QUANTIFYING GREEN SPACE COOLING EFFECTS ON THE URBAN MICROCLIMATE USING REMOTE SENSING AND GIS TECHNIQUES

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Presentation outline:
- Aim of presentation
- Background of study
- Study area
- Research methodology
- Results and analysis
- Conclusion and Recommendation
Aim of presentation:

To present - the research findings in quantifying the green space cooling effects on the urban microclimate.

Background of Study

• Rapid growth - reduction of vegetated areas, increased the built-up surfaces and also possible cause of UHI.

• UHI phenomenon has been found in cities throughout the world - defined that the urban air and surface temperatures are hotter than their rural surroundings.

• The built-up surfaces trap the incoming solar radiation during the day and then re-radiate it at night.
The vegetated area helps to keep the temperature of the surrounding lower than the developed area by its shadow and evapotranspiration.

In earlier study - the temperature of urban parks is found to be 1–2°C, and sometimes even 5–7°C cooler than their urban surroundings.

- **Park Cool Island (PCI)**- an irregular pattern of cooler areas within generally warmer urban areas.

- **PCI** - has strong cooling effects on the local surrounding.

- The shadows of high density trees and the water element in the urban green spaces contribute to cooling effect factors.
Background of Study

- Urban green spaces – has positive cooling effects within surrounding urban areas even in small size.
- Maximum cooling effects - not reached in the bigger park but was due to the compactness of green space.
- **Satellite imagery + GIS** – used to monitor the land use changes and land surface temperature (LST).
- Green spaces - can create a cooling effect that extends to the surrounding areas.

Area of Study

- **Map of Selangor**
- **Part of Petaling District:**
  a) Shah Alam Lake Garden
  b) Tasik Bandaran Kelana Jaya
  c) Subang Ria Recreational Park

These areas are selected due to rapid urban development activities and existence of these cities over the last 30 years.
Research Methodology

Data Acquisition

Data Pre-Processing

Data Processing

Data Analysis

Data acquisition:

- Satellite Imagery (Landsat 5TM 2009) Downloaded from USGS website
- Meteorological Data acquired from MMD
Research Methodology

Data preprocessing – Image Subset for area of study, TIR band and NDVI

Landsat full scene-path/row (127/58)

Data Processing:

• Land use – unsupervised classification with 5 types of land use classes.

• NDVI:
  \[
  \text{NDVI} = \frac{(\text{NIR} - R)}{\text{NIR} + R}
  \]
  Where, NIR - the pixel digital number (DN) of TM Band 4, R – DN of TM Band 3

• LST- Mono-Window Algorithm:
  \[
  T_s = \{a(1-C-D) + [b(1-C-D) + C + D]T_i - DT_a \} / C
  \]
  where:– Ts is LST in Kelvin; \(a = -67.355351\); \(b = 0.458606\); \(C = \varepsilon_i \times T_a\); where \(\varepsilon_i\)=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.
Data Processing:

- **Park Cooling Effect Intensity** –
  
  Park cooling intensity \((\Delta T) = T_u - T_p\)
  
  where, \(T_p\) is the average LST inside the park
  
  \(T_u\) is the average LST outside the park

- **Relationship with Distance from Park Boundary** - Linear Correlation

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Green Space Cooling Effects Buffer Distance

- a) Shah Alam Lake Garden
- b) Bandaran Kelana Park
- c) Subang Ria Recreational Park

The 50 m multiple ring buffer with maximum buffer distance of 1000 m generated from outside the green space/park boundary.
Data Analysis:

• Surface Temperature Distribution within different land use/land cover.

• Vegetation cooling effects on surrounding areas.

Outputs:

• Map of land use/land cover, NDVI map, LST map in 2009.

• The detail urban green space profile in selected study area.

• The cooling effect intensity and correlation between cooling effect intensity and buffer distance.
Results and Analysis

Land Use/Land Cover and NDVI Map

Legend:
- Water bodies
- High Dense Trees
- Mix Vegetation
- Built-up area
- Open land

Land Use Map of 2009
NDVI classification Map of 2009

Results and Analysis

LST Map

<table>
<thead>
<tr>
<th>Land use/ Land Cover</th>
<th>2009 (Temperature °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>25.3</td>
</tr>
<tr>
<td>High Dense Tree</td>
<td>25.4</td>
</tr>
<tr>
<td>Mix Vegetation</td>
<td>28.0</td>
</tr>
<tr>
<td>Built-up area</td>
<td>30.8</td>
</tr>
<tr>
<td>Cleared Land</td>
<td>28.7</td>
</tr>
</tbody>
</table>
Kelana Jaya area has been transformed to the new urban area and surrounded by industrial area, high rise building, facilities building (i.e.; stadium and sports centre), road and commercial building. As the profile line crossed over the grass area the temperature remain unchanged.
The surrounding area consists of multiple land use (i.e.; Highway, high rise building, private club and residential). Water body also could be another variable besides vegetation that can help lowering the surface radiant temperature.
Green Space Cooling Intensity

<table>
<thead>
<tr>
<th>Park</th>
<th>Buffer Range (m)</th>
<th>PCI Intensity ($\Delta T^\circ C$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Shah Alam</td>
<td>25.5</td>
<td>1.33</td>
</tr>
<tr>
<td>Kelana Jaya</td>
<td>26.4</td>
<td>2</td>
</tr>
<tr>
<td>Subang Jaya</td>
<td>25.8</td>
<td>1.1</td>
</tr>
<tr>
<td>$T_p(\circ C)$</td>
<td>550</td>
<td>500</td>
</tr>
<tr>
<td>Shah Alam</td>
<td>25.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Kelana Jaya</td>
<td>26.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Subang Jaya</td>
<td>25.8</td>
<td>3.3</td>
</tr>
</tbody>
</table>

i. In the 50 m buffer zone the intensity range from 1$\circ C$ – 1.7$\circ C$.

ii. As the buffer distance reaches the 500 m buffer zone, the intensity value increases by 3$\circ C$ to 3.3$\circ C$.

iii. However, the highest intensity value is 3.9$\circ C$ at the buffer distance of 400 m in the Bandaran Kelana Park. The land use/land cover types within the 400m buffer zone are mainly commercial and built-up areas. The mean in this region is approximately 26.4$\circ C$.

Correlation Between Cooling Effect Intensity and Buffer Distance

a) Shah Alam Lake Garden

\[ y = 0.0051x + 0.774 \quad R^2 = 0.9088 \]

- Strong positive correlation between cooling effect intensity and proximity from the park boundary are clearly evident.
- The $R^2$ coefficients for Shah Alam Lake Garden (0.9088), Bandaran Kelana Park (0.816) and Subang Ria Recreational Park (0.9174).
- Urban green spaces are capable of reducing the high radiant temperature of the surrounding areas.
Conclusion and Recommendation

i. The cooling effects of parks - depends on the park profile (water body, high density trees, mix vegetation, built-up area and open spaces).

ii. The composition of different land use/land cover within the parks generated different average park temperature.

iii. The cooling effect intensity increases as distance from the park boundary increases. The temperature difference between the interior of the park and the zones 500 m from the park boundary is more than 3°C.

iv. Further research should include detailed studies on the urban green spaces cooling effect based on various park design, park size and park orientation.

v. Findings from this study will help urban planners or urban designers to understand the interaction between urban parks and UHI effects especially in a hot and humid tropical climate region like Malaysia.
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