Modelling of Land-Use/Land-Cover Change and Its Impact On Local Climate of Klang River Basin

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Abstract. Land-use and land-cover (LULC) change has significant effect on local climate variables such as temperature and rainfall as it alters the energy budget, water budget and atmospheric variables. Past studies have shown urban areas can result in high temperature and alter rainfall amounts and intensity. This study therefore looks at spatio-temporal change in land-use/land-cover, and trends in precipitation and temperature for the Klang river basin. The aim of the study is to determine the effects of these changes in land-use on precipitation and temperature trends. Precipitation data was tested using the Mann-Kendall statistics test. Precipitation amount and two precipitation indices (simple day intensity index (SDII) and R95p) for the full year period and both the monsoons and inter-monsoon periods are tested. For temperature, land surface temperature maps of the study area for the years 1999, 2006 and 2017 was created from the thermal band of the images. Remote sensing is used for modelling spatio-temporal changes in LULC of Klang river basin using multi-temporal LandSat dataset (1999, 2006, and 2017). The LULC modelling shows an increase in urban area of 51.5% from 1999-2017, and decrease in natural vegetation 17.6% and cultivated land 35%. The results of precipitation analysis show a mixture of both positive (increasing) and negative (decreasing) trends for stations in the study area, and for temperature there is an increase of 10.1 °C in maximum temperature from 1999-2017. The correlation test shows a positive correlation between precipitation and temperature, but the relationship is not significant. The LULC change has significant impact on temperature; however, the increasing temperature has an insignificant positive correlation with rainfall. This could indicate that the change in rainfall is mostly due to other factors.

Keyword: Monsoon, Man-Kendall Test, Indices, Land-use Change, GIS.

1. Introduction
The human induced land-use and land-cover change (LULC) has great impact on the environment (Kaufmann et al. 2007). LULC changes surface properties like albedo, roughness, soil moisture, thermal characteristics and water features and hence this can alter water budget, energy budget and atmospheric variables (Salleh et al., 2013). Urbanization is a major factor contributing to land use change, where 55% of world population live in urban areas. In Malaysia, the urban population is currently at 76% and it is projected to continue increasing in the near future (UN 2018). Urbanization can affect weather variables like temperature and precipitation, where increase in surface temperature due to heat absorbing
materials like concrete and steel result in the phenomenon known as Urban Heat Island and this increase in temperature can result in formation of rain producing clouds over urban areas (Collier, 2006; Earth Observatory NASA, 2006). Urbanization can also modify and alter precipitation; studies have shown urbanization leading to increase in precipitation amount and frequency (Huff & Changnon, 1973; Liu & Niyogi, 2018; Niyogi et al, 2017; Sheng et al, 2015). This study aims analyse the spatio-temporal changes in land use for the greater Klang river basin, and its influence on the rainfall and temperature changes.

2. Material and methods

2.1. Study Area
The highly urbanized Klang River Basin is located in Selangor, with a size of 1899.85 km². The basin receives rainfall during Northeast monsoon (Nov-March), Southwest monsoon (May-Sep) and two inter-monsoon periods (April & Oct), with an average annual rainfall that ranges from 1900mm-2600 mm. The monthly mean temperature ranges from 26-28 °C, with a daily mean humidity of about 80-85%. Figure 1 shows the location of Klang River Basin and the location of the meteorological stations used for this study.

![Figure 1. Map of Selangor and Klang River Basin](image)

2.2. Data
Land-use maps are developed from Landsat Operational Land Imager images dated 1999, 2006, and 2017 downloaded from the United State Geological Services website at (http://earthexplorer.usgs.gov/). The thermal band of the same images are used to develop land surface temperature maps. Daily precipitation data for 12 stations, 10 obtained from Department of Irrigation and Drainage (DID) for the
period 1975-2015 and 2 obtained from Malaysian Meteorological Department (MMD) for the period 1995-2018 is used.

2.3. Land-use Modelling
The Landsat images are mosaicked to improve coverage over the study area. Data merge operation is conducted to improve the spatial resolution of the multispectral of the visible bands of the Satellite image. Maximum likelihood algorithm under supervised classification is performed to classify the land-used maps. The classes consist of water, natural vegetation, cultivated land, urban, and bare land, the area of each class is then calculated.

2.4. Rainfall Trend Analysis
Mann-Kendall trend test is used for rainfall trend analysis. This is a non-parametric (i.e., distribution free) test used to detect the presence of linear or non-linear trends in time series data. The M-K test assesses if a series is steadily increasing/decreasing or unchanging. Trend analysis was carried out for rainfall amount and two rainfall indices. The significant level was taken at 0.001, 0.01 and 0.05. The Inverse Distance Weighting (IDW) interpolation we used to interpolate the trend analysis and created spatio maps of the trends.

The two indices are obtained from the Expert Team for Climate Change Detection and Indices (ETCCDI) list.

i) Simple Day Precipitation Index (SDII):
SDII is the ratio of annual total precipitation to the number of wet days (≥ 1 mm). It is calculated by the equation below:

\[ SDII_j = \frac{\sum_{w=1}^{W} RR_{wj}}{W} \]  

Where RRwj is the daily precipitation amount on wet days, w (RR ≥ 1mm) in period j. If W represents number of wet days in j.

ii) R95p:
R95p represents the very wet day, and it is calculated when annual rainfall on wet days is greater than the 95 percentile:

\[ R95p = \sum_{w=1}^{W} RR_{wj} \]  

Where RRwj >RRwn95, Let RRwj be the daily precipitation amount on a wet day w (RR ≥ 1.0mm) in period i and let RRwn95 be the 95th percentile of precipitation on wet days in the 1961-1990 period.

2.5. Land surface temperature
The thermal band of the Landsat images for years 1999, 2006 and 2017 were used to create land surface temperature (LST) maps. To obtain the LST maps first atmospheric spectral radiance was calculated, then the radiance was converted to At-Sensor temperature, this was followed by calculating NDVI for emissivity correction, which consists of 3 steps; (1) Calculating NDVI, (2) Calculating the proportion of vegetation and (2) Calculating land surface emissivity. The final step is the calculation of the land surface temperature, where the following equation is used:
\[ T_s = \frac{B_T}{1 + \left( \frac{\lambda B_T}{\rho} \ln \varepsilon \lambda \right)} \]  

(3)

Where \( T_s \) is the LST in Celsius (°C), \( B_T \) is brightness temperature at sensor (°C), \( \lambda \) is the average wavelength of thermal band, \( \varepsilon \lambda \) is the land surface emissivity and \( \rho \) is \( (h \cdot c / \sigma) \) which is equal to 1.438 x 10^{-2} mK in which, \( \sigma \) is the Boltzmann constant (1.38 x 10^{-23} J/K), \( h \) is Planck’s constant (6.626 x 10^{-34} Js) and \( c \) is the velocity of light (3 x 10^8 m/s).

2.6. Correlation test

Pearson’s correlation test is carried out for rainfall and temperature data for the two MMD department stations to see if there was any relationship between the two variables.

3. Results and discussions

3.1 Land-use Change

The land use change modelling showed an increase in urban areas of about 364.2 km² (51.5%), decrease in natural vegetation 85.4 km² (17.6%), decrease in cultivated land 207.4 km² (35%), and decrease in bare land 66.8 km² (70%) from 1999-2017, with water bodies increasing slightly about 4km². The land use maps are shown in figure 2. The land-use modelling shows a significantly large increase in urban areas, especially from 2006 to 2017. The increase in urban areas can contribute to the increase in surface temperatures, which in turn could alter precipitation properties, as shown by past studies like (Argueso et al, 2016; Han et al, 2013; Collier, 2006).

![Figure 2. Land-use maps for years 1999, 2006, and 2017.](image)

3.2. Land surface temperature

The land surface temperature maps show increase in temperature and an upwards shift in temperature range during the 1999-2017 period. The temperatures ranged from 9.5-31.2 °C, 8.5-36.1 °C and 12.1-41.3 °C during the year 1999, 2006 and 2017 respectively. The highest temperatures occurred in urban areas, followed by cultivated land and the lowest temperatures occurred in natural vegetation areas. There was increase in both minimum and maximum temperatures in the 18-year period, with maximum temperature increasing by 10.1 °C. This indicates that the increase in urbanization directly affected surface temperatures resulting in higher temperatures.
3.3. Trend Analysis
The rainfall trend analysis from 1975-2015, showed a mixture of positive and negative trend with some cases being significant. Out of the 12 stations, three stations namely (Subang, Petaling Jaya and Pusat Penyelidikan) had positive trend throughout the whole year and both in the monsoons and inter-monsoons periods, with Penyelidikan station having mostly significant trend. These three stations as shown in the map are located in and around urban areas; therefore these positive trends in rainfall amounts and intensity could indicate urban areas have an impact on rainfall in this area.
Figure 4. Trend analysis for Rainfall Sum, SDII and R95p for the full year period. (Yellow colour represents significant trend).

Table 1 shows the trend for SDII and R95p indices for both monsoons and inter-monsoon periods. The analysis shows positive trend for R95p during NEM for all the stations, and a mixture of positive and negative trend for SDII during NEM and SWM. The Pusat Penyelidika and Petaling Jaya stations had positive trend for all monsoons and inter-monsoon periods for both the indices, and in particular during NEM Pusat Penyelidika station had significant positive trend. The inter-monsoon periods show a mixture of positive and negative trend with some stations having no trend. This could explain that urban areas influence rainfall, alter its intensity, and amount especially during monsoon seasons.

| Station Name     | SDII Trend | R95p Trend |
|------------------|------------|------------|
|                  | NEM Test Z | SWM Test Z | IntM1 Test Z | IntM2 Test Z | NEM Test Z | SWM Test Z | IntM1 Test Z | IntM2 Test Z |
| Ldg. Bukit Kerayong | -2.75**   | -1.0       | -0.33       | -2.59**      | 0.53       | 0.48       | -0.71       | -2.48*       |
| Ldg. Sg. Kapar   | -0.03      | 0.82       | 0.13        | 0.76         | 1.44       | 1.19       | 0.72        | 0.70         |
| Setia Alam      | -4.10***   | -2.85**    | -2.14*      | -2.33*       | 1.36       | 0.10       | -0.05       | 0.16         |
| Ldg. Elmina A   | 0.57       | -0.98      | -0.59       | -0.51        | 1.21       | -0.38      | -0.42       | -0.55        |
| Pusat Penyelidika| 4.03**     | 3.25**     | 0.51        | 1.38         | 2.92**     | 1.63       | 0.63        | 0.36         |
| Ldg. Braunston  | -0.50      | -1.24      | -0.31       | -1.82        | 1.26       | 0.98       | 2.26*       | 0            |
| Ldg. Bkt. Cherakah| 2.80*      | 1.95       | 0.39        | 0.80         | 2.01*      | 1.78       | 2.80**      | 0            |
| Ldg. Tuan Mee   | -1.0       | -1.35      | -1.46       | -1.18        | 0.82       | 0.62       | 0           | -0.60        |
| Ldg. Bkt. Ijok  | -1.40      | -1.36      | -2.04*      | -2.0*        | 1.28       | 1.35       | -0.18       | -0.42        |
| Ldg. Sg. Buloh  | -2.39*     | -3.02**    | -2.09*      | -1.61        | 0.11       | -1.46      | -0.30       | 0.10         |
3.4. Correlation test
The correlation coefficient r for rainfall and temperature for Petaling Jaya station was r=0.116 with a significance of 0.591, for Subang station r=0.29 and a significance of 0.892. The results show a positive relationship between rainfall and temperature, but this relationship is not significant, indicating that temperature rise may only play small part in affecting rainfall. Other factors like urban aerosols, urban roughness, wind and in the case of coastal cities sea breeze (Liu & Niyogi, 2019; Ooi et al, 2017) may have more influence on rainfall, and should be considered in future studies.

4. Conclusions
The economic and population growth in Malaysia has resulted in rapid urbanization and the Klang basin has experienced great increase in urban areas especially from the year 2006 onwards. This increase in urban areas has resulted in significant rise in surface temperatures, where an average increase of 6.3°C between 1999-2017 occurred, with urban land having the highest temperatures. The rainfall trend showed a mixture of positive and negative trend, but out of the 12 stations 3 stations located in urban areas showed mostly positive trend, with one station having positive trend for all indices. However, the correlation test between temperature and rainfall although being positive was not significant. Therefore, we can conclude that increase in temperature may have a small effect on rainfall and that other factors, like urban roughness, urban aerosols, sea breeze and wind may have more of an impact than UHI on rainfall, hence future studies should consider their effects.

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