to monitor the land use changes and as well as their surface temperature map (Mohd, Hashim, & Noor, 2004; Takeuchi, Hashim, & Thet, 2010).

It is clearly demonstrated that the implications of rapid urban growth are decreased vegetated areas, increased the surface temperature and modified the urban microclimate. Maturity of the trees and vegetation can be considered as a vital parameter to measure the temperature in urban area through its shadow and transpiration. GIS and ERDAS software, and statistical method are acceptable as technical methodology in analyzing environmental behaviour especially in combating UHI. This study will investigate the land use changes using remote sensing Landsat image and identified the green spaces growth impact on the urban microclimate.

3.0 Methodology

3.1 Study Area
The study area consists of part of the Shah Alam City. The area is selected due to rapid urban development activities over the last 30 years. The climate of the cities is categorized as a hot and humid tropical climate. Temperatures tend to remain constant with maximum values of between 31 and 33°C, while the minimum between 22 and 23.5°C. Relative humidity is around 72–78%. The geographical location of the study area is shown in Figure 1. The study area is located at 3°N Latitude and 101°E Longitude in average elevation of 10m. The meteorological data were obtained from local weather station of Subang, Shah Alam was provided by Malaysia Meteorological Department (MMD), coincide with the time and date of the Landsat TM satellite pass.

3.2 Generation of land use/land cover maps
Satellite images are used to generate the land use/land cover maps of two different dates. The detail of satellite image data (Landsat 5 TM) used in this study dated on 21st February 21, 1991 and January 21, 2009 is acquired from the Malaysian Remote Sensing Agency (ACRS). The eighteen year period is selected to ensure the vegetation growth within this study area is matured. The process of generating land use maps is done using the ERDAS Imagine digital image processing software. The unsupervised classification method is used to generate land use/land cover maps. The process based on first-order polynomials and root means square errors (RMSE) obtained less than half of pixel values. The percentages of land use/land cover changes are later calculated. These values of land use/land cover can use to estimate the land use/land cover types individually.

3.3 Land surface temperature (LST) retrieval
The thermal infrared band (Landsat 5 TM Band 6) records the radiation in the spectral range between 10.4 and 12.5μm from the surface of the earth. Land surface temperature ia used to provide primary information on the surface physical properties and climate. The mono-window algorithm method is adopted in this study to generate the LST (Sobrino, Jiménez-Muñoz, Paolini, & Jime, 2004). The mono-window algorithm requires three parameters; emissivity, transmittance, and effective mean atmospheric temperature. The atmospheric water vapour content and the near surface air temperature are used to calculate the air transmittance and effective mean atmospheric temperature (Liu and Zhang, 2011). The third parameter is emissivity, which is calculated from the normalized difference vegetation index (NDVI). The mono-window algorithm is given as:-

$$T_s \qquad \{a(1-C-D) + [b(1-C-D) + C + D]T_i - DT_a\} / C \qquad (1)$$

where:- T_s is LST in Kelvin; $a = -67.355351$; $b = 0.458606$; ($C = \varepsilon_i \times T_a$; where ε_i=emissivity can be computed from NDVI); $D = (1 - T_a) [1 + (1 - \varepsilon_i) \times T_a]$; T_i is the brightness temperature (K) and T_a is the effective mean atmospheric temperature.

3.4 Generation of Normalized Difference Vegetation Index (NDVI) Maps

GIS spatial analysis and zonal statistical analysis technique are used to visualize the vegetation fragmentation and the surface temperature distribution. Equation 2 is used to calculate the NDVI of the study area. The proposed emissivity values from the different NDVI range; NDVI<0.2 (bare soil), 0.2<NDVI<0.5 (mixture of bare soil, vegetation and hard surfaces) and NDVI> 0.5 (fully vegetated) are 0.99, 0.98 and 0.98 respectively.

$$NDVI = (NIR - R) / (NIR + R) \qquad\qquad (2)$$

where
NIR - the pixel digital number (DN) of TM Band 4
R - DN of TM Band 3

3.5 Relationship between NDVI and LST

To obtain the relationship between NDVI and LST, 25 sample points are measured within the detailed study area. Regression analysis is carried out to determine the correlation between these two parameters. The regression equation models are retrieved by fitting the trend line using Microsoft Excel.

4.0 Results and Discussions

4.1 Land use/ Land cover Changes

The land cover changes for the two dates of part of the Shah Alam City are significantly detected and presented in the land cover maps in Figure 2. The total acreage of the study area is 16,904.547 hectares. The detail acreage of the individual land cover of the study area is listed in Table 1. Over the period of 18 years, there is a significant decrease in the high dense trees (forest and agricultural land) land cover category. The total area in the mixed vegetation category (crops, parks and bushes) and built-up areas (commercial, residential and administrative building) increased by 11.24% and 13.63% respectively. The cleared land decreased due to its conversion to built-up areas. More trees are being planted to replace the lost of natural greenery within the study area.

Figure 2: (a) Land use/ Land cover maps of 1991; (b) Land use/ Land cover maps of 2009

Table 1: Land use/land cover coverage

Land Use/Land Cover Class	Area in Hectare				Changes (%)
	1991	Percentage (%)	2009	Percentage (%)	
(1) Water bodies	464.554	2.75	317.827	1.88	-0.87
(2) High Dense Trees	5726.516	34.09	2807.432	16.61	-17.48
(3) Mix Vegetation	3503.806	20.73	5403.899	31.97	+11.24
(4) Built-up area	4300.606	25.44	6608.361	39.09	+13.65
(5) Cleared Land	2873.065	17.00	1767.028	10.45	-6.55
Total	16,904.547	100	16,904.547	100	

4.2 Land surface temperature (LST)

The LST distributions of 1991 and 2009 are shown in Figure 3. The mean temperature for individual land use/land cover is summarized in Table 2. The lowest and highest radiant temperature for 1991 are 25.8°C (in the high density tree area) and 30.8°C (in the built-up area). Meanwhile, for 2009 the radiant temperatures range between 24.0 and 38.0°C. The highest mean temperature is within the built-up area while the lowest is within water bodies. The implication of urban development by replacing natural vegetation to built-up surfaces such as concrete, stone, metal and asphalt clearly can increase the surface radiant temperature. Although there is a significant increase in the built-up areas, the surface temperature is still relatively lower (Figure 3(b)) due to the vegetation growth. On average, over eighteen years of development, regular mature trees, green parks, and other vegetation in urban area potentially can reduce urban temperature and its surrounding.
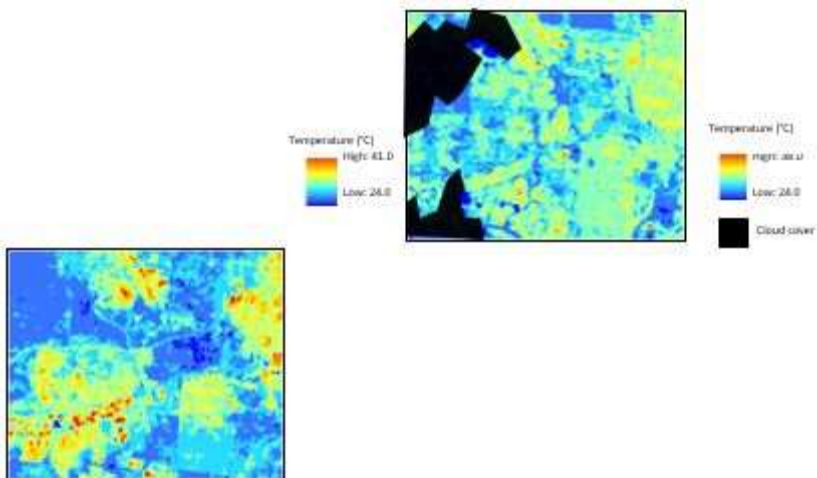

Figure 3: (a) Land surface temperature (1991); (b) Land surface temperature (2009)

4.3 Analysis of normalized difference vegetation index (NDVI)

Figures 4 show the NDVI maps generated from the Landsat 5 TM imagery for the year 1991 and 2009. The increase in the vegetative growth coverage within the study area can clearly be seen due to the maturity of the trees. As the more trees and vegetation within the study area are getting matured, the NDVI value increases and hence lowering the LST.

(a)   (b)

Legend:

 <0.2 : Cleared Land and Built-up Area
0.2≤NDVI<0.5 : Mix of Built-up/Bare Soil and Vegetation
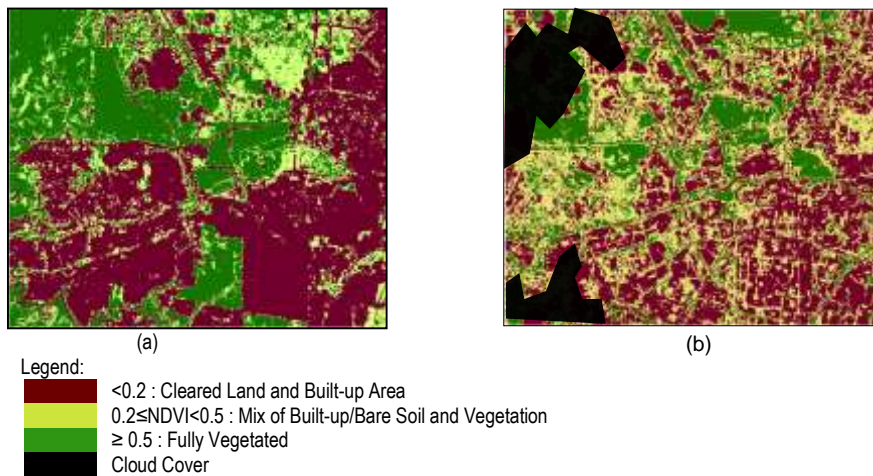≥ 0.5 : Fully Vegetated
Cloud Cover

Figure 4: (a) Vegetation growth (1991); (b) Vegetation growth (2009)

Aerial photo of 1992 (Figure 5(a)) and digital orthophoto of 2009 (Figure 5(c)) are used to visualize the urban growth of the study area. The lake garden area is surrounded by residential, high rise building, road and commercial areas. Figures 5(b) and d) show the NDVI maps of two different dates Figure 5 (b), illustrate that lower NDVI values are clearly evident in water bodies and built-up areas. However, over the period of 18 years, NDVI in these areas significantly increased, although there is no significant change in the coverage of the water bodies and built-up areas. This situation occurred due to the significant vegetation growth within this area. Figure 5(d) shows the NDVI pattern of the year 1991 and 2009, the lower NDVI value is mainly located in the water bodies. Although there is slightly difference between the highest NDVI values, the pixel count for the NDVI higher values in the built-up and vegetated areas significantly increased over the 18 year period in a study area of Shah Alam Lake Garden. Thus, mature vegetation can help to reduce of the hard surface emissivity and lowering the solar exposure of the building envelope as well as cooling down the high temperature in built-up area.

As shown in aerial photo of 1992 (Figure 6(a)), the Kelana Jaya study area is not well developed and exhibit the natural green landscapes. However, due to the rapid urban development, the area has been transformed to the new urban area and the developed area surrounded by mixed development, which is shown in the digital orthophoto of 2009 (Figure

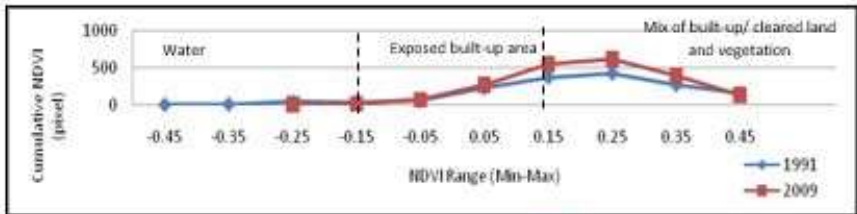6(c)). Figures 6(b) and (d) visualized the vegetation decreasing value in the year 1991 and 2009.
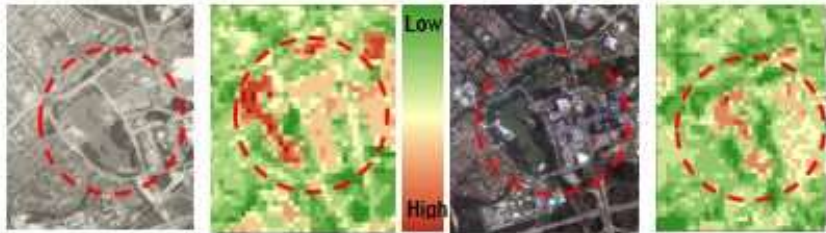
(a) Scanned aerial photo of Shah Alam Lake Garden in 1992
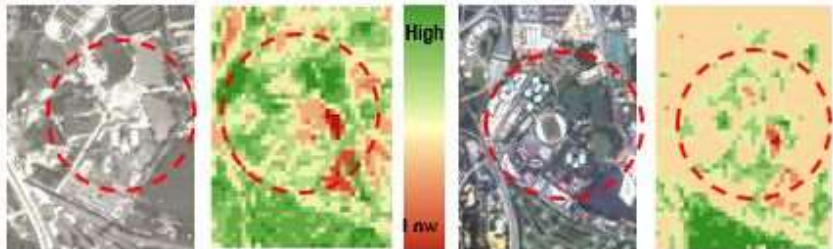
(b) NDVI Image1991 (High:0.457; Low: -0.527)

(c) Digital Orthophoto of Shah Alam Lake Garden in 2009

(d) NDVI Image 2009 (High:0.464; Low: -0.192)

(e) Comparison of NDVI pattern in the Shah Alam Lake Gardens

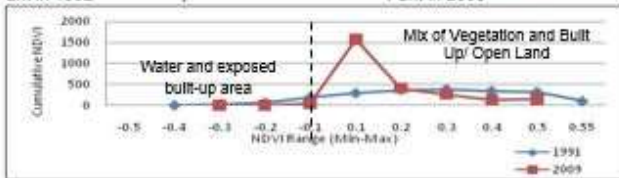Figure 5: Aerial images, NDVI maps and NDVI pixel count of the detailed study area

(a) Scanned aerial photo of Bandaran Kelana Park in 1992

(b) NDVI Image1991 (High:0.523; Low: -0.493)

(c) Digital Orthophoto of Bandaran Kelana Park in 2009

(d) NDVI Image 2009 (High:0.504; Low: -0.224)

(e) Comparison of NDVI pattern in the Shah Alam Lake Gardens

Figure 6: Aerial images, NDVI maps and NDVI pixel count of the study area

Hence, the graph plotted in Figure 6(e) shows the significance of non-vegetation value in 2009 where the ground surfaces are converted to cleared-land and built-up surfaces. Vegetation plays vital roles to alleviate the heat island effect by means of transpiration, shading and heat absorption. High trapped solar radiation in the building may cause high energy usage and disturbing human internal thermal comfort.

4.4 Correlation between NDVI and LST

Land surface temperature (LST) is sensitive to vegetation and soil moistures urfaces; hence it was used to detect land use/land cover changes. Various studies have been carried out to investigate LST using the vegetation. Figures 7 show the correlation of LST and NDVI in both clipped study areas in 1991 and 2009.
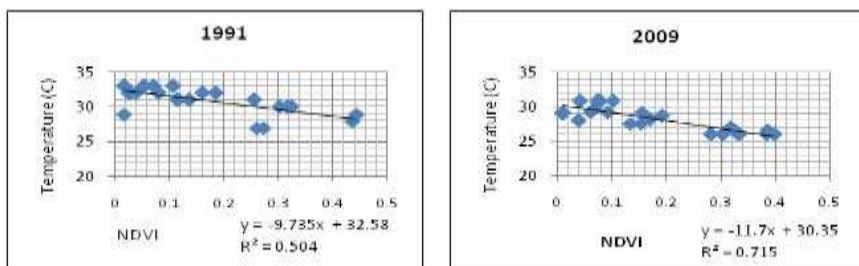
(a) Correlation of LST and NDVI in Shah Alam Lake Garden
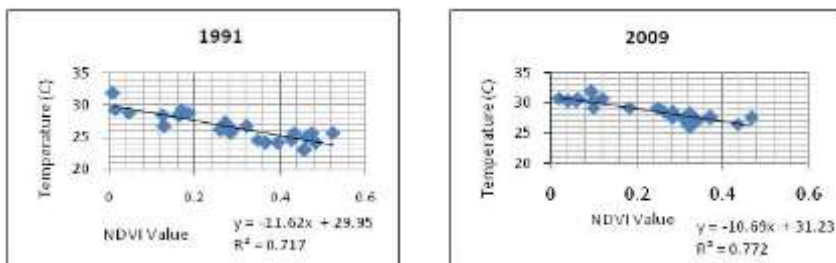
(b) Correlation of LST and NDVI in Bandaran Kelana Park

Figure 7: Relationship of NDVI and LST of the study areas in 1991 and 2009

Strong correlation between surface temperature and NDVI values are found in Shah Alam area are 0.504 and 0.715 in 1991 and 2009. The Kelana Jaya area exhibit strong correlations between surface temperatures and NDVI values are 0.717 and 0.772 in 1991 and 2009 respectively. Precisely, replacing vegetation and greening landscaping in the new urban area can help to reduce the radiant temperature of the built-up area, which significantly important to mitigate the phenomena of UHI.

5.0 Conclusion

Five major classes of land covers; water bodies, high dense trees, vegetations, built-up area, and cleared land have a dramatic changes in land use between 1991 and 2009, where high dense tree land cover areas have relatively decreased about 17.48%. This area is transformed to built-up land cover and cleared land. The results show that LST and thermal signal of built-up and cleared land have distributed to rise average radiant temperature. While the vegetated area and water body experiencing lower temperature. The initial findings have shown that there are significant increases in the built-up areas in the Shah Alam City over a period of 18 years. There is a strong negative correlation between LST and NDVI, which indicates vegetation helps to reduce the LST of an area. Vegetation landscaping in urban areas has high potential to modify hot and humid tropical microclimates in the cities of Malaysia.

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