# Simulation of Urban Green Space Landscape and Land Surface Temperature using Land Change Modeler

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### *Abstract*

*Uncontrolled urban development and uncoordinated master planning are commonplace. Managing green space for climate adaptation may difficult. There is a lack of empirical information in the past and present spatial distribution to predict urban green space and land surface temperature (LST) in an urban city. LST is the most important parameters to study the energy interactions and cycles between the atmosphere and ground surface. LST is governed by surface heat fluxes, which in turn is affected by urbanization. Surface and atmospheric modifications due to urbanization lead to a modified thermal climate that is warmer than the surrounding rural areas, particularly at night. This study aims at predicting the effect of land surface temperature on urban green space landscape in the context of urban expansion. Understanding these phenomena are needed to provide a basis for effective green space planning. Landsat images of 1988, 2002 and 2017 were used to assess the spatiotemporal of landscape changes and land surface temperature in this area. Land Change Model-Markov Chain was used to simulate the effect of urban expansion and urban heat effects on green space landscape. The result shows that the increase of urban expansion and land surface temperature could lower the urban green space and potential loss of the area. The result from this study may provide significant insight into understanding the importance of landscape of green space for cooling the area and provide a healthy environment for dwellers.*

***Keywords:*** *land surface temperature, landscape change, urban expansion, urban heat*

## 1. Introduction

Urban expansion and climate change have caused the decline of green space in an urban city. Climate change impacts is related to increases in temperature in urban areas due to the process of urban growth and development. For example, according to [1], the temperatures in the metropolitan cities in the UK is up to 7°C difference. Heat increasing to effect on urban populations that cause loss of life and human discomfort. Green space is very important for cooling the area and provide a healthy environment for dwellers. Urban green space is important for reducing temperatures, via its functions such as cooling through evapotranspiration, storing and reradiating less heat than built surfaces, and through direct shading. Decrease the impact of high temperature could help human life, comfort and activities. Recent research indicates that if the green cover is increased by town centres and other densely built-up areas, the maximum surface temperatures would be kept at approximately the same level as the 1961-1990 baseline conditions. However, managing green space for climate adaptation may difficult. The percentage of built-up area is more than 70% in 2010 in the major cities of Southeast Asia. For example, Kuala Lumpur had significantly lower green space with less than 20% of green space coverage in 2011 [2]. Therefore, increasing green space in highly development area is a



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valuable adaptation to mitigate the threat of high temperatures to human health and comfort. In order to mitigate increasing the temperature, understanding the spatial structure and pattern of green space is needed.

Land Change Modeler (LCM) and Markov Chain modelling, integrated with GIS data and remote sensing satellite imagery was used in this research to model the changes of the landscape. This integrated model is an easy application to enable process of understanding historical changes [3].

Changes in the area of urban landscapes are also associated with the optimization of cooling the area and comfort for a human being [2]. The interpretation of landscape change and ecological quality associated with urban heat effects on urban green spaces could understand the complex patterns and processes in the integrated studies of climate change adaptation and well-being [4]. Urban green space characteristics such as size, shape, distance, distribution, vegetation density and high in species play a vital role in defining their ecological quality and landscape function [2]. However, there is a lack of empirical information in the past and present spatial distribution to predict land surface temperature (LST) and green space change. Therefore, in order to mitigate the urban heat effect, understanding the changes of green space landscape to provide a basis for effective green space planning for Malaysia expansion city (Kota Bharu, Kelantan as a case examples) is needed. This research aims to predict landscape change of green space and land surface temperature to mitigate urban heat effect in an urban and suburban city for improving the healthy environment and quality of life of urban dwellers.

## 2. Methodology

### 2.1. Study Area

Kota Bharu is selected for this study due to the rapid urban expansion, the emergence of as urban regions, and the future challenges posed by economic growth, environmental degradation, and large social and environmental challenges concerns ahead. Kota Bharu is the capital state of Kelantan located at °8′23.54″N and 102°14′31.93″E has been chosen as the case study. The city of Kota Bharu is located in the north region of Kelantan State with an area of 39939 hectares, which is 2.62 percent of the total area of the state and is administered by the Kota Bharu Municipal Council (MPKB) (Fig. 2). Kota Bharu is the most developed area compared with 9 other districts and become the main catalyst for the development of the Kelantan. Kota Bharu is surrounded by the South China Sea in the north of Pangkalan Datu River, Pengkalan Chepa river in the east, Pendek River district in the South and Kelantan River in the west. Kota Bharu is located on the flat surface and this gives an advantage to the development and local resident to be concentrated in the area. The daily temperature in Kota Bharu is approximately 26°C. The average rainfall for each year is 2,700 mm and it rises in October, November and December. Kota Bharu becomes an attraction to local residents due to the rapid development of the economic sector that provides job opportunities to the people. The total population in the year 2010 is 509, 600 people. In 2016, it was about 1.45 million people which increased by 12% from 2010.

### 2.2. Data Acquisition and Processing

Land use/land cover maps of 1985, 2002 and 2017 have been derived from image processing using ERDAS Imagine 2014. The LULC was reclassified into three land use types i) built-up area, ii) green space and iii) waterbody. The maps were used to predict the green space area of 2030 in Kota Bharu. These datasets were converted to vector and raster grid file formats for simulation and land change analysis.



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### 2.3. Groudthruthing and Data Collection

Groudthruthing was conducted to collect data on the variable factors such as waterbody, road, agriculture area and built up area by using survey and Global Positioning System (GPS).

### 2.4. Land Change Modeler

In this study, land use/land cover (LULC) changes were analyzed using the Land Change Modeler (LCM) software package [3]; available as ArcGIS 10.2 extension, http://www. clarklabs.org). The landscape change analysis consists of two stages. LULC maps of 1988 and 2003 was used to predict the year 2017. After verification model of actual 2017 and observed for 2017, the actual LULC maps of 2003 and 2017 was modelled the modelling of potential change to simulate the landscape in the year 2035.

### 2.5. Parameter Prediction

The variables used to derive a transition of LULC using the empirical likelihood of change [6] include: a) Digital Elevation Model (meter), b) slope (degree), c) soil type, e) distance to green space edge (m), f) distance to build up area edge (m), g) distance to waterbody edge (m), h) distance to road (m), i) land surface temperature. These factors were used to determine the potential spatial distribution of built-up area growth and green space [5] the ‘Euclidean Distance’ tool in ArcGIS 10.2 [3].

### 2.6. Cramer’s V

Cramer's V analysis was used to measure the relationship between green space landscape and the drivers of change in a land use transition quantitatively [5].

### 2.7. Markov Chain Modelling

After the LCM model was verified, green space landscape in 2035 was simulated based on the green space landscape maps in the period from 2003 and 2017 using the probability Markov chain modelling. This process was used to quantify land transition area in the period from 2017 to the predicted date using the probability of change [2].

### 2.8. Model Verification of Land Surface Temperature

The probability of green space landscape change for the period 1988 to 2003 was modelled using an Artificial Neural Networks (ANN) and Multi-Layer Perceptron (MLP). The system of MLP capable to find the relationships among variables and it is the most effective for potential transition modelling [6]. Based on [2], the validation module in LCM was used to compare the agreement and disagreement between maps were adopted by using to evaluate the 2017 predicted result compared to the actual green space area. Model output was validated using land surface temperature data year 2017. The high percentage of agreement allow for the process of modelling the future scenario.


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### 2.9. Land Change Analysis

Percentage area and rate of change of each type of land use/land cover were calculated between 1988 and 2003, and between 2003 and 2017 to determine the amount of green space converted to built-up areas and other land uses. The formula to calculate the proportional rate of change for each LULC [7] is:

$$C = (A_j - A_i) / A_i \tag{1}$$

where C represents the proportional change in LULC and Ai and Aj represent the area of the land type in years i and j, respectively.

## 3. Results and Analysis

### 3.1. Variables of Prediction

Fig. 1 shows the variable maps of a) distance to built-up area edge (m), b) land surface temperature slope (degree), c) Digital Elevation Model (m), d) soil type, e) distance to green space edge (m), f) distance to the road (m), g) distance to waterbody edge (m), and h) slope.

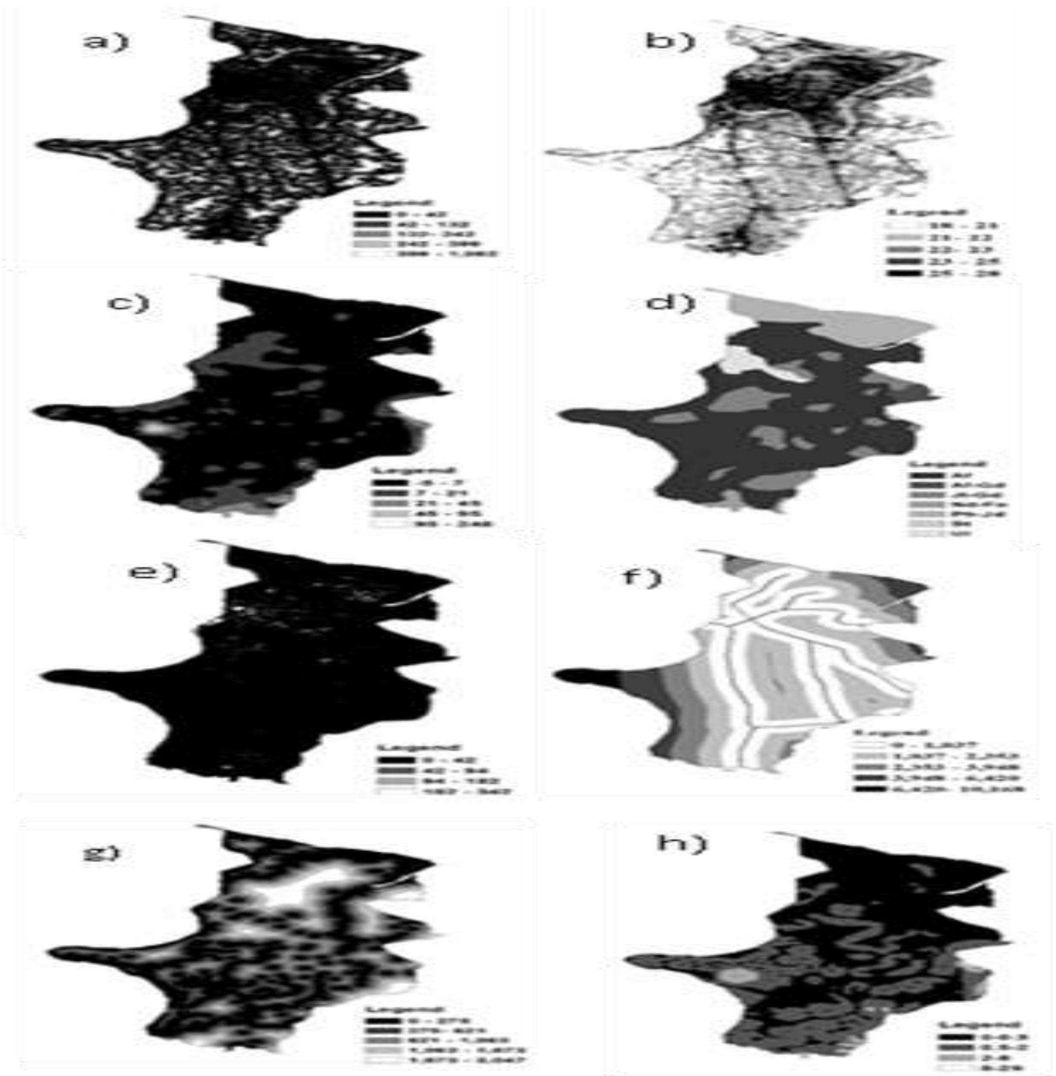


**Fig. 1: The variable maps used for prediction**



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### 3.2. Prediction Cramer's V Value

The value of more than 0.05 is acceptable to be used for the modelling of the Markov Chain. Distance from waterbody show the highest value from 1988 to 2003 and 2003 to 2017 (Table 1).

**Table 1: Cramer's V value of variables**

| Parameter | Cramer's Value | |
|---|---|---|
| Period | 1988-2003 | 2003-2017 |
| Digital elevation model | 0.08 | 0.11 |
| Slope | 0.08 | 0.08 |
| Soil type | 0.16 | 0.14 |
| Distance from road | 0.15 | 0.15 |
| Distance from waterbody | 0.39 | 0.32 |
| Distance from green space | 0.34 | 0.25 |
| Distance from built-up area | 0.33 | 0.31 |
| Land Surface Temperature | 0.16 | 0.3 |

### 3.3. Markov Chain Modelling

In the period 2017-2035, there are major changes from green space to built-up areas in Kota Bharu with Markov Chain values of 0.21. The value of Markov Chain for the probability of transition from built-up areas to green space was 0.55 (Table 2).

**Table 2: Markov Chain modelling values for 2035**

| Land Use Types | Built-Up Area | Green Space | Waterbody |
|---|---|---|---|
| Built-up area | 0.43 | 0.55 | 0.02 |
| Green space | 0.21 | 0.78 | 0.00 |
| Waterbody | 0.10 | 0.32 | 0.57 |

### 3.4. Model Verification

Fig. 2 shows the percentage agreement and persistence were 84.6%, the false negative was 8.4%, and the false positive was 6.9%. The high level of agreement indicated that the model and the relevant variable were suitable (Table 3) to simulate the future.

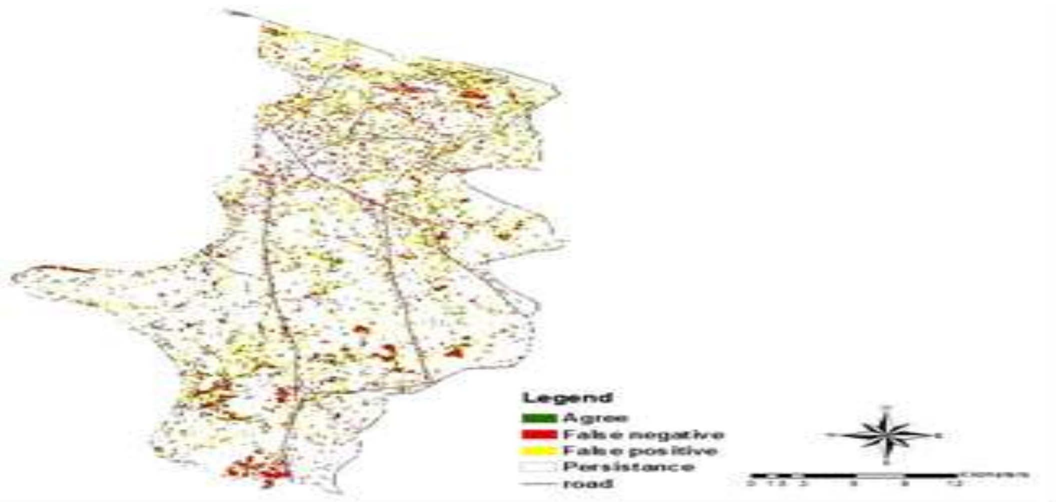


**Fig. 2: Validation map of the simulated model of Kota Bharu in 2017**



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**Table 3: Area (ha) and area percentage of validation for simulated model**

| Term of Validation | Area (ha) | Area (%) |
|---|---|---|
| Agreement | 1526.68 | 3.9 |
| Persistence | 31222.5 | 80.7 |
| False Negative | 3262.37 | 8.4 |
| False Positive | 2689.8 | 6.9 |

### 3.5. Landscape Changes

Landscape change of Kota Bharu was examined based on built-up area, green space area, and water body. The result shows built-up areas at Kota Bharu were a significant increase in the 1988 to 2003 time period with 7.7% change rate. However, the change rate of built up area at Kota Bharu was decreased to 4.01% in the 2003 to 2017 time period. The changes rate of built up area is expected continuous reduce in the 2017 to 2035 time period (Fig. 3). Furthermore, Kota Bharu has experienced the high green space area loss with 7.5% change rate in the 1988 to 2003 time period. In the 2003 to 2017 time period, the changing rate of green space area loss was decreased to 2.7%. It is interesting to highlight that the green space area is predicted will be expanded with a change rate of less than 1% in the 2017 to 2035 time period (Fig. 3). Besides that, water body at Kota Bharu has experienced rapid losses in the 1988 to 2003 time period (<1%) and 2003 to 2017 time period (1.3%). In the 2017 to 2035 time period, water body at Kota Bharu is predicted will reach 1.1% of loss rate (Fig. 3).

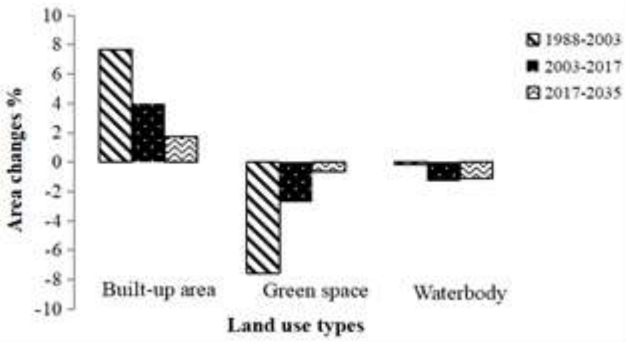


**Fig. 3: The rate of change of land use**

## 4. Discussion

This research information contributes to the understanding of the dynamics of current changes in LULC structure (Fig. 2 and Table 3). In the city, the predictions indicate a further increase in built-up areas and a decrease in green space by 2035 (Fig. 3). The historical spatial changes were influenced by the uncontrolled planning policies. This work has shown how an integrated landscape ecology approach in LULC simulation modelling has the capability to quantify the spatial effects of successful planning interventions under rapid urban expansion and their effect on urban green space dynamics. The model provides the guideline and illustrating possibly improvements to the master planning strategy and inform effective planning in the future. This study illustrates a novel approach and application to LCM-Markov chain models, namely as a diagnostic tool to identify evidence of past or current planning interventions. This is particularly critical in cities undergoing rapid urban expansion, where assessing the relative impact and degree of success that planning can have is often difficult to obtain.

The transition of green spaces into the built-up areas has recognized one of the major threat for habitat degradation worldwide [2] and therefore, it is becoming important to understand the changes in the urban ecosystem (Table 2). Ineffective urban development



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planning can cause changes to the composition and configuration of green space [8]. In Malaysia, lack of monitoring poses challenges for the adoption of appropriate land management strategies. In addition, uncoordinated master planning strategies often lack information on the historical changes to the urban and green space area [9]. There is still unclear understanding of the spatial effects of urban planning arising from rapid urban expansion. Therefore, the finding is important and timely as it highlights the planning problems faced by rapidly expanding cities, distinguish the best master planning strategies under a rapid urban expansion scenario and urban heat temperature and propose a new integrated methodology for simulating urban expansion and land surface temperature that can be used by administrative planners and decision-makers to assess, understand and monitor the effectiveness of master planning for climate change adaptation.

## 5. Conclusion

This study has sought to understand that urban expansion negatively impacts the landscape of green space changes to mitigate urban heat effect in an urban and suburban city for improving the healthy environment and quality of life of urban dwellers. Urban expansion results in green space loss, increasing fragmentation and land surface temperature. Historical and future urban expansion have negative implications on green space area and increase in land surface temperature.

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