Microclimate Regulation by Trees in a Subtropical High-Density Urban Environment during Sunny and Cloudy Weather

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Introduction

Problems

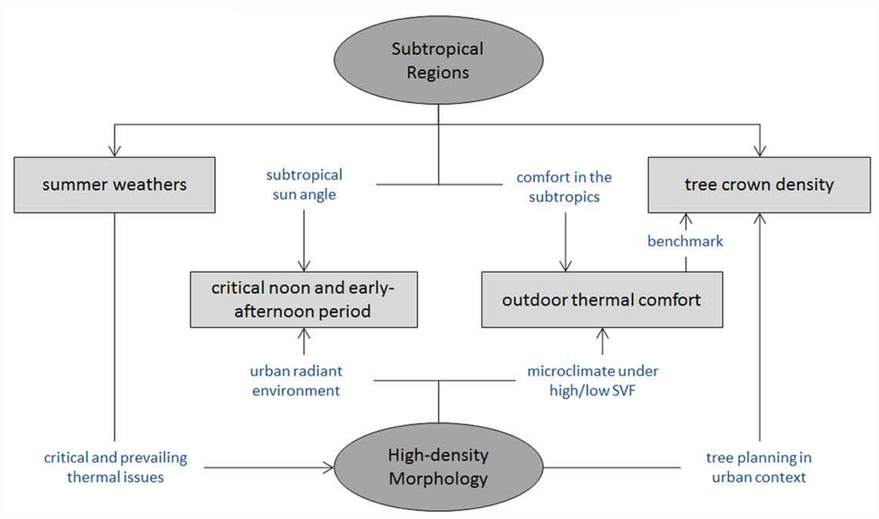
1. Hot-humid summers of subtropical Hong Kong cause thermal discomfort
2. Discomfort is further intensified by the urban heat island (UHI) effect (Goggins et al., 2012)

Contexts

1. Thermal impact of greenery in high-density urban area has seldom been studied (Wong and Chen, 2005)
2. Few urban climatic studies have been conducted on hot-humid climates (Roth, 2007)
3. Sky view factor (SVF) is a key indicator for outdoor comfort in the (sub)tropics (Krüger et al., 2011; Lin et al., 2010).

Objectives

1. To investigate the thermal behavior of urban trees under different SVFs
2. To evaluates the cooling effects of urban trees in both sunny and cloudy weather to address the critical and prevailing issues



Measurement Methodology

Thermal effects of trees under SVF 0.2-0.8 are determined with field survey.
Measurements were taken from 12:30 to 14:00 under sunny and cloudy weather
Environmental variables measured under tree canopy and exposed reference point
(Armson et al., 2012; Konarska et al., 2014):

downward solar radiation
ground surface temperature
air temperature
relative humidity
wind speed
global temperature

T_{mrt} values are calculated with reference to the measured data (Thorsson et al., 2007);

For data representativeness, weather criteria were set for data collecting:
sky condition remains constant 30mins before measurement and during the measuring period
data collected under weak wind condition (wind speed <1.5m/s)

(a) sun exposure period in high-density urban areas

Lai On Estate, SVF 0.3
summer sunshine period 11:00-14:30

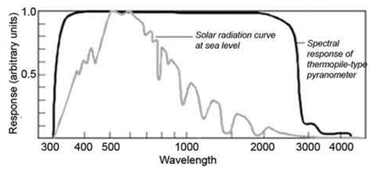
Minden Ave, SVF 0.2
summer sunshine period 11:30-14:00

(b) measurement equipment

HOBO sensor

TESTO400
measuring instrument

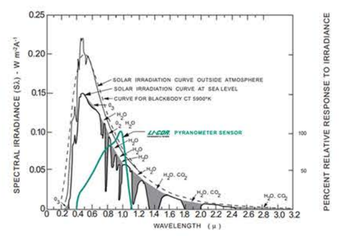
KIPP & ZONEN
radiation indicator



FLIR
thermography camera

Mobile Box

LI-200 pyranometer

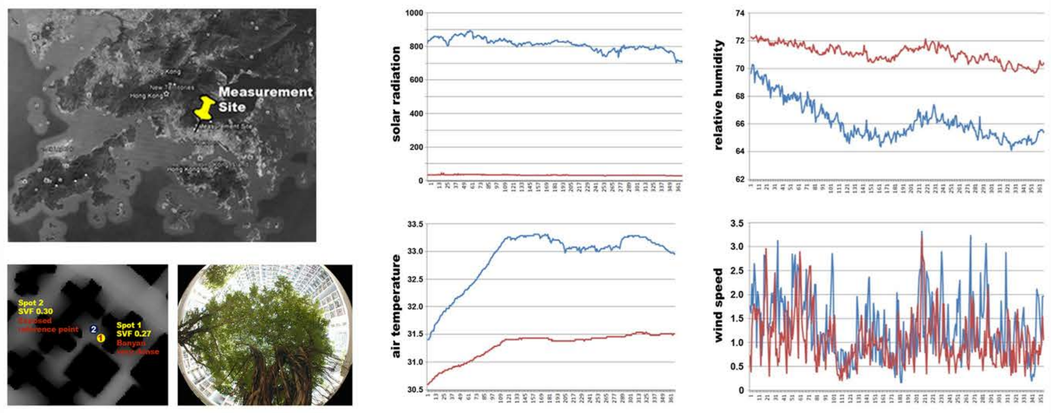


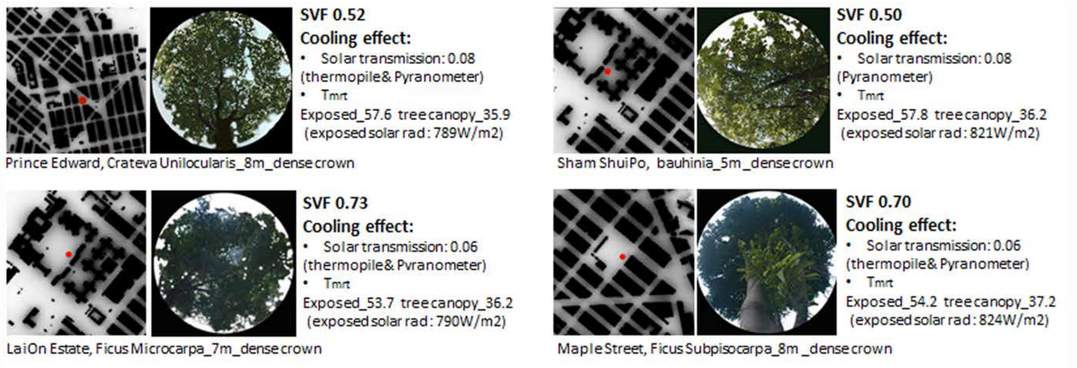
Simulation Methodology

The three-dimensional microclimate model ENVI-met 3.1 is used for the modeling study; this model is an effective simulation tool for urban climate study (Ali-Toudert and Mayer, 2006; Ng et al., 2012). Moreover, the accuracy of ENVI-met in terms of modeling the urban environment under Hong Kong's climatic conditions has been verified (Ng et al., 2012).

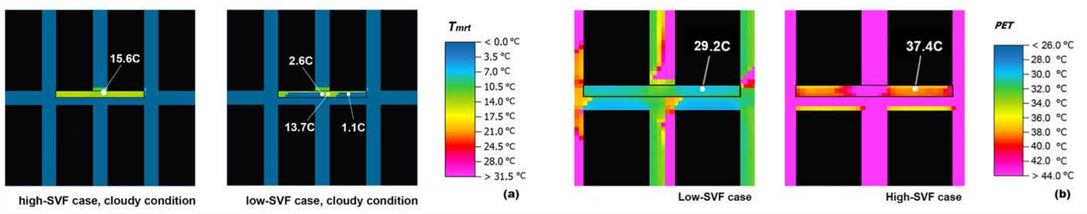
To test cooling effects of trees in high-density urban areas in summer cloudy weather.
75m and 25m high building blocks to simulate low-SVF (0.2) and high-SVF (0.6)
Tree effects are evaluated by T_{mrt} reductions and PET values under tree canopy

Site survey investigating the cooling effects of trees in the urban environment





simulation results on cooling effect of tree on Tmrt (a) and PET (b) in low and high SVF cases



Study Result

measurement

The measured data indicated that the net tree effects were significantly related to SVF. This result can be interpreted from two perspectives: **First, similar levels of cooling by the trees were observed under similar SVF levels.** Given dense trees with a solar transmission range of 0.06–0.08, the cooling in Tmrt were 21.7 °C and 21.6 °C in urban sites with 0.5 SVF. By contrast, these temperatures were 17.5 °C and 17.0 °C in urban sites with 0.7 SVF during sunny days. **Second, the cooling magnitudes of the trees differed significantly in urban environments with high and low SVFs in both sunny and cloudy conditions.** Specifically, the net cooling effects on Tmrt under high and low SVFs varied by 7° in sunny conditions. Under cloudy conditions, this difference increased to 12 °C. **The observed data showed that the cooling effects of urban trees were particularly significant during sunny days with respect to both global temperature and Tmrt. On the other hand, the influence of building morphology on the cooling of trees was more evident in cloudy condition.**

simulation

The findings showed that for a given crown density, the shading effects of street trees differed in low-SVF and high-SVF cases. In the low-SVF case, these effects exhibited considerable spatial diversity. Tmrt was reduced by 16 °C under the shading of dense trees in high-SVF case. The cooling magnitude of Tmrt varied from 1 °C to 14 °C in the low-SVF case.
The modeling study showed that with tree planted in low SVF environment, Tmrt under tree canopy dropped to 34 °C and PET value was cooled down to 29.2 °C; very close to the outdoor comfort threshold in the hot-humid subtropics. As cloudy weather dominates the summer period in the regions, the results of the study indicate that **tree planting would substantially improve outdoor thermal comfort in the high-density urban environment in (sub)tropical cities.**

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