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# Accelerated Urbanisation and the Changing Trend of Rainfall in Tropical Urban Areas

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**Abstract:** Urbanisation is a dynamic process which involves the expansion of urban related areas with definite environmental impacts, one of which is the alteration of the urban micro climate including the frequency and magnitude of rainfall events. This article analyses the effects of urbanisation on the changing rainfall pattern of highly urbanised Kuala Lumpur. For the purpose of comparison, Mantin rainfall station was chosen to represent the area with the least urbanisation. The diurnal rainfall data for both Kuala Lumpur and Martin stations were collected for the 20 years period of 1981 to 2000. They were then divided into two extreme intensity categories *viz.* light and heavy rainfall. The overall results showed that the yearly average rainfall for Kuala Lumpur displayed an upward trend since 1990. This was different from the more fluctuating trend before the 1990 period. In conclusion, the Kuala Lumpur Cityhall would do well to heed this finding as an important hydrometeorological barometer, especially in reducing the frequent occurrances of flash flood in Kuala Lumpur. Not only must urban climate issues such as urban rainfall be included in the city's 'green' and sustainable development policies, but that more importantly such policies must be enforced in the subsequent course of Kuala Lumpur urban landscape planning.

**Key words:** Precipitation · Urbanisation · Changing trend · Rainfall intensity

## INTRODUCTION

Urbanisation is a dynamic process involving areal expansion that implicates the natural physical landscape and the socio-economic sectors. It leads to environmental degradation and threatens the ecosystem health [1, 2]. Previous studies had shown that urbanisation could alter the urban micro climate, in particular, the frequency of precipitation day and the intensity of precipitation [3-7] as well as flood hazards [8, 9]. As the city grows, the expansion of impervious surfaces creates major changes in surface albedo, urban temperature and urban heat budget, thus giving rise to various impacts on microclimate processes [5, 10].

Urban areas may create events of high rainfall frequency and magnitude due to the urban heat island effect and increase water input into an urban catchment [11]. As a consequence, the urban microclimate especially rainfall and temperature trends of the city may get altered due to urban hydrometerological imbalance [12-14]. With global warming being at the forefront of environmental issues all over the world today, the impact of changing rainfall trends on the urban life cannot escape notice. This includes the situation in tropical cities such as Kuala Lumpur. On this note, this paper analyses the effects of urbanisation on Kuala Lumpur's rainfall pattern for the last few decades by comparing it to that of a Malaysian rural area.

## MATERIALS AND METHODS

**The Study Area:** Malaysia's population statistics has showed that nearly 95% of the country's population live in urban areas [15]. Kuala Lumpur was the capital and is the largest city in Malaysia. The city comprises an area of 244 $km^2$, with an average elevation of 21 m. Historically, accelerated urbanisation in Kuala Lumpur has taken place at the beginning of 1970's when large tracts of green spaces, forest and unused lands were converted into the normal urban uses of commercial and business centers, government offices, residential areas and public amenities.

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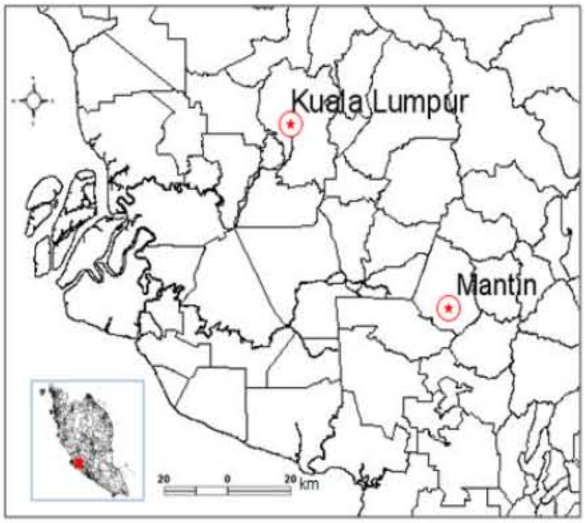


Fig. 1: The location of the two rainfall stations used in this study

Since then, rapid urban development had led to more and more people migrated to Kuala Lumpur, resulting in more areas at the periphery of Kuala Lumpur to be converted into squatter settlements. In the latest 2005 estimation, the population of Kuala Lumpur was about 1.6 million with an average natural population increment of 2% per year. Based on this figures by the year 2020 Kuala Lumpur will accommodate about 2.5 million people [15].

Figure 1 shows the two locations of the rainfall stations being used in this study.

One station was the urban Kuala Lumpur rainfall station and the other was Mantin representing a more rural area. The Kuala Lumpur station or better known as Bukit Nenas Meteorological station (3.153°N, 101.703°E) was located at the heart of the city business district, an enclave with the highest percentage of urban impervious surfaces in Malaysia. It was situated at about 60 m above sea level and managed by the Geography Programme of Universiti Kebangsaan Malaysia. The Mantin rainfall station (2.829°N, 101.825°E) was located near Mantin town and about 40 km to the south-east of Kuala Lumpur. Almost 95 % of the land within 10 km radius of Mantin was designated for agricultural activities such as rubber and oil palm plantations. Located at about the same height of Bukit Nenas Meteorological station, Mantin station was supervised and maintained by the Malaysian Drainage and Irrigation Department (DID).

**Data Collection:** The diurnal rainfall data were collected for a period of 20 years spanning from 1981 to 2001. The diurnal rainfall data were then divided into three intensity categories, namely light, moderate and heavy rainfall. These categories corresponded respectively to intensity levels for every 2 hours of less than or equal to 5 mm, between 5 and 17 mm and greater than 17 mm [14]. However, for this study only two intensity categories were taken into consideration i.e., light and heavy intensities.

The justification for using such rainfall intensity levels was to observe any significant impact of urbanisation on rainfall. All statistical tests were run with *SPSS Version 12 for Windows* and also Excel programme on a Windows platform. For the long term rainfall intensity analysis, the time period was divided into several groups to assess any significant change within the studied period. Before the datasets were run into the tests, the normality of the data was tested by Kolmogorov-Smirnov one sample tests using a normal distribution and 2-tail Lilliefors probabilities. All statistical tests were performed for significance at the 99 percent confidence level. Since based on the normality test the dataset was not normal, the non-parametric test was carried out by using the Kruskal Wallis One-Way Analysis of Variance test. The non parametric of Kruskall-Wallis test was applied based on several groups of rainfall period (1981 to 2001) to analyse changes in rainfall patterns.

## RESULTS AND DISCUSSION

The preliminary results revealed that the daily rainfall patterns for Kuala Lumpur and Mantin were classified as the west coast climate type of Peninsular Malaysia denoting that they belong to the same hydrometeorological region [16]. Figures 2 and 3 show the three dimensional (3D) patterns of light and heavy rainfall intensities for Kuala Lumpur for 24 years period.

Looking at Figure 2, the three dimensional figure of light rainfall for Kuala Lumpur confirmed that the driest months were at the begining of the year as well as between the months of June and August-September. The wettest months for the light rainfall intensity were November-December. It can be seen that the intensity of light rainfall prevailed almost every hour of the day in those months especially at night, late at night and late morning.

Figure 3 shows the three dimensional pattern of heavy rainfall intensity for Kuala Lumpur for 24 years period. Once again the driest months prevailed in January-March period, especially during early morning hours. Meanwhile, during the months of June-September,

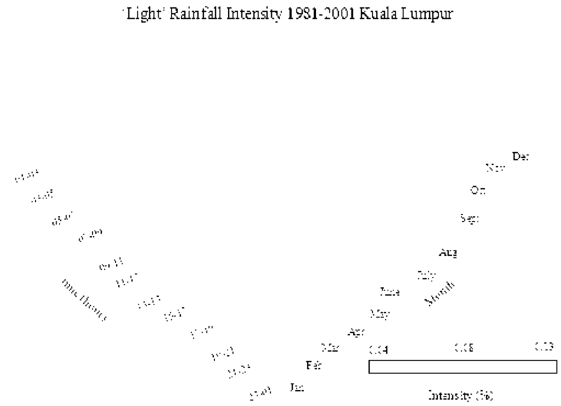


Fig. 2: Light rainfall intensity (1981-2001)

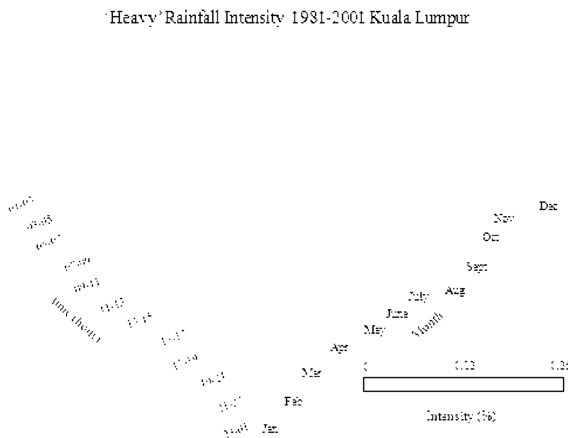


Fig. 3: Heavy rainfall intensity (1981-2001)

Table 1: The monthly average (frequency) of rainfall intensity for both stations

| | Rainfall intensity | |
|---|---|---|
| Rainfall stations | < 5 mm/ 2 hour | Above 17 mm /2 hour |
| Kuala Lumpur | 16.2 | 4.0 |
| Mantin | 18.2 | 1.9 |

the driest time of the day was observed during late evening and midnight. Although the wettest months also prevailed in September-December, they were observed during the early hours of the day i.e., between midnight and early morning.

The monthly average (frequency) of rainfall intensity for both stations had different patterns (Table 1).

There was a change in the rainfall intensity especially for light rainfall observed in the urban area. The urban station displayed less light rainfall intensity within the studied period. However, the heavy rainfall intensity had positively shown a rising trend in frequencies, in particular for the urban station (Figure 4).

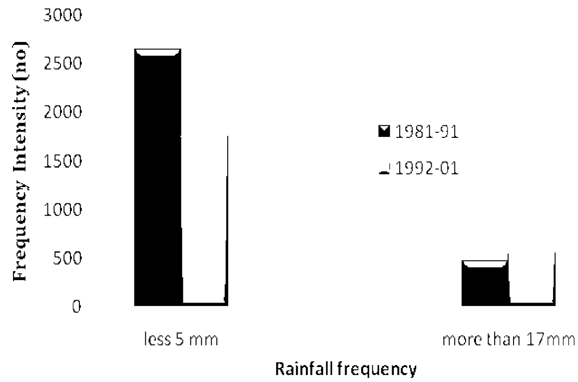


Fig. 4: Changes in rainfall frequency at Kuala Lumpur

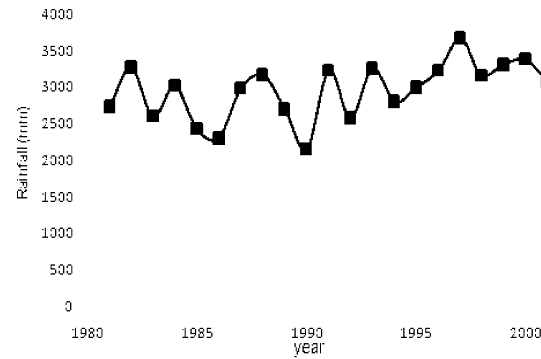


Fig. 5: Yearly average rainfall of Kuala Lumpur (1981-2001)

In general, since 1990, the yearly average rainfall for Kuala Lumpur displayed an upward trend. This is different than the rainfall trend before the 1990 period whereby it showed a more fluctuated trend (Figure 5).

The Kruskal Wallis statistical test was carried out to analyse changes in the rainfall pattern (Table 2).

Except for the light rainfall intensity for the urban station, all other rainfall intensities were not significant at the 0.01 required level. This could be due to other factors such as the microclimate alteration due to urbanisation.

Due to the rainfall changing pattern, the occurrances of drier environment were observed more during the months of January-March and June-August, especially in the afternoon and late evening for the light rainfall intensity (Figure 6a). For heavy rainfall intensity, the wetter environment which could trigger water-hasard episodes such as flash flood in low lying areas was observed more frequently during July-November, particularly in the early morning (Figure 6b).

Table 2: Kruskal Wallis statistical test result for Kuala Lumpur and Mantin stations

| | Rainfall intensity | | | |
|---|---|---|---|---|
| | < 5 mm/ 2 hour | | Above 17 mm /2 hour | |
| Statistical test | Kuala Lumpur | Mantin station | Kuala Lumpur | Mantin station |
| Chi-square | 60.4 | 27.8 | 18.9 | 29 |
| dF | 18 | 18 | 18 | 18 |
| Asymp Sig. * | 0.00 | 0.07 | 0.45 | 0.06 |

*Tested for the significance level of 0.01

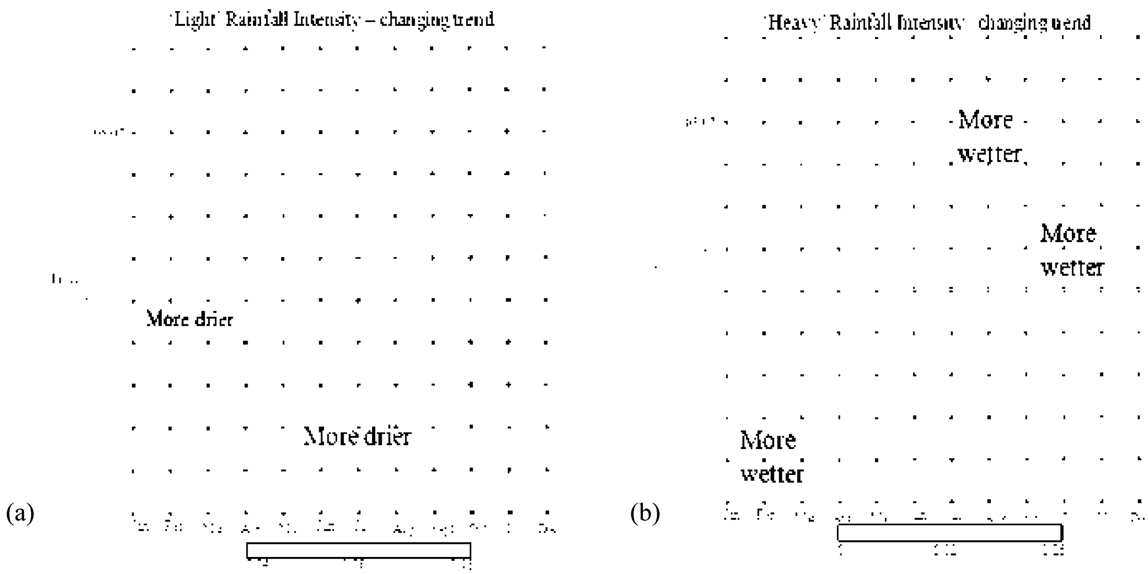


Fig. 6: The changing rainfall trend of Kuala Lumpur

This changing trend in of urban rainfall at in Kuala Lumpur could be linked to changes in surface albedo which increased the patches of heat island within urban core. Urban heat island is a common phenomenon in major cities in the world, including Malaysia [17, 18]. By definition, urban heat island is a phenomenon whereby temperatures in urbanised areas are higher than temperatures observed at the surrounding and periphery areas. This is because the presence of many more and large areas of dark surfaces like concrete roofs, pavements and asphalt means that more heat from the sun would be absorbed during the day and released as latent heat at night. In contrast, at in the periphery and suburban areas where there are more vegetation and green areas, excessive heat would be used by vegetation to run processes such as photosynthesis, evaporation and transpiration. As such less heat was used to heat-up the environment.

Theoretically, leaves use evapotranspiration to collect dust from the air and heat to evaporate moisture which then reduces the outside temperature. Evapotranspiration occurs when plants secrete water through the pores in their leaves. The water uses up heat when it evaporates and cools the air, leaving the green roof at a lower ambient temperature throughout the day. Adding more vegetation to cities, therefore, will help to reduce urban heat island effects, which in turn would reduce greenhouse gas emissions and smog.

## CONCLUSION

In conclusion, this paper shows that urbanisation has played a significant role in changing the rainfall trend of the highly urbanised Kuala Lumpur as compared to the much less urbaniseed Mantin. Nevertheless, changes observed in both rainfall stations could also be due to the effect of global warming the confirmation of which must await further experiments.

It must be noted that although a set of 'green' and sustainable development policies has already been proposed in Malaysia [19] it lacks a climate input, in particular, policies pertaining to climate issues such as extreme urban rainfalls. Morever, enforcement of the policy stipulations is crucial. Intense urban heat island may cause frequent and heavy rainfall in urban areas causing leading to flash flood hasard and other environmental problems. This underlines the need for urban areas such as Kuala Lumpur to embark on adaptation processes that focus on the improvement of bare and unused lands as well as increasing the area of green field in order to reduce the adverse effects of urban heat islands.

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