THE IMPACT OF VEGETATION ON THE ENVIRONMENTAL CONDITIONS OF HOUSING ESTATES IN SINGAPORE

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ABSTRACT

The population of Singapore is expected to increase from 4 million to 5.5 million in 40 to 50 years' time. To a point in time, there will be a need to clear vegetation to build more houses to accommodate the growing population. However, as a result of this substitution of vegetation with dark coloured surfaces and buildings, the air temperature of the environment will be much higher than before, leading to the phenomenon of the urban heat island effect. Thus, the aim of this study is to investigate the impact of vegetation on the ambient air temperature and relative humidity in two neighbourhoods with distinctively different coverage of vegetation.

Experiments were conducted simultaneously in two areas with different coverage of vegetation, which were located next to each other. The instrumentations were set up on both sites over a period of 14 days to measure the ambient air temperature and relative humidity at the respective locations. From the experimental results collected, the site with higher greenery coverage had shown to have lower temperature and higher relative humidity in comparison to the other site. The site with lower vegetation coverage has a maximum average temperature of 34.63^{o}C whereas the site with higher vegetation coverage has a maximum average temperature of 32.46^{o}C. The maximum average temperature difference between the two sites is 2.32^{o}C. However due to this higher vegetation coverage, it has also caused a significant built up of moisture in the air and resulting in higher relative humidity.

1. INTRODUCTION

In the early 80's, most part of the Singapore island was covered with vegetation. But by the late 80's, about 90% of the vegetation had already been cleared. Singapore's rapid urbanisation and industrial growth have exerted a heavy toll on its flora and fauna. Habitats were destroyed when coastal areas were reclaimed to provide for more land, and forests were cut down to provide residential and commercial sites. Currently, Singapore is largely urban in character, although some natural rainforest can be found in the Bukit Timah Nature Reserve and the adjacent Central Catchment Area [1]. As Singapore becomes urbanised and densely populated, a lot of emphasis is placed on greenery, as air temperature in Singapore will increase significantly if there are no action taken to balance the concrete built ups.

Buildings along the streets form urban street "canyons" that cause the urban surface to take on a distinctly three-dimensional character. These changes affect the absorption of solar radiation, surface temperature, evaporation rates, storage of heat and the turbulence and wind climates of cities and all these can drastically alter the environment. Human activities in cities also produce emissions of heat, water vapour and pollutants that directly impact the temperature, humidity, visibility and air quality in the atmosphere above cities. On slightly larger scales, urbanisation can also lead to changes in precipitation above and downwind of cities. In fact, urbanisation alters just about every element of climate and weather in the atmosphere above the city, and sometimes downwind of the city [2].

There is a projected population increase from current 4 million to 5.5 million in 40 to 50 years time. Hence, we can expect an increase in demand for housing, where the Singapore government will have to build more housing for the people. As such building on every piece of land that can be found in Singapore becomes inevitable.

Large areas of vegetation will have to be destroyed in order to develop more new towns. Naturally vegetated surfaces will be replaced by buildings and paved streets. But most importantly, the additions of vegetation are usually lagging behind the town development. As a consequence of replacing vegetation with dark coloured surfaces, city temperature is now higher than ever before. This unusual phenomenon is referred to as the "urban heat island effect". The lack of vegetation and the use of dark coloured surfaces such as asphalt are two of the largest contributors to urban heat. Thus, the main objective of this study is to identify the impact of vegetation in the residential area, with respect to the ambient air temperature and relative humidity.

2. LITERATURE REVIEW

Citywide temperatures are affected by the individual contributions of all the buildings and vegetation on it. Studies had shown that vegetation had significantly reduced the temperatures in city areas. The reduction in the green area densities will have an adverse effect on air temperature [3].

Rosenfeld et al. [4] illustrated the case for downtown Los Angeles over the period 1882-1984. With increasing irrigation and orchards, the city of Los Angeles cooled by 2K until the 1930s. Since then, as asphalt replaced trees, the city was warmed by 3K. The phenomenon is universally typical with no exception to Singapore.

Studies of neighbourhood-sized developments are not as numerous. Schmid et al. [5] had conducted a suburban scale study done in Vancouver B.C. which shows significant energy flux variations within land areas of 10^2 to 10^3 meters. Another study is to compare temperatures of a vegetative canopy, a mature evergreen tree belt and surrounding open fields [6]. The results of this study showed that the average daytime canopy temperature was 2°C (3.6°F) lower than the open fields.

Temperature measurements in suburban areas recorded similar but smaller variations in daytime peaks of 2°C to 3°C between neighborhoods under mature tree canopies and newer areas with no trees. In Tokyo, zones with vegetation are 1.6K cooler in summer places than places without vegetation [7]. Bowen [8] reports a 2-3K temperature reduction due to evapotranspiration by plants.

Duckworth and Sandberg [9] found that temperatures in San Francisco's Golden Gate Park, which contains high levels of vegetation, average about 8K cooler than nearby areas that have much lesser vegetation.

Studies had been done by researchers, which try to simulate the effect of additional vegetation on the temperatures and had provided useful information. Huang et al. [10] have reported that computer simulations predict that increasing the tree cover by 25% in Sacramento and Phoenix, USA would decrease air temperatures by 6 to 10.0°F.

Gao [11] had also done some simulations to show that green areas decrease maximum and average temperatures by 2K, while the vegetation can reduce maximum air temperatures in streets by 2K. Simulations by Sailor [12] indicate a potential for reducing peak summertime temperatures in Los Angeles by more than 1.3K, through the implementation of a 0.14 increase of fractional vegetation cover.

3. METHODOLOGY

3.1 Description of the Two Sites

Site 1 is a developed, residential site with moderate vegetation on ground level and a rooftop garden with an estimated greenery cover of 22%. Site 1 consists of Block Nos 127, 128A, 128B, 128C, 128D and 128 (Carpark) situated at Punggol Field Walk Road. In this site, a total of 8 measurement points were taken. The HOBO meters were installed at a height of 2 m above the ground level. The HOBO meters are portable mini data loggers that can log in the temperature and relative humidity data continuously at a set interval. Out of the 8 hobo meters, 6 of them were attached to trees and 2 were attached to lampposts (see Fig. 1). Site 2 is also a developed residential site but with considerable less vegetation on ground level and no vegetation on the top of the carpark with an estimation of 7% greenery cover. Site 2 consists of Block Nos 183, 183A, 183B and 184 (Carpark) situated at Cres Rivervale Road. Similarly for site 2, 8 hobo meters were set up at a height of 2 m above the ground level. Out of the 8 hobo meters, 6 of them were tied to the lampposts and 2 of them to the trees (see Fig. 2). Table 1 shows the percentage coverage by the vegetation for the two sites.

3.2 Setting Up of Instrumentations

The experiment was conducted over a two-week period starting at 8:00 am on the 21st Sept 2003 and ending at 8:00 am on the 5th Oct 2003. Generally most of the days experienced wet weather at some point of the day as this experiment was conducted during the rainy season of Singapore. The days with fair weather were 2nd, 3rd and 4th Oct 2003. The hottest day was 4th Oct 2003. In order to be able to conduct a two-week experiment, the data were recorded at intervals of sixteen minutes. In order to increase the accuracy of the measurements, the hobo meters were evenly spread out in each site so that measurements for the whole site were well-covered. The observation points were spaced at about 33 m from each other.

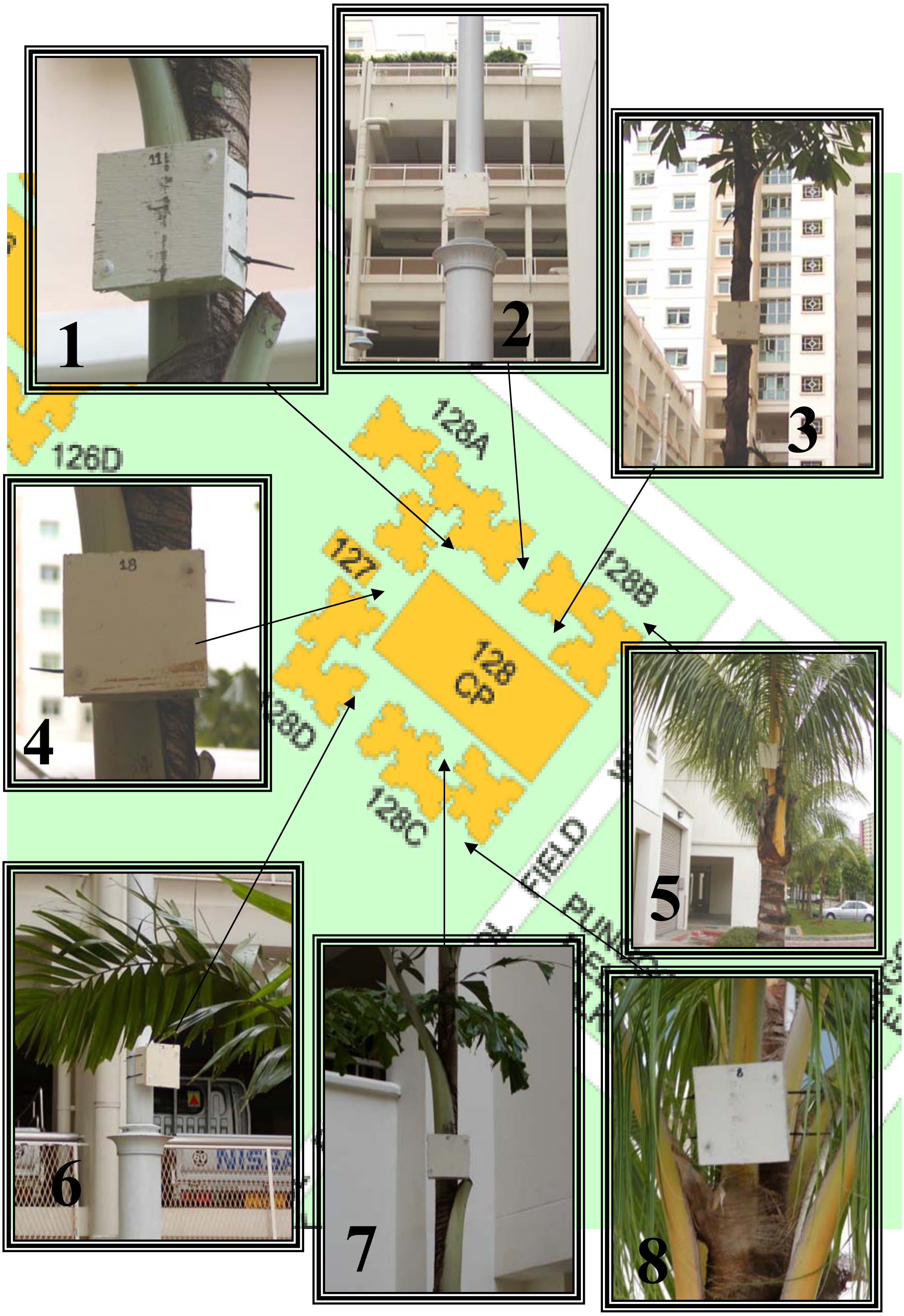

Fig. 1: Locations of hobo meters in site 1

Fig. 2: Locations of hobo meters in site 2

Table 1: Calculations of the vegetation coverage of site 1 and site 2

	Area covered (m^2)	Area covered/Total area surveyed	Percentage (%)
SITE 1			
Grass, Gravel/soil (<0.15 m)			
Shrubs (0.15 m-1.5 m)	**2383**	**2383/10719**	**22**
Other vegetation (>1.5 m)			
Pavement/Building	**8336**	**8336/10719**	**78**
SITE 2			
Grass, Gravel/soil (<0.15 m)			
Shrubs (0.15 m-1.5 m)	**720**	**720/10719**	**7**
Other vegetation (>1.5 m)			
Pavement/Building	**9999**	**9999/10719**	**93**

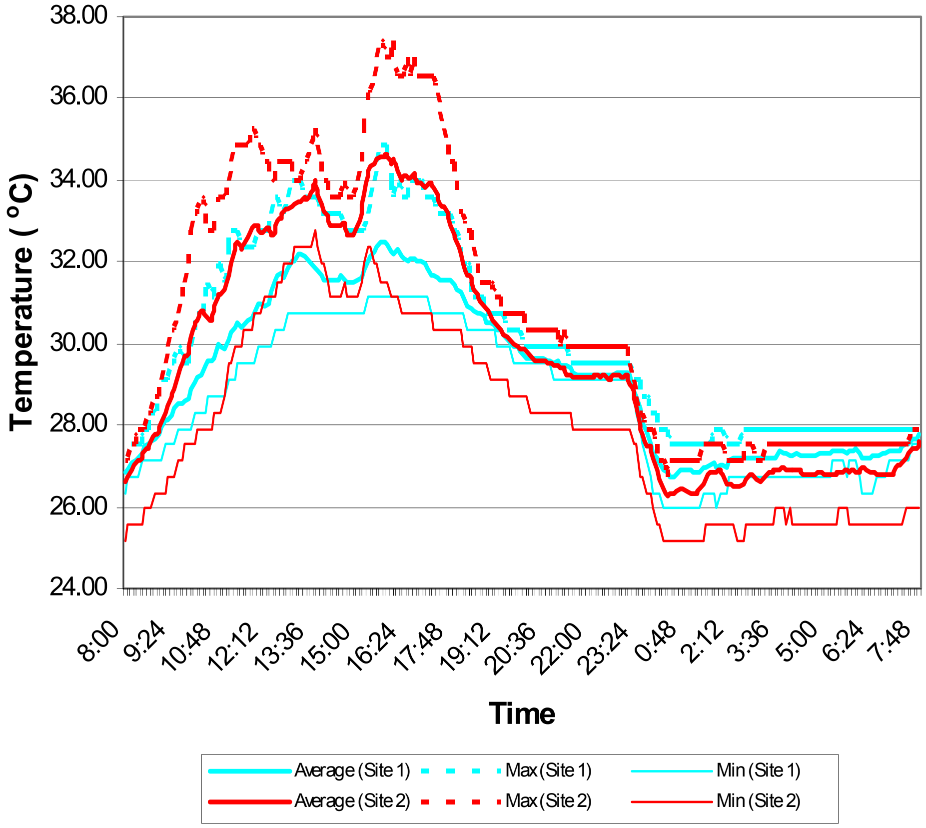

Fig. 3: Comparison of the ambient air temperature between the two sites

4. DATA ANALYSIS

4.1 Analysis of Ambient Air Temperature

Fig. 3 shows the ambient air temperatures of the two sites. On a representative fair day (day 13), for a short period in the morning till around 0906, both sites had shown quite similar average ambient air temperature readings. For the time period between 0906 and 1912, site 2 temperatures were higher than site 1. The temperature in site 2 rose more rapidly than site 1 and reached the maximum average air temperature of 34.63°C at the time 1554. A maximum average temperature of 32.46°C at the time 1548 was detected in site 1. The maximum average temperatures of the two sites were found to occur at around the same time. The maximum average temperature difference between the two sites occurred at 1606 with a value of 2.32°C. The temperature in site 2 started to decrease at 1712 and reached similar readings with site 1 at around 1912. Hence, the results of this experiment reinforced the fact that site 2, with a lower vegetation cover, is generally warmer than site 1. It can be deduced that vegetation contributes to a certain extent to lower the ambient air temperature of site 1. The presence of vegetation has a cooling effect on the environment and hence providing comfortable surroundings to the residents. Evapotranspiration from trees contributes to creating lower temperature in the surroundings. Hence, the higher temperature that was experienced by site 2 can be attributed to the lack of greenery in this site.

4.2 Analysis of Relative Humidity

Fig. 4 shows the comparison of the relative humidity for the two sites. The average relative humidity was by and large lower in site 2 as compared to site 1. Site 1 with higher vegetation coverage, where the plants through their process of evapotranspiration released moisture into the surroundings air and thus leading to a higher relative humidity in the air as compared to site 2. Although, the presence of vegetation brought about cooler temperatures where residents enjoyed, the side effect of higher relative humidity also occurred at the same time. Site 2 has lesser vegetation coverage, which is the basis for the relative humidity to be much lower than site 1. The low relative humidity in site 2 illustrates that the air in site 2 could hold more moisture than site 1.

5. CONCLUSION

As more and more large areas of vegetation are being replaced with asphalt, buildings and other hard surfaces, the vegetation effect on the environment's climate will have to be investigated in order to discern the importance of vegetation. Many studies had shown measurable temperature differences between areas, which had different vegetation coverage. However comparatively, studies on neighbourhood-sized developments are not as numerous. This research paper aims to determine the impact of vegetation on the environment in the neighbourhood with respect to ambient air temperature and relative humidity.

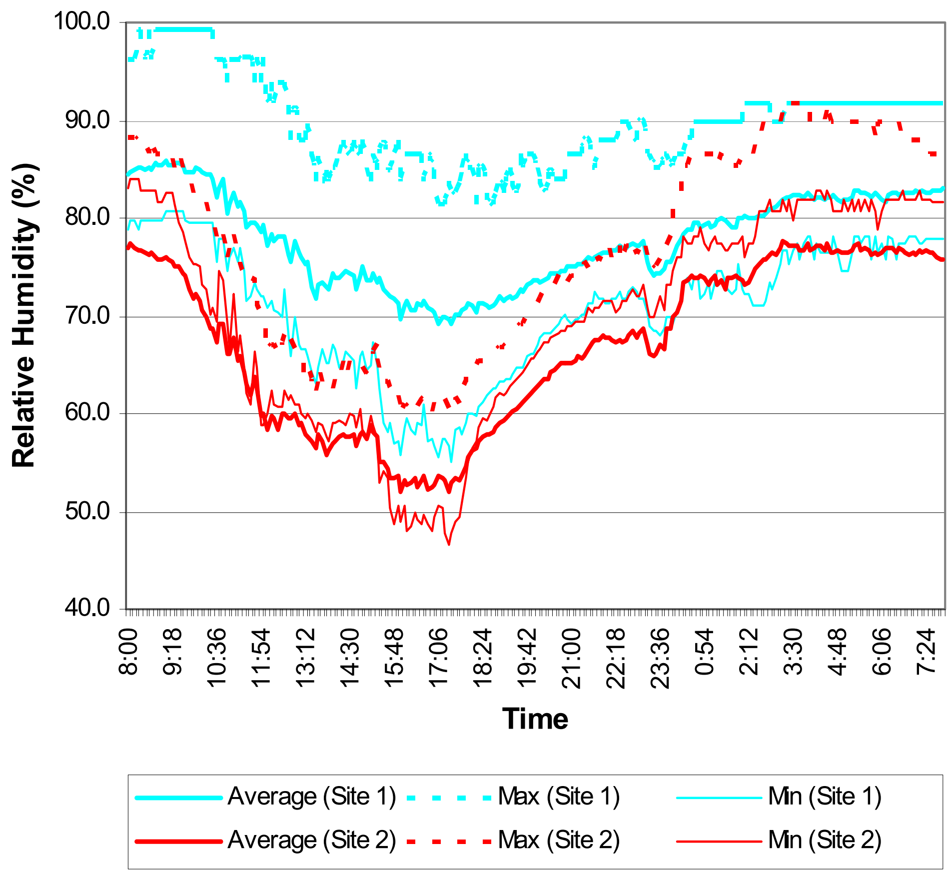

Fig. 4: Comparison of the relative humidity between the two sites

On a selected hot day, the experimental results clearly show the temperature differences between the two selected sites. From the obtained results, one can observe that site 1 with 22% vegetation coverage had lower ambient air temperature as compared to site 2 with 7% vegetation coverage. Site 2 has a maximum average temperature of 34.63^{o}C whereas for the site 1 is 32.46^{o}C. The maximum average temperature difference between the two sites is 2.32^{o}C. The average relative humidity of site 2 is much lower than site 1. Site 1 with higher vegetation coverage will result in higher relative humidity whereby vegetation will release moisture into the air through the process of evapotranspiration. Even though the presence of vegetation lowers the air temperature, the side effect that is brought about is a higher relative humidity.

From the data analysis, the experimental results put forward the considerable impact of vegetation on the ambient air temperature and relative humidity. An area with higher vegetation coverage will have effects on the two parameters that are concerned in this experiment. The lower air temperature and higher relative humidity in site 1 reflect the importance of sufficient vegetation in the neighbourhood. The process of evapotranspiration of trees contributes to a certain extent of lowering the ambient air temperature and thus leading to a higher relative humidity in the air of site 1. Hence, the results also show the need of replacing the hard surfaces like asphalt with vegetation wherever it is possible.

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