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Assessing the cooling effects of different vegetation settings in a Hong Kong golf course

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Abstract

This microclimatic study at a golf course in sub-tropical Hong Kong targets the investigation of differential cooling abilities of a rough grass area and a woodland strip as compared to a bare-concrete rooftop control site. Preliminary results indicate that the woodland strip has a stronger cooling effect and creates more thermally comfortable environments than the other two plots. The research is projected to inform and encourage appropriate use of vegetation in tropical cities to combat rising temperatures due to the urban heat island effect and climate change.

Peer-review under responsibility of the organizing committee of GU 2016

Keywords: cool island effect; vegetative cooling; urban heat island; climate change; urban greening

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1. Introduction

The compact, subtropical city of Hong Kong is packed with dense roads and buildings, creating a labyrinth that traps heat from direct incoming solar radiation and anthropogenic activities. The resulting urban heat-island (UHI) effect, further exacerbated by climate change, has led to a warming trend and more extreme weather events. Furthermore, the grave shortage of easily developable land has engendered a city with inadequate supply of green sites and hence deprivation of their cooling capacity. The built-up areas have suffered from more occurrences of very hot day (>33°C) and hot night (>28°C) phenomena which indicate rising temperatures[1, 2].

It is becoming increasingly challenging for cities to maintain thermally comfortable temperature ranges. Heat stress would adversely affect outdoor activities and extreme conditions like heat waves would pose serious health threats. Elevated urban temperatures can increase the need for air-conditioning and induce upstream emission of greenhouse gases and air pollutants at power plants. Moreover, it can degrade air quality by catalyzing ozone and smog formation[3]. Recent research findings have highlighted the important role played by urban vegetation in cooling cities as a solution to the above problems. High quality and appropriately located urban vegetation can maximize effective evapotranspiration cooling through absorption of latent heat, as well as reducing the amount of solar radiation reaching the ground by shading and reflection[4]. The bodies of urban green infrastructures have been aptly labelled 'cool islands'[5-7] in contrast to the heated artificial urban fabric around them.

1.1. The urban heat island effect

UHI is defined as the difference in urban temperatures and the temperature in the suburbs or non-urban pockets embedded in built-up areas[5, 7]. The urban area is observed to be warmer, with lower relative humidity and wind velocities[7]. High-density urban development and paucity of urban vegetation could further aggravate the UHI effect[8].

Dark building and paving surfaces have stronger thermal admittance (i.e. heat absorbance) capabilities[5, 9] than lighter-toned counterparts. Furthermore, popular construction materials such as asphalt, concrete and glass absorbs large amounts of heat from solar radiation, and the stored heat is readily transmitted to the surroundings mainly by convection and long-wave radiation[10]. Extensive coverage by artificial impermeable materials[11], and meager presence of vegetation characterize the typical compact urban form[12] in comparison to the surrounding countryside. On top of incoming solar radiation in the form of short-wave radiation, heat and heat-retaining pollutants are released as a result of intense human activities and soaring energy use levels[11] (e.g. traffic and buildings). Furthermore, dense high-rise buildings obstruct heat dissipation by air flow and confine the reflection of short-wave radiation back into the atmosphere[5].

1.2. Hong Kong's climate and urban heat island situation

Located at 22.3°N, 114.2°E, Hong Kong lies along the south coast of China's Pearl River Delta. Its south-east Asian location gives it a sub-tropical climate dominated by the regional monsoon climatic system. NE winter and SE summer monsoon winds largely affect local temperatures and weather[13]. They bring humid and hot summers (26-31°C, >80% relative humidity), and mild but dry winters (~10-19°C). Severe weather conditions occur seasonally; tropical cyclones are most common in July and September while thunderstorms are frequent from April to September.

Hong Kong has been affected by climate change bringing increasingly warmer weather over the years. In conjunction with urbanization over the last century, the number of hot days (≥ 27.7°C) in Hong Kong has increased while the cool days (≤ 18.8°C) decreased, and all four seasons (especially spring and winter) displayed warming trends[14]. Since 1985, climate-change effect on Hong Kong's mean temperature has caused an average decadal increase of 0.16°C [1]. The average of very hot days (i.e. daily maximum temperature ≥ 33.0°C) per annum was 12 for the period of 1974-2014; however, the number of very hot days in the last decade have surged above the average, with 30 and 33 very hot days recorded in 2009 and 2014 respectively[1]. An increasing trend was also observed for the number of hot nights (i.e. daily maximum temperature ≥ 28.0°C), with 34 hot nights recorded in 2014 when compared to the average of 22.5°C recorded for the 40-year period before.

1.3. The PCI effect and vegetative cooling

There is a diverse background of scientific literature on the alleviation of the urban heat island. In urban areas, vegetated parks are usually the coolest places in daytime[9], especially in areas affected by the UHI effect[7] which is most prominent on clear and calm weather regardless of the time of day[15]. In these circumstances, a park hosts cooler temperatures and are referred to as a 'park cool island' (PCI)[6, 16] in comparison with the heated urban surroundings. Some studies focus on the formation, strength and extent of the PCI effect, using remote sensing techniques for cities such as Taipei[17] and Shanghai[18]. Many studies also made use of field experiments to collect data on PCI performance in an urban setting[8, 19]. Others investigated whether park size and shape have an effect on the aforementioned elements. It is generally believed that rounder parks have an extended PCI effect[16, 20], but whether larger parks have a stronger PCI effect is contested[17, 21].

The actual strength of PCI depends greatly on urban geometry as manmade layouts and surfaces would affect the spreading of cool air from green areas and reflection of solar radiation[22-24]. Tree shade is another significant factor as a simulation study demonstrates that it may reduce solar radiation for up to 96.5%[25]. It is rather certain that shading by tree foliage contributes significantly to a strong PCI effect. This setting coupled with a grass covered ground base provides another positive boost for cooling[26]. Furthermore, it was found that a street with sidewalk trees which provided ample shade and evapotranspiration than streets without[8], and modeling of buildings with green walls and roofs showed a possible maximum reduction of 8.4°C in the late summer afternoons in Hong Kong[27].

1.4. Significance of the study

Making use of various vegetation settings in a Hong Kong peri-urban golf course[28], this microclimatic study investigates the differential cooling effect of a rough grass area and a woodland strip. A control site is set up at a barren concrete rooftop within the golf course to mimic worst-case weather conditions. Microclimate parameters including temperature, relative humidity, black globe temperature and wind speed are monitored throughout the hot and humid summer months of June to August.

Focusing on differential cooling capacities of vegetation settings, the study's unique design differs from solely PCI-focused studies that compare the temperature of a certain point within a urban park with other locations away from the park[19]. By selecting representative and extensive sites of vegetation within the golf course, the study is also anticipated to provide more representative data than small plots studies in confined courtyards[26]. Applicable to other tropical cities as well, these results can inform remodeling and conservation of existing urban green areas to reap long-term improvements to the environment and human wellbeing.

2. The study

2.1. Study area – the Hong Kong Golf Club

An example of open green area with mainly grass cover with discontinuous tree canopies, golf courses are potential PCIs in a heated urban fabric[29]. Located in Fanling of the Hong Kong New Territories, the Hong Kong Golf Club (HKGC) is in an area of low building density. The HKGC is a well-vegetated site of 170 hectares, of which over 50% are forests; it is bordered by a line of trees within fencing that creates a buffer with the urban conditions (i.e. main roads) around the area. Furthermore, only a controlled number of electrical golf carts are allowed to operate within the HKGC area, minimizing the effect of anthropogenic heat (e.g. vehicle exhaust, air conditioners) on measurement plots and allowing the analysis to focus on vegetation strengths and characteristics.

2.2. Research design and data collection

The study investigates the differential cooling capacities of plots with different vegetation composition. Site locations were decided upon after several field visits in 2015; a rough grass area (Fig. 1a) and a woodland strip (Fig. 1b) were chosen as representative plots for the study. To provide baseline data, a control site at a barren rooftop of a two-story building within the golf course was also set up.

Stagnant airflow and wind blockage are identified as biometeorology problems in the urban areas of Hong Kong[30], and the lack of tree shade in parks and urban areas see minimal possibilities for outdoor thermal comfort in summer in Hong Kong. The rough grass area is a vast area of open, exposed grassland bordered by the row of trees that buffers between the golf course and the main road. The woodland strip is located in the heart of the golf course, characterized by a grass groundcover dotted with a variety of trees which provide shade. Both vegetation settings are largely sought after by greenery-deprived Hong Kong residents as a backdrop for outdoor recreation activities such as picnicking and playing games. These settings, however, are either non-existent or inaccessible with Hong Kong urban parks. This study would be able to shed light on the microclimatic-related points to note when installing these designs in future park renovation and management.

All control and treatment plots were fitted with the same set of equipment which recorded the following microclimatic data: (i) air temperature at 150 cm, (ii) relative humidity at 150 cm, (iii) wind speed, (iv) wind direction, (v) wet-bulb temperature, (vi) black globe temperature and (vii) incoming and outgoing radiation. Data loggers are programmed to record data at 15-minute intervals and are connected to a photovoltaic panel or a rechargeable battery.

Setting up of monitoring equipment begun early May 2016, pilot testing of the equipment followed and was completed within the month. Data collection officially began on 1 June 2016. Data collection for the study is planned for June to August 2016, covering the entire summer which brings hot and humid weather conditions to the city. It is expected that microclimatic data of sunny, cloudy and rainy days will be collected; for each type of weather condition, at least two representative days (i.e. 24-hour intervals beginning 00:00) will be used for data analysis.

Fig. 1. Treatment plots – (a) rough grass area and (b) woodland strip.

3. Preliminary results and discussion

As this paper is written in July 2016, it has only taken into consideration data freshly reaped from the preceding month and no further as to allow sufficient time for analysis. Data for analysis were selected based on microclimatic levels recorded at the control site, mainly taking into consideration the daily sunshine duration and amount of rainfall. The month of June 2016 was dominated by clear sky, and sunny days – 4 to 11 hours of sunshine duration and no rainfall[31].This resulted in a biased collection of data of mainly sunny days, with a shortage of representative rainy or cloudy days. Two of the hottest sunny days, namely 2 June and 27 June 2016 were chosen for preliminary analysis in this paper. The latter day was the hottest in June as similarly recorded at the Hong Kong Observatory's (HKO) nearby Sheung Shui weather station, with the daily maximum temperature of 36.2°C[32]. The threshold for data collection to qualify as a 'rainy' one is rainfall of >10mm[31]; this was only met at three incidences of data logging during the whole month, and is insufficient for meaningful results. It is projected that rains will approach the territory in July and August as a result of the summer monsoon and typhoons which originate from southeast of Hong Kong.

3.1. General weather of June 2016

For Hong Kong, the month of June 2016 had a mean temperature of 29.4°C which was 1.5°C above normal. The mean maximum temperature was even 2.2°C above normal at 32.4°C[33]; maximum temperatures of below 30°C were recorded for a mere three days within the month[34]. Despite several isolated episodes of torrential rain, the monthly rainfall was only 347.4 mm which was over 100 mm below normal[33]. Data from the HKO weather station at Sheung Shui indicated that the area was even hotter with the mean daily maximum of 32.9°C and a monthly rainfall of 281 mm[35].

3.2. Overview of daily meteorological observations on selected days

The days of 2 and 27 June 2016 are selected for analysis due to the record of representatively high temperatures and fulfillment of the requirements of a 'sunny day'. Air temperature measurements at 150 m indicated that the average daily temperature of the two days was 31.3°C at the control site; this was higher than both temperatures at the rough grass area (30.4°C) and woodland strip (30.0°C). The mean relative humidity at the control site was 77.2% whereas the rough grass area and woodland strip were more humid at 82.5% and 82.2% respectively. All three sites had a wind speed ranging from 0.5 to 1.0 m/s.

3.3. Detailed observations of selected dates

For both days of 2 and 27 June 2016, records of incoming solar radiation at the control site indicated that sunrise and sunset occurred around 05:45 and 19:00. In general, daily minimums or relatively low temperatures are found before sunrise after a long night of cooling and the heat collected from the previous day has dissipated to a large extent. The daily average temperature on 27 June was higher but it was also a drier day as reflected by lower average relative humidity levels (Table 1). On 2 and 27 June respectively, the day's minimum of 28.3°C and 27.2°C were recorded at the control site exactly at assumed time of sunrise (Table 1); this was also true for the grass and woodland plots at or before sunrise. As the day sets in, plot temperatures start to increase afterwards as incoming solar radiation gradually increases with higher angles of the sun. Minor temperature depressions during daytime on a sunny day would mostly be attributable to cloud movements which create intermittent blockage, these time stamps were cross-referenced with the data of incoming solar radiation and were matched with lower readings.

For all plots on both days, daily maximums were recorded between 12:45 to 14:00, and highest records were found at the control plot (2 June: 35.7°C; 27 June: 35.6°C). The woodland plot was coolest, with maximums of 34.3°C (2 June) and 33.9°C (27 June). Diurnal temperature ranges for the plots spanned from 7.3°C to 8.4°C, with larger ranges found on 27 June. The rough grass area had the largest diurnal range (8.0°C) on 2 June while the largest range on 27 June was found at control (8.4°C). The amount of daily average incoming solar radiation (118.94

Wm^{-2}) was lowest at the woodland strip due to the barriers created by tree foliage, while the exposed plots of control and rough grass area received >210 Wm^{-2} on average.

Table 1. Key microclimatic recordings at all plots on 2 June and 27 June 2016

Date	2 June			27 June		
Plot	Control	Rough grass area	Woodland strip	Control	Rough grass area	Woodland strip
Average temperature (°C)	31.1	30.2	29.9	31.5	30.5	30.1
Average relative humidity (%)	77.3	83.5	82.6	75.2	81.5	81.7
Average wind speed (m/s)	0.42	0.09	0.32	0.20	0.17	0.26
Average incoming solar radiation (Wm^{-2})	234.5	218.9	110.6	280.8	247.1	127.3
Minimum temperature (°C)	28.3	27.1	27.0	27.2	26.6	26.2
Recording time	05:45	01:30	23:30/ 23:45	05:45	05:15/ 05:30	05:45
Maximum temperature (°C)	35.7	35.0	34.3	35.6	34.9	33.9
Recording time	14:00	14:00	12:45	12:45	13:30	13:15
Diurnal range (°C)	7.4	7.9	7.3	8.4	8.3	7.6

Some anomalies were observed for 27 June and will be reported here. First, a sudden drop in air temperature at all three sites at 14:30 (Fig. 2b) were recorded by 0.68°C (control), 1.43°C (grass) and 0.47°C (woodland) during peak times. They may be explained by a thick overcast that reduced solar radiation at the control and grass sites from over 700 Wm^{-2} to below 300 Wm^{-2} and a decrease from around 230 Wm^{-2} to 140 Wm^{-2} at the woodland site. Second, the sharp drop of temperature at the grass site recorded at 23:30 by 1.59°C; there was a simultaneous increase in the amount of outgoing solar radiation from 1.20 Wm^{-2} to 3.93 Wm^{-2} (23:30) and 5.39 Wm^{-2} (23:45). It is speculated that an overcasting cloud was suddenly displaced from above the site by strong winds in the sky, but since there is no data to verify this plunge, the data at time points 23:30 and 23:45 are eliminated from the PCI index analysis.

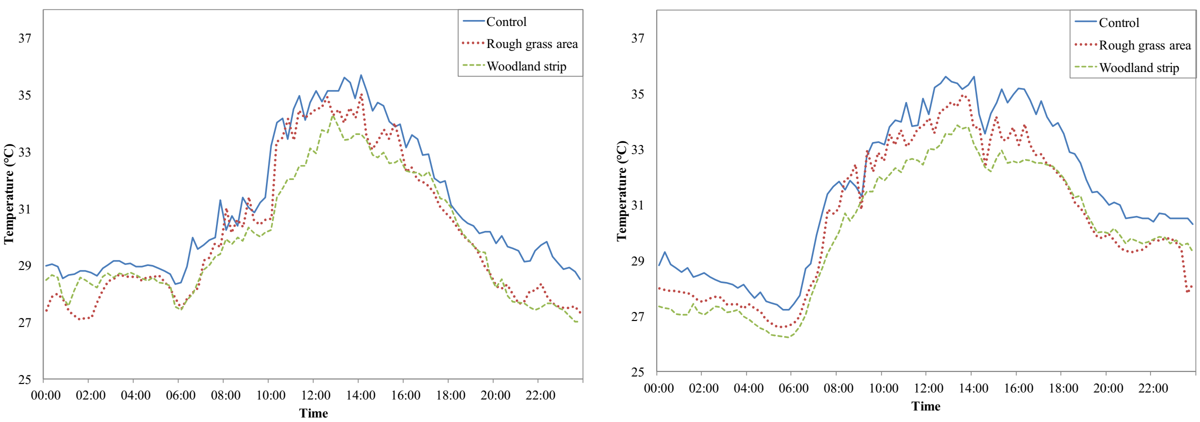

Fig. 2. Twenty four-hour profile of air temperatures recorded at the grass, woodland and control plots

(a) 2 June 2016 (b) 27 June 2016

3.4. Temperature difference between vegetated plots and control

The park cooling effect reflects the difference between vegetated plots and that of the control which mimics the temperature in the urban area. The temperature difference is calculated by subtracting the temperature at control from that at the grass and woodland sites; a cooler vegetated site would result in a negative figure which represents a positive PCI index (Fig. 3a and b). When compared to the control site as the base case, the rough grass area displayed an average daily temperature difference (i.e. PCI index) of -0.90°C and -0.94°C on 2 and 27 June respectively. Larger average PCI indexes of -1.14°C and -1.42°C were found at the woodland strip for the two days. The two-day average indicated that the woodland strip has a 32.0% stronger PCI effect (-1.28°C) than the rough grass area (-0.97°C).

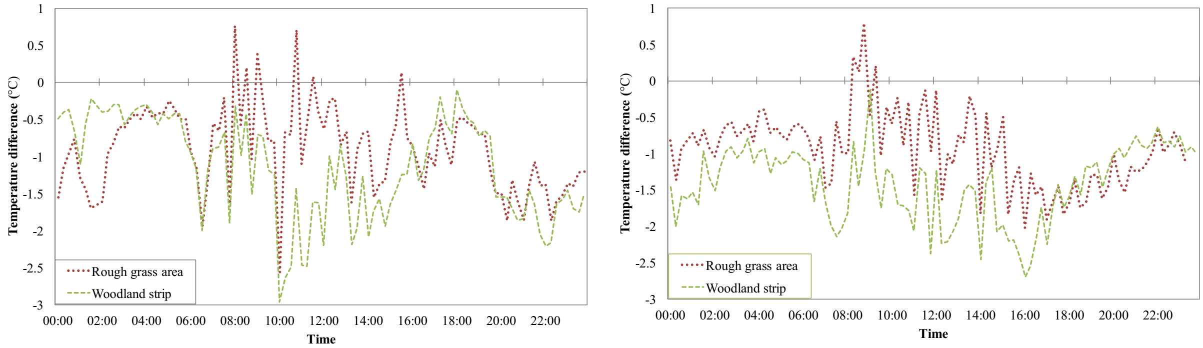

Fig. 3. Temperature differences between the grass and woodland plots relative to the control plot

(a) 2 June 2016 (b) 27 June 2016

Both the grass and woodland plots display maximum temperature differences at the same times for both days. At 10:00 on 2 June, maximum temperature differences of -2.56°C and -2.97°C were found at the grass and woodland plots respectively (Fig. 3a). The other day (27 June) saw strongest park cooling effects at 16:00, with grass and woodland plots displaying temperatures differences of -2.01°C and -2.70°C respectively (Fig. 3b). For both days, the PCI at the rough grass area was weakest in the morning before 09:00 – temperatures there were 0.76°C (8:00, 2 June) and 0.80°C (8:45, 27 June) higher than at the control. On the other hand, despite weakest PCIs at the woodland strip at 18:00 on 2 June (-0.10°C) and 9:00 on 27 June (-0.13°C), temperatures at this vegetation set-up were always lower than that at control. For the rough grass area, some 5.3% of positive PCI values were recorded, meaning that the grass area was hotter than the base case in these instances which were clustered between 08:00 and 10:00 for both days.

3.5. Physiological equivalent temperature (PET) analysis

A preliminary PET analysis was conducted with the software *Rayman 1.2*; the PET scale was chosen due to its wide application and recognition by academic studies and ease of comprehension with the use of the degrees Celsius (°C) as its unit[36]. PET is also an appropriate indicator for year-round thermal comfort analysis of different climates. PET is calculated to identify thermal stress levels which correspond individually to a level of thermal comfort; the relevant range concerned in this study is presented in Table 2[36]. Lower levels of heat stress would increase thermal comfort and lower the chances of adverse health effects (e.g. heat stroke, heart conditions).

Table 2. Ranges of heat stress level and thermal perception in correspondence to PET

PET (°C)	Heat stress level	Thermal perception
18 – 23	Non-existent	Comfortable
>23–29	Slight heat stress	Slightly warm
>29–35	Moderate heat stress	Warm
>35–41	Strong heat stress	Hot
>41	Extreme heat stress	Very hot

Adapted from Matzarakis et al.[36]

Based on the above findings regarding PCI strengths, the times of 10:00 on 2 June and 16:00 on 27 June were chosen to represent strong PCI scenarios. The times of 8:45 on 2 June is chosen to represent a weak PCI scenario. The average data from the two selected days were employed in the analysis. As it is summer time, the clothing index is assumed to be at 0.3 with the combination of short sleeves and shorts [37]. Assumptions were made according to a male of 35 years old, 175 cm tall and weighing 75 kg. Both physical activities of relaxed standing (70 W/m^2) and moderate walking (150 W/m^2 at a pace of 4.3 km/h) were tested, with metabolism values taken from the ASHRAE standards[38]. The sky-view factor (SVF) was calculated by *Rayman* from fish-eye photos taken with a SIGMA circular fish-eye lens (4 mm, 1:2.8) at a height of 150 cm. Produced in June 2016, the photos accurately portray the overhead vegetation during the investigated period. The SVF of the control, grass and woodland plots are 0.782, 0.664 and 0.415 respectively; the barren rooftop as control is most exposed while the woodland strip is most shaded.

The PET values calculated with the *Rayman* model is presented in Table 3. For all scenarios and cases, the highest PET was found at the control, where six out of eight scenarios resulted in strong or above heat stress levels. The mean radiant temperature at control was calculated at 60.8°C (27 June, 16:00) while peak PETs of at 48.7°C (i.e. person standing) and 48.9°C (person walking) were displayed in the same scenario. In some 75.0% of the 16 illustrated cases, vegetation in the two treatment plot was able to lower the heat stress level by one index when compared to control. Even in the case of a weak PCI (2 June, 09:00), the woodland strip would deliver a -19.3°C PET difference for a walking person when compared to the control. Heat stress was even lowered by two levels from 'extreme' to 'moderate'. This large reduction of PET lowers a walking person's thermal perception of 'very hot' at control to 'warm' if he is resituated and walks in the woodland strip.

Table 3. PET of standing and walking at strong and weak PCI scenarios (all units are in°C)

Strong PCI scenarios						
Date and time	2 June, 10:00			27 June, 16:00		
Plot	Control	Rough grass area	Woodland strip	Control	Rough grass area	Woodland strip
PCI	-	-2.56	-2.97	-	-2.01	-2.70
Mean radiant temperature	37.7	31.9	32.3	60.8	37.4	36.8
PET of standing person	36.6	32.5	31.1	48.7	35.6	35.8
Heat stress level*	Strong	Moderate	Moderate	Extreme	Strong	Strong
PET difference to control	-	-4.1	-5.5	-	-13.1	-12.9
PET of walking person	37.1	32.8	31.1	48.9	35.6	36.2
Heat stress level*	Strong	Moderate	Moderate	Extreme	Strong	Strong
PET difference to control	-	-4.3	-6		-13.3	-12.7
Weak PCI scenarios						
Date and time	2 June, 09:00			27 June, 09:00		
Plot	Control	Rough grass area	Woodland strip	Control	Rough grass area	Woodland strip
PCI	-	0.76	-0.71	-	0.80	-0.13
Mean radiant temperature	56.3	35.6	30	32.2	31	32.2
PET of standing person	48	34.7	29.4	32.9	32.1	32.8
Heat stress level*	Extreme	Moderate	Moderate	Moderate	Moderate	Moderate
PET difference to control	-	-13.3	-18.6	-	-0.8	-0.1
PET of walking person	48.6	35.3	29.3	33.2	32.3	33.2
Heat stress level*	Extreme	Strong	Moderate	Moderate	Moderate	Moderate
PET difference to control	-	-13.3	-19.3	-	-0.9	0

*Heat stress levels and corresponding PET: No thermal stress (>18 to 23°C), slight heat stress (>23 to 29°C), moderate heat stress (>29 to 35°C), strong heat stress (>35 to 41°C) and extreme heat stress (> 41°C).

3.6. Discussion

Scrutiny of the 24-hour air temperature observations, PCI calculations and PET analysis has set out the following findings. The control on the bare rooftop has effectively recorded worst case conditions of highest air temperatures and > 50°C of mean radiant temperatures which created conditions for extreme heat stress. The cooling ability of the woodland strip surpasses that of the rough grass area, with higher absolute maximum (-2.97°C) and daily average (-1.28°C) PCI indexes. As for the rough grass area, a -0.92°C two-day average PCI was recorded, and the maximum PCI was -2.56°C. However, the area is also susceptible to more rapid heating than the control in the morning, resulting in several instances of higher air temperatures. As tested with the activities of walking and standing, during a sunny day in Hong Kong summertime, a higher level of thermal comfort could be experienced in a woodland strip followed by rough grass area. It would be extremely heat stressful and physiologically unbearable to conduct activities on exposed bare concrete surfaces.

The results of this study is in-line with the general academic agreement that trees are the most efficient cooling elements in parks, with much better performance than grass surfaces alone[7, 23, 26]. Foliage can shade solar radiation while creating cooler temperatures through evapotranspiration, creating more comfortable temperatures for people [39]. In fact, tree shade may contribute up to 80% of the cooling effect[8]. Furthermore, studies found that land cover with trees and grass, similar to the woodland strip in this study, is the most efficient in cooling [26]. A simulation study by Shashua-Bar and Hoffman[24] found that tree shade coverage and tree cluster geometry determines the cooling effect of trees. Holding tree shade coverage, tree clusters with smaller height/ width ratios have stronger cooling effects as there is a smaller amount of air trapped in the cluster to be cooled. A small plots study found that tree shade confines the rate of globe temperature increase to 1.1 to 1.3 times of plot air temperature rise while globe temperature at exposed plots of concrete and grass surge at rate of 1.6 to 2.1[21]

The rough grass area was found to have weaker PCI abilities; in previous studies, unshaded grass surfaces were found to be even more heated than surrounding urban areas in daytime, hosting the least comfortable thermal conditions at >3°C higher than the coolest park in the same study[7]. Under the limitation of shade-less situations and that evaporative cooling by grass is restricted to the ground level, unshaded grass would provide minimal improvement of thermal comfort and negligible PCI contribution[26].

4. Research outlook

Preliminary findings of this study have established basic strengths of the woodland strip (with grass base) as a cooling agent during the sunny, summer day of Hong Kong in June. Although the rough grass area does not appear to perform too well in this aspect, any drawing of conclusions is too early as the overall performance of these vegetation settings can only be determined after all data is collected after August. The above analysis of sunny day data will be repeated with a larger base of representative days which is expected to accumulate throughout the months. It is also important to scrutinize vegetative cooling under different weather conditions, and the study is yet to reap usable data on rainy days.

There is an expansive outlook for data analysis, including investigation of correlations between the plots' PCI index, SVF and other microclimatic parameters (e.g. incoming solar radiation). PET analysis will also broaden to include more physical activities and with a wider scope of background weather parameters, and inter-plot comparison of PCI performance under different weather conditions will be carried out. The outcomes would benefit smart and appropriate design and conservation of urban green spaces as cool islands Hong Kong and other tropical cities, with further projection of long-term environmental benefits both locally and globally.

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