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Study of green areas and urban heat island in a tropical city

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Abstract

Green areas in cities have been considered as potential measure in mitigating the urban heat island (UHI) effect. In this paper, a mobile survey was conducted to explore both the severity of UHI effect and cooling impacts of green areas at macro-level in Singapore. Islandwide temperature distribution was mapped relying on data derived from the mobile survey. This study has indicated a strong correlation between the decrease of temperature and the appearance of large green areas in the city. Although there is no distinct borderline between 'urban' and 'rural' areas in Singapore, maximum temperature difference of 4.01 °C was observed.

Introduction

With rapid urbanization, there has been a tremendous growth in population and buildings in cities. The high concentration of hard surfaces actually triggered many environmental issues. The urban heat island (UHI) effect, one of these environmental issues, is a phenomenon where air temperatures in densely built cities are higher than the suburban rural areas. The primary root of heat island in cities is due to the absorption of solar radiation by mass building structures, roads, and other hard surfaces during daytime. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures at night.

The UHI phenomenon was first noticed by meteorologists more than a century ago (Howard, 1833). Since then, the UHI effect has been well explored worldwide (Oke, 1978; Landsberg, 1981; Santamoouris, 2002; Akbari, Rosenfeld, & Taha, 1990; Tso, 1996). Some of the most important factors which may influence the UHI effect include canyon geometry, thermal properties of materials, anthropogenic heat, the urban greenhouse effect, and evaporation surfaces (Santamoouris, 2002). According to Landsberg (1981), UHI, as the most obvious climatic manifestation of urbanization, can be observed in every town and city.

Green areas are actually the ecological measure to combat the problems of the concrete jungle. They are quite different from the built up environment. Any surface planted with vegetation has a different Bowen ratio[1] than a mineral surface since the incoming solar radiation is converted into energy for transpiration and photosynthesis through plants and the sensible heat flux is consequently lower. At night, the energy of the outgoing net radiation from a green surface is fed from the thermal heat flux and the latent heat flux. Therefore, the temperature around the green area is lower than that around the built environment.

The role of green areas in moderating the urban climate has been explored all over the world during recent years. The studies can be roughly divided into three categories. Firstly, meteorological data and satellite images were employed to study the effect of green areas in cities at macro level. Saito (1990/1991) studied the relationship between meteorological elements and green distribution in Kumamoto City in Japan and concluded that the air temperature distribution was closely related to the distribution of greenery in the city. Kawashima (1990/1991) examined the effects of vegetation density on the surface temperatures in the urban and suburban areas of Tokyo Metropolis and observed lower surface temperature in green areas. Secondly, some in-depth field measurements were carried out to explore the cooling effect of green areas at micro-level. Jauregui (1990/1991) found that in a large urban park (Chapultepec Park) in Mexico City, the ambient temperature was 2–3°C lower than its surrounding built-up area and its influence reached a distance of 2 km, about the same as its width. Sonne and Vieria (2000) conducted measurement over a 1 year period at three Melbourne and Florida sites and found that temperature measured in a forested natural park was consistently lower than that measured in a residential development with an extensive tall trees canopy while the temperature measured in this residential development with extensive planting was always lower than that measured in a residential development with very few trees. Finally, numerical calculations were set up to predict the thermal benefits of green areas in cities. Avissar (1996) studied the potential impact of vegetation on the urban thermal environment by use of a mesoscale atmospheric model. Honjo and Takakura (1990/1991) estimated the cooling effect of green areas on their surroundings with the use of a numerical model.

The cooling effect of green areas in cities has been confirmed by the above studies. It is doubtless that the UHI effect is aggravated mainly due to the lost of green areas in the urban environment. In Singapore, rapid population influx has led to demands for converting natural areas to pubic housing. The heat island for Singapore city has been documented (Tso, 1996). However, less focus has been placed on the cooling effect of

documented (Tso, 1996). However, less focus has been placed on the cooling effect of city's green areas at macro level. To address this issue, temperature measurements were conducted throughout the island by the use of automobiles. The aim of the study was to detect the severity of UHI and cooling impacts of green areas in Singapore.

Section snippets

Methodology

The land use of Singapore: Singapore is a garden city without distinct borderline between urban and rural areas. However, the two existing predominant green areas, the primary forest of 75 ha in the middle of the island and the open space/recreation area in the northeast of the island, are basically located at the northern part of the country while most built-up regions like industry areas, residential areas, the CBD area and the airport are located at the southern part. Therefore, the northern…

The first survey

The first survey was to preliminarily investigate the correlation between temperatures and different land uses. The survey route running from west to east actually passed through quite a number of different land uses, like industrial areas, residential areas, the forest and the airport. The results are illustrated in Fig. 6. The solid line shows the fluctuation of ambient air temperatures while the dotted line represents the variation of relative humidity during the first survey. The highest…

The relationship between green areas and ambient air temperatures

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To further uncover the UHI effect island wide, the ambient temperatures were analyzed according to different regions. The Singapore Island has been administratively divided into five regions: west region, central region, north region, northeast region and east region (see Fig. 9). According to Fig. 7, central region, west region and east region are mostly 'urban' areas where less vegetation is planted but high density of buildings are constructed. North region and northeast region are mostly…

Conclusion

The study has clearly indicated the presence of UHI effect in Singapore. The maximum difference of 4.01 °C was observed between well planted area and the CBD area. In addition, the mapping of temperature has shown a clear variation of temperature from southern 'urban' area to northern 'rural' area. All these indicate the severity of UHI effect in Singapore.

The study also confirmed the cooling effect of green areas at macro level. From both the two mobile surveys, the survey routes near to large…

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